

Executive Summaries of All ESR and ER Real Research Projects 2013-17.

Overview

The ongoing loss of local adaptive capacity among East Africa's diverse populations, especially over the last 30-40 years, combined with current under-appreciation of the scale and significance of the temporal dynamics of its landscapes and social-ecological systems, inspired the Resilience in East African Landscapes ITN's three core scientific objectives:

- To integrate available records of past environmental change (from different sites a diverse range of indicators) to accurately document past ecosystem dynamics in East Africa, using a combination of historical maps, aerial photographs and satellite remote-sensing data to produce high spatial and temporal reconstructions of ecosystem, land use and settlement change at the landscape scale.
- To develop methods to extrapolate site-scale data on past ecological and environmental conditions to the landscape scale by, for example, applying models to link ecosystem distributions in the past, present and future under alternative climate-change and human-interaction scenarios; and by quantifying the rate and timing of ecosystem shifts due to changing population growth, migration and human/ecosystem interactions.
- To determine the connection between ecosystems, livelihoods, conservation and climate change and to use this knowledge to assess impacts on livelihoods in the vital economic sectors underpinned by ecosystem resource planning and policy (e.g. agriculture and tourism), both within the research area, and more generically across Africa.

To achieve its scientific and training objectives, REAL will conduct multi-disciplinary research aimed at answering five key research questions (R1-5) in each of four study sites in East Africa. These were:

R1: What magnitude and spatial pattern of natural, climate-driven ecotone change has occurred in East Africa at different temporal scales over the last c. 1500 years?

R2: How much variability were East African social-ecological systems able to accommodate without reaching potentially crippling tipping points or thresholds?

R3: What is the temporal scale at which climate change becomes a major driving force for societal change?

R4: At what point do changes in ecological and social boundary conditions become so significant that [radical] restructuring of society is needed?

R5: Which past and present adaptation and mitigation practices can fruitfully inform decision-making and governance structures to result in sustainable resource use?

Addressing these research questions was approached via three work packages (**WP 2-4**), supplemented by a work package (**WP5**) aimed at dissemination and knowledge transfer.

WP2 Past Scenarios, c. AD 900-1930: This work package had archaeological (**ESR 1 & 2**) and palaeoecological (**ESR 3 & 4**) components, and concentrated on collection and analysis of time-series data about either continuing or changing human-environment relationships in regional social-ecological systems over long temporal scales. The key research questions addressed were: What has been the magnitude and variability of ecosystem change over the last c. 1500 years, and did notable spatial differences occur? How much variability were the prevailing social-ecological systems able to accommodate without reaching a limiting tipping point or threshold? At what point, and why, did changes in ecological and social parameters force the restructuring of communities? And, what were the consequences of this restructuring in terms of the organisation of human society, subsistence strategies, and their resilience to stress?

Executive summary ESR 1 (Nik Petek)

The environmental degradation of the Lake Baringo area has been the subject of studies for almost a century with pastoralism commonly seen as the key driver. However, elsewhere in Kenya it has been shown that pastoralism contributes significantly to the biodiversity of savannahs over decades and centuries. Many previous studies undertaken in Baringo have focused on a short timeframe to understand the degradation, thus excluding the events leading up to it and also the history of the landscape and its people. This study sought to rectify this, by taking a long-term perspective with a focus on the historical ecology of the Lake Baringo lowlands. It investigated the histories of people occupying the area and how people were embedded in the landscape over decades, centuries and millennia and how they shaped and adapted to the environment.

Data from four seasons of excavation and survey were used to provide a detailed image of the Lake Baringo lowlands' pastoral history and specifically the historical ecology of the Ilchamus ethnic community currently occupying the southern Baringo lowlands. Findings show that the Baringo lowlands and much of the Lake Baringo basin have been a largely pastoral landscape for the past 3000 years, however the forms of pastoralism just like the intensity of usage have changed with environmental conditions and cultural preferences. Archaeological material show a denser habitation during the drier, Turkwel period than the subsequent wetter, Sirikwa period. Furthermore, over the past 200 years we observe the formation of a new Ilchamus ethnic community formed from previously distinct identity groups, which can be seen archaeologically, as pottery bears resemblance to Lanet and Kisima wares, and economically. Within a span of 200 years the inhabitants around the southern end of Lake Baringo shifted from hunting and gathering, to agriculture, to pastoralism, and agro-pastoralism. These changes

were swift and in response to internal and external preferences and pressures. Each of these economies left a specific imprint on the Baringo environment visible in settlement patterns and the vegetation. But the vegetation has changed significantly only over the past seven decades.

The results also show that pastoralism itself cannot be blamed for the degradation, since it has been present in the landscape for thousands of years, whereas the scale of degradation and change of today is a recent phenomenon (see ESR 3 & 5). Moreover, we should understand that communities can and do rapidly change their subsistence based on opportunities and restrictions with concomitant effects on identity and the environment. This has significant implications for how we understand and discuss archaeological cultures, but also the historical ecology of an area, as identities and economies must be seen to be much more fluid and unrestricted than has hitherto been the case.

Executive summary ESR 2 (Anna Shoemaker)

In present day Amboseli pastoral livelihoods are in decline as rangelands are settled, fenced, and converted to farmlands, and the periodicity and intensity of droughts grows more severe. The circumstances driving pastoralists to abandon herding are closely tied to historical as well as environmental processes, and understanding the historical conditions that led to the Amboseli of the present plays a crucial role in informing projections of future land use changes in the region on the short and long-term scales. Yet the history of Amboseli as conceptualized and discussed by scholars working in the area is the history of an ecosystem inhabited by subsistence based pastoralists. There is a persistent notion that Maasai pastoralists in Amboseli only began to engage in agricultural production systems in the last few decades, and that livestock surpluses were not produced for trade. There is an implication that the pastoralism practiced on this landscape has been somewhat timeless until very recently, structured on a pattern of mobility fixed on seasonal migrations that did not extend beyond the ecosystem.

The results of this project challenge these assumptions, finding evidence for continuity but also change in pastoral production systems during the last millennium using oral traditions and archaeological and historical sources. In particular, the project used the landscape as a unit of analysis and situated Amboseli at the intersection of diverse environmental and cultural spaces. Amboseli lies at the border where pastoral rangelands meet Mt Kilimanjaro, an island of intensive agriculture. Relations of exchange stretching across these production zones have been incentivized for centuries if not millennia as people stand to profit from the differences emerging in resources, weather, and socio-economic conditions. Historical sources, oral traditions and archaeological excavations all reveal that the livelihoods of Maasai in Amboseli were entangled with agriculturalists and other specialized producers lying within and beyond the basin. The Maasai occupation of Amboseli began after 1800 CE though based on evidence

from excavations the pastoralists who preceded them shared a proclivity for goods of coastal origin from around the 15th century CE. From the mid-second millennium CE there has been an intensification of trade activities and agricultural production in the wider Amboseli region, and we may expect that pastoral production systems in Amboseli were impacted by this, with there being a trend towards generating surpluses for exchange set against changing environmental parameters (see ESR 4). During the last millennium the production systems of pastoralists and agriculturalists were not operating in isolation of one another, yet a balance was maintained between farmers and herders and neither of these economies overwhelmed the other.

While pastoral production systems in Amboseli have long been oriented to exchange, and relations with agriculturalists have been ongoing for centuries, there was an upheaval c.1900 CE as the colonial era began in East Africa. The British colonial government treated 'ethnic' communities in East Africa as markedly distinct in their identities and livelihoods and downplayed the fluidity of the socio-economic landscape. On Kilimanjaro the rise of a plantation economy and the re-direction of land and labour towards export crops radically transformed agricultural production (see ESR 6) that had previously been oriented towards local consumption. Despite these changes trade continued to occur along the border, and farming continued to articulate with the pastoral economy in Amboseli. However, there were new developments. For one, due to the alienation of farmlands in the humid highlands, recently introduced crops such as maize and cassava were increasingly planted in the lowlands at the expense of dry-season grazing. Pastoral rangelands were further appropriated and subdivided compounding limitations on access to grazing. The number of people living in Amboseli continued to grow due to artificial land scarcities elsewhere, but livestock holdings did not. It is only very recently that farming activity has begun to threaten to overwhelm the balance between agriculture and pastoralism in Amboseli, despite the long history of these production systems in the area.

Executive summary ESR 3 (Geert van der Plas)ⁱ

Long-term dynamics of the East African landscape are determined by the interaction between natural climate variability and human activity. This project investigates the relative importance of these drivers of landscape change using records of plant pollen, fungal spores and charcoal preserved in dated lake sediments from different sites across Kenya. The first study site is Lake Simbi, close to Lake Victoria in western Kenya (Colombaroli *et al.*, 2016).ⁱⁱ This project explored the relationship between changes in climate, vegetation and biomass burning (i.e., fire regime) during the last 1200 years. Incidence of fire was found to be controlled mostly by decade-scale climate variation, with intermediate levels of moisture availability maximizing biomass burning. Ancient human disturbances between 1000 and 1200 AD seem to have amplified the effects of climate on fire, in contrast to modern times when agricultural landscape conversion suppresses

the natural fire regime. Up to 1/3 of past vegetation changes, mostly expansion/contraction dynamics of the woodland ecotone, can be explained by variation in fire regime.

Lake Bogoria is a hypersaline lake in the Kenya Rift Valley at the base of the Marmanet-Laikipia Escarpment. The region's climate is tropical semi-arid, with large inter-annual rainfall variability overprinting an annual mean of 750 mm. In this sub-project we compared the pollen and charcoal records with an independent climate reconstruction derived from the same sediment record covering the last 1300 years (De Cort et al., in press).ⁱⁱⁱ Our reconstruction shows regional continuity of a relatively open savanna vegetation. Two major changes during the periods ~1180-1335 AD and ~1910-2014 AD, when Afromontane forest and to a lesser extent woodland expanded relative to grassland, were likely caused by changes in precipitation. The occurrence of herbs indicative of disturbance and cultivated trees such as pine (*Pinus*) suggest that human impact on the landscape played an important role from around AD 1910 onward, and the resulting landscape fragmentation has significantly impacted the local fire regime. Human activities will likely continue to be a main driver of vegetation change, and future trends in biomass burning will depend both on future trends in precipitation and land-use change.

A 2650-year pollen record from Lake Challa near Mt. Kilimanjaro documents the evolution of a mainly open grassland savanna ecosystem. Expansion of woodland occurred around 550 AD and throughout the period AD 1100-1600. Cultivated cereals are present from at least AD 1600 and increase from AD 1725 onward, documenting expansion of human activity in the region. Historical records place the introduction of maize (*Zea mays*) in East Africa around the end of the 16th century, but in many inland regions it became a common food crop only in the 20th century. The aim of this sub-project is to document the introduction and spread of maize through East Africa with good temporal and spatial resolution, using high-resolution plant pollen data from robustly dated bog and swamp sediment records. To this aim, pollen analysis focuses specifically on the large grass pollen grains uniquely attributed to maize. Lead-210 and/or Cesium-137 dating of the sediments is required to date the regional first appearance of maize with appropriate precision. Where available, historical agricultural records are used to quantify the time difference between the documented start of maize cultivation and its first appearance in a local pollen record. Preliminary results from Lake Challa and Lake Simbi date the first pollen-inferred appearances of maize around AD 1860 and AD 1940, respectively. In the northern basin of Lake Bogoria which is situated adjacent to long-lived human settlements the first appearance of maize is dated to around AD 1870, but in the southern basin within a largely pristine landscape it is recorded only from about 1995 onwards, pointing to a relatively small dimension of the pollen source area(s). Integration of our results from these and other East African lakes with equally well-constrained published data may eventually create a chronological marker horizon for pollen records of East Africa's recent environmental history.

Executive summary ESR 4 (Esther Githumbi)

Despite an increase in the number of East African palaeoenvironmental studies, there are still many knowledge gaps due to the extensive diversity of the landscape caused by the variability in climate and topographic features. Understanding long-term historical change enables us to comprehend the historical drivers of ecosystem change and the interaction of the drivers at different scales that produce the current landscapes in which we live. This is crucial if we are to comprehend current ecological functions and processes and develop sustainable land-use management plans that address the current critical issues that we are now facing such as declining biodiversity. ESR4 sought to address these knowledge gaps by applying a multi-proxy approach analysing pollen, macro-charcoal, sediment characterisation and elemental profiles to document palaeoecological records and reveal environmental changes since the late Pleistocene-Holocene transition period in the Mau Forest (Kenya) area and since the mid-Holocene from Amboseli (Kenya). Mau Forest was characterised by diverse Afrotropical forest taxa between ~16,000 cal yr BP and ~13,000 cal yr BP that decreased during the Younger Dryas. During the early Holocene, there was a slight increase in montane tree taxa and the main vegetation change noted during the Holocene was the increase in woody shrubs and herbs. The pollen, sediment characterisation and elemental profiles revealed that climatic variability was the main driver of forest composition change and periods of aridity and wetness were identified at ~15,000, ~13,400, ~12,000 and ~1200 cal yr BP where there was increased organic matter, sand, magnetic susceptibility with peaks in detrital elements suggesting periods of wetness.

Four new Amboseli records dating from the mid Holocene (~5000 cal yr BP) revealed a predominantly dry environment characterised by localised wet and dry phases and fire activity. The spatial differences observed from the Amboseli records are attributed to hydrological variance as the swamps are all fed by ground water and the differential use by humans and wildlife. Kimana, Enkongu and Esambu swamps are Cyperaceae dominated; the pollen records indicate that Amboseli is a grassland savannah dominated by Poaceae, *Acacia*, *Commiphora* and *Euphorbia*. The pollen composition, abundance, and charcoal concentration levels vary between the four Amboseli sites indicating localised drivers and controls of fire at each site.

The palaeoecological records presented in this study provide long-term insights into the development of Mau Forest and the Amboseli. The multi-proxy approach has improved our understanding of change in the Mau forest vegetation and the Amboseli savannah composition, the drivers of the changes observed including climate, fire and human activities (See ESR 2) and the utility of such long-term records in development of ecosystem management policies.

WP3 Present Scenarios, c. AD 1930-today: This work package focused on the present and very recent past. It comprised four distinct projects, two with an ecological focus (**ESR 5 & 6**), and two with anthropological and geographical/historical foci (**ESR 7 & 8**). WP3 took its cue from the observation that land use in East Africa is undergoing profound social-ecological transformations connected to tremendous urban growth rates, globalization of the horticulture industry and rapidly emerging national and global markets for diverse other natural resources.

Executive summary ESR 5 (Aynalem Degefa)

Land degradation due to loss of vegetation and fertile soils is one of the major environmental problems affecting the catchments of lakes Baringo and Bogoria in Kenya's central Rift Valley. In a first case study we used magnetic-susceptibility and grain-size measurements on three dated sediment cores from Lake Baringo to evaluate whether the depositional record of this shallow and climate-sensitive lake has sufficient continuity and integrity to trace the history of anthropogenic catchment disturbance through analyses of the changing rate and nature of sediment input. The studied sediment sequences display a similar stratigraphy of fine-grained lacustrine clays, deposited on top of stiff clays formed when Lake Baringo fell completely dry during an episode of prolonged drought (~rain failure) in the late 18th and early 19th century (cf. Anderson 2016).^{iv} A pattern of cyclic sedimentation during the early to mid-20th century reflects seasonal alternation between sediment input from river discharge and from enhanced local soil run-off, associated with high population and livestock pressure.

The thickness of lake sediments deposited in the past 200 years increases from north to south, due to high sediment influx from the Perkerra and Molo rivers, which drain the southern Baringo basin. Sedimentation rates increased 5- to 6-fold from the 19th to the 20th century, consistent with historical data on increasing soil erosion and land degradation since the 1920s. Sediment accumulation in Lake Baringo over the past 60 years has been very high (from $0.5 \text{ g cm}^{-2} \text{ yr}^{-1}$ in the north to $1.2 \text{ g cm}^{-2} \text{ yr}^{-1}$ in the south), but this has had less influence on variation in mean water depth than climate-driven fluctuations of the lake's surface level. These results prompted two follow-up studies. First, the project aims to obtain and collate all gauge-derived and other instrumental water-level data from Lake Baringo, to better assess the relationship between historical climate variability, fluctuations of Lake Baringo, and hence long-term changes in the region's water availability (or scarcity). Second, the project aims to directly link the documented changes in the rate of lake sedimentation through time with the history of human occupation in the Baringo catchment derived from archeological and historical records (cf. ESR 1).

Linked to a case study by ESR 3, sedimentological and geochemical analyses were also conducted on the sediment record of Lake Bogoria, located immediately south of Lake Baringo, to unravel

both the timing and relative magnitude of historical land-use change in its 700 km² catchment. Lake Bogoria is one of the few Kenyan lakes that did not dry out during the early-19th century drought, so that its sediment record provides an uninterrupted archive of past environmental change. From the early 17th century to ~AD 1800, relatively dry climatic conditions (De Cort et al. in press) rendered the region unattractive to both farmers and pastoralists. The dominant sediment source during this period were coarse-grained, well-drained catchment slopes with illite clays immediately surrounding the lake. From the early decades of the 19th century farmers started to clear forest and woodland areas for cultivation by setting fire. This destabilized clay-rich smectite-kaolinite soils in headwater areas of the catchment, through which the Sandai-Waseges river flows before entering Lake Bogoria; however, human activity was still too low to significantly alter total sediment accumulation. Also the magnitude of anthropogenic biomass burning at that time, while substantial, did not exceed natural variability at the multi-decadal time scale.

Following ~60 years of relatively stable land use with little biomass burning, at the start of the 20th century both charcoal fluxes and sediment accumulation start to increase gradually. Both accelerated from AD 1970 onwards, presumably triggered by the land redistribution following Kenya's Independence in 1963. Since the early 2000s sediment accumulation has increased further to >10 times its base level, reflecting the severe land degradation and soil erosion associated with intensified land use, whereas biomass burning has fallen back to early 20th-century levels. In general, the results of this work emphasize that while impacts by indigenous populations on natural resources in the Kenya Rift Valley during the pre-colonial period may not be negligible, they appear to be dwarfed by the sheer magnitude of environmental disturbance occurring today, driven by land redistributions and rapidly accelerating demographic pressure since the 1960s.

Executive summary ESR 6 (Maximillian Chuhila)

Studies of land use change have attracted relatively limited attention from historians compared to other disciplines like human geography and anthropology. ERS 6's history of land use change in Kilimanjaro sought to address this by undertaking a study of how different actors interacted and shaped the whole process of land use on the slopes of Mount Kilimanjaro between 1920s and 2000s. The results showed that land use change involved a myriad of complex interrelations that cut across a number of actors. The actors were government policies and plans, uses of a particular land, the social, economic and political construction and affiliation to a landscape. The study used the slopes of Mount Kilimanjaro to show how the Chagga have interacted with the challenges of population increase and market economy that had impact on land availability and use. It argues that while government plans were vital in determining land use, they were not enough to give directions towards particular forms and styles of land uses, it

remained to be negotiated with other factors just mentioned above. Also the study shows that it is not always the case that only population pressure and economic motives influence the way people interact with their environment but a combination of population pressure, economic motives and social cultural motives.

By using documentary sources, oral histories and contemporary sources such as satellite imagery reading and interpretation, the study concluded that access to land use was diverse and varied across and within similar environments in the whole period of study from 1920s to 2000s. The variation resulted from the nature of the societies themselves, their environments and how authorities tended to regulate access and use. The thesis shows near the end that adaptation and resilience to both social-cultural, economic motives and pressures of societies moving from one area to another with somehow different characteristics was entwined in the challenges of struggling to re-establish in new environments and the social-cultural connections to land and resources. It was easier for the Chagga to maintain strong cultural ties with the highland but not to transfer knowledge and skills of highland cultivation, food habit and livestock domestication to the lowland. The reasons behind this were based on the presence of some relatives, social-cultural values and properties in terms of banana fields and houses on the highlands that could not be moved to the lowlands. The question of what type of economic activities and social interactions were to be established on the lowlands was determined by the suitability of the lowland and not necessarily the skills from the highland. For instance, cultivation of perennial crops could not be possible because the lowlands received seasonal rainfall and had no access to reliable irrigation furrows like the highlands.

Executive summary ESR 7 (Eric Kioko)

The Maasai/Kikuyu agro-pastoral borderlands of Maiella and Enoosupukia, located in the hinterlands of Lake Naivasha's agro-industrial hub, are particularly notorious in the history of ethnicised violence in the Kenya's Rift Valley. In October 1993, an organised assault perpetrated by hundreds of Maasai vigilantes, with the assistance of game wardens and administration police, killed more than 20 farmers of Kikuyu descent. Consequently, thousands of migrant farmers were violently evicted from Enoosupukia at the instigation of leading local politicians. Nowadays, however, intercommunity relations are surprisingly peaceful and the cooperative use of natural resources is the rule rather than the exception. There seems to be a form of reorganization. Violence seems to be contained and the local economy has since recovered. This does not mean that there is no conflict, but people seem to have the facility to solve them peacefully. How did formerly violent conflicts develop into peaceful relations? How did competition turn into cooperation, facilitating changing land use?

To answer these questions this project explored the value of cross-cutting ties and local institutions in peaceful relationships and the non-violent resolution of conflicts across previously violently contested community boundaries. It mainly relied on ethnographic data collected between 2014 and 2015. The study built on several theoretical approaches in anthropology and the social sciences – specifically, violent conflicts, cross-cutting ties and conflicting loyalties, joking relationships, peace and nonviolence, and institutions, in order to understand shared spaces that are experiencing fairly rapid social and economic changes, and characterised by conflict and coexistence.

In the researched communities, cross-cutting ties and the split allegiances associated with them result from intermarriages, land transactions, trade, and friendship. Two key institutions, local peace committees, an attempt to standardise an aspect of customary law, and Nyumba Kumi, a strategy of anchoring community policing at the household level were found to play critical roles. In 2010, the state “implanted” these grassroots-level institutions and conferred on them the rights to handle specific conflicts and to prevent crime. The results demonstrate that the studied groups utilise diverse networks of relationships as adaptive responses to landlessness, poverty, and socio-political dynamics at the local level. Material and non-material exchanges and transfers accompany these social and economic ties and networks. In addition to being instrumental in nurturing a cohesive social fabric, such alliances could be thought of as strategies of appropriation of resources in the frontiers – areas that are considered to have immense agricultural potential and to be conducive to economic enterprise. Consequently, these areas are continuously changed and shaped through immigration, population growth, and agricultural intensification. However, cross-cutting ties and intergroup alliances may not necessarily prevent the occurrence or escalation of conflicts. Nevertheless, disputes and conflicts, which form part of the social order in the studied area, create the opportunities for locally contextualised systems of peace and non-violence that inculcate the values of cooperation, coexistence, and restraint from violence. Although the neo-traditional institutions (local peace committees and Nyumba Kumi) face massive complexities and lack the capacity to handle serious conflicts, their application of informal constraints in dispute resolution provides room for some optimism.

Executive summary ESR 8 (Chris de Bont)

This project closely followed the intentions described in the application for ESR 8. The project developed a specific focus on smallholder irrigation on the Kilimanjaro lowlands (i.e. in the Pangani basin). Based on the expertise of the ESR, local conditions at the site, and for the overall scientific goals of the REAL project, this site turned out to be the most relevant place for carrying out this case study. The specific topic investigated concerned the effects of modernization policies aimed at smallholder irrigation in relation to irrigation investments and

development that is led by farmers themselves (and not a direct outcome of governmental irrigation policies). Hence, the project addressed questions about what type of irrigation practices and technology can be considered as the “right”, or most promising and relevant, type of irrigation development for the region (Lankford, 2009).^v A key starting point for the project was the diverse, widespread and relatively successful irrigation farming by smallholders in East Africa’s drylands over the last few centuries. A key problem that the project addressed was why national irrigation policies largely neglect the successful aspects of smallholder farming, and instead rather pictures them as inefficient and archaic. This in turn results in policies that tend to overemphasize the advantages arising from government supported public or public-private investments in irrigation aimed at modernizing the smallholder sector, and play down the capacity of smallholders themselves to improve, and modernize, their irrigation schemes. The project investigated this issue by drawing on a historical review of modernization policies in Tanzania from the 1930s to the present and their impacts on irrigation practices, and via two in-depth studies of recent and ongoing cases of farmer-led development and expansion of irrigation practices. One case study focused on the recent expansion of smallholder irrigation using petrol pumps to access groundwater, while the other case study assessed the development of a farmer-led canal irrigation scheme with particular attention to the implications of a demand-driven policy model. Results will be reported as a PhD-thesis (to be presented and defended in June 2018), consisting of three scientific article manuscripts, submitted or to be submitted to, peer-reviewed scientific journals, as well as a comprehensive summary of the project. The three articles each resolve a specific set of questions related to the overarching research topic. A general conclusion is that farmer-led initiatives to develop irrigation practices and improve the production of irrigated crops in the region should be given more serious attention as part of national policies for irrigation development.

WP4 Future Scenarios, today to 2100 AD and beyond: Ecosystems and the services they provide (e.g., timber, water, carbon storage, nutrient cycling, soil formation) are crucial for livelihoods and national development worldwide, particularly in East Africa where people’s livelihoods connect strongly with their environment. Challenges to this relationship in the form of climate change, land-use transformation, population growth & migration, and complex global environmental policy are rapidly accelerating. Population growth together with socio-economic development unavoidably results in strong resource competition between agriculture, forest and biodiversity conservation, water provision and carbon sequestration. The goods and services provided by ecosystems are under particular threat in East Africa’s mountain ranges and the associated lowland lake catchments. Four sub-projects (**ESR 9-12**) explored these issues in different study areas and their possible implications for socio-ecological resilience at different spatial and temporal scales.

Executive summary ESR 9 (Christine Adongo)

The goal of this project was to develop a proposal on *land use and the struggle for resources Kenya Rift valley*, focused on the implementation of a geothermal project as the main driver of socio-ecological changes of a pastoral landscape. With an environmental science background, it was expected that ESR9 would develop an interdisciplinary research at the crossroad between environmental sciences and anthropology. During the project anthropological research was undertaken among the *Kekonyokee*, a *Maasai* subsection of the *Olkaria Volcanic complex*, who have adapted to various ecological conditions. As such, the project is in line with the understanding of landscapes changes due to the inclusion of pastoralist communities in the wider commercial economy. Key components have been collection of interview data from community members on their reactions to and engagement with different institutional actors and companies involved in implementing geothermal energy in Kenya. Geothermal companies such as AKIIRA are trying to promote new sustainable models to implement geothermal, and the research project initiated new collaboration with a Japanese team from the *Research Institute for Humanity and Nature* (Kyoto). Currently, ESR 9 is finalising her thesis having returned to Kenya in July 2017, although owing to the tense political situation in western Kenya, she is likely to delay submission until January 2018. The vice chancellor of Jaramogi Odinga Odinga University (Bondo, Kenya) who is partner of a project led by Benoit Hazard has informally indicated that he hopes to recruit her as lecturer after her defence.

Executive summary ESR 10 (Marie Gravesen)

This project sought to explain the 2016-2017 wave of land invasions in Laikipia, Kenya, by exploring the situation before this state of emergency occurred and the different types of changes that western Laikipia has undergone. A regional approach was used to explore the social-ecological dynamics between five different actor groups, namely: pastoralists, smallholders, conservationists, ranchers and absentee holders. Specifically, the study focussed on three case areas, Lorien, Thome and Ol Moran, each illustrating distinct aspects of the history of land distribution, land-use systems, and ethnicity-related conflicts that represent present-day Laikipia as a contested environment. Investments and institutional presence is fragmented: ranches, conservancies and towns are well-connected to the state in terms of economic, political and institutional functioning, whereas, areas such as Lorien, Ol Moran and Thome that are located in between these development-impacted islands of enclosures, are defined by an absence of state services such as a provision of security and protection of private property rights. This lacking representation by public and private institutions effectively intensifies tension and conflict. Overall, the study found that the historical development and influence of political and ethnic factors, along with issues of land distribution, are among the main ignition points for the general tension on the plateau, and what ultimately led to the 2016 and 2017 state of emergency.

Executive summary ESR 11 (Annemiek Schrijver)

This project followed the overall intentions described for WP4 focusing on issues of resource competition, migration processes, land use transformation, climate change adaptation, and policy contexts. During the initial assessment of potential study sites for the study, it was decided to shift the focus from smallholder's investments in agro-ecology to the dynamics of pastoral mobility (in the Kenyan drylands), as this topic stood out as a better match with the expertise of the ESR and the overall scientific goals of the REAL project. The temporal focus of the project was on the current dynamics (including the recent past) and the implications of these in face of future environment and development challenges. The 4th Assessment Report of the Intergovernmental Panel on Climate Change (IPCC 2007) underscored the need for research on climate-change adaptation to ensure sustainable food security and development.

The project by ESR 11 tackled this by addressing issues of food and livelihood security among marginalized pastoralist communities in Laikipia and Samburu Districts, Kenya, who are particularly vulnerable as a result of resource depletion and competition arising from, for example, national industrial development and climatic changes. In this way the project specifically targeted the current (and future) challenges facing pastoralist production systems in the Kenyan drylands. More specifically, the project investigated the shifting and increasingly more complex nature and adaptation of mobility and natural resource use practices of pastoralists. Recurrent droughts, land degradation and loss of forage, but also increasing enclosures of land for community conservation, government-led settlement schemes, and large-scale infrastructural investments to support extractive industries are examples of shifting conditions. These shifts have a profound impact on pastoralists' opportunities to access grazing while making mobile pastoralism, as a highly valued strategy to manage grazing areas and exploit resource variability, both a necessary and increasingly complex production strategy. A variety of projects by the government and NGOs have, and are, being, implemented to manage and improve the productivity of Kenyan rangelands, e.g. by managing pastoral mobility. Yet, questions about how pastoralists perceive socio-environmental changes and actually govern and adapt their mobility patterns and resource use to climate change and emerging spatial restrictions has received limited attention. The project investigated this by drawing on case studies from Laikipia and Samburu Districts.

Results will be reported as a PhD-thesis (to be presented and defended in 2018), consisting of four scientific article manuscripts, submitted or to be submitted to, peer-reviewed scientific journals, as well as a comprehensive summary of the project. The articles each resolve a specific set of questions related to the overarching research topic. Using a political ecology lens, the thesis documents how resources are used, how grazing and mobility is planned for, how access is negotiated, and how boundaries and territory are constructed and performed both within

and beyond the context of current policies and development projects and strategies in the region. A general conclusion is that the complexities and future prospects for pastoral mobility and production systems should be given more serious attention as part of national development strategies.

Executive summary ESR 12 (Rebecca Kariuki)

ESR 12's research project aimed at understanding the interactions between land use patterns, climate change and conservation in the Amboseli and Maasai Mara ecosystems in southern Kenya. These two areas were selected as study sites as the project was interested in evaluating the impact of land use and climate change across a grazing and sedentarization gradient in southern Kenya. Amboseli and the Maasai Mara ecosystems are arid savannas adjacent to each other and have largely been used for livestock production and wildlife conservation. However, due to differences in micro-climates, natural resource management and socio-economic factors, there are different land use patterns in the two areas. Using an interdisciplinary perspective, ESR 12 designed and implemented a social-ecological model to study the interaction between the bio-physical and socio-economic factors. Relationships and threshold levels between biophysical factors were simulated in a dynamic vegetation model and used as input factors in the social-ecological model. Empirical data on pastoral land use change decision making criteria was collected using semi-structured interviews with local community experts in the study sites. Together with secondary data from published literature and government and internet repositories and databases, the empirical data were used to set the assumptions and rules that govern the contribution of micro-level land use change decisions by each pastoralist community to the macro-level land use change patterns observed in the study sites. The time frame for the model simulation is current (from about the 1960s) with several possible scenarios of land use patterns based on future changes in rainfall patterns, land tenure types and monetary benefits for pastoralists from wildlife conservation initiatives. For each simulated scenario, there are outputs on pastoralists' income levels and livestock and wildlife density in the two study sites.

A general conclusion from the simulation is that in Amboseli, most pastoralists, especially those with land near permanent water bodies, change from livestock grazing to agriculture, whereas in the Maasai Mara pastoralists living near the protected area are likely to use their land for livestock grazing combined with conservation activity. It is envisioned that results from the simulation will contribute to science as well as to the planning and management of natural resources in East African savannas. They will be reported as a PhD thesis which will be comprised of a book chapter, three peer reviewed journal articles and comprehensive introduction and synthesis chapters. The book chapter covers ESR 12's literature review while the three articles separately address the biophysical, social and social-ecological components of

the research project. Currently, two articles have been submitted for publication and the others are in preparation with a goal of completing and defending the entire PhD thesis in early 2018.

Executive summary ER1(Colin Courtney Mustaphi)

ER1 focused primarily on quantifying local and regional scale land cover changes and contributed palaeoenvironmental datasets to established global international databases such as the Global Charcoal Database. ER1 worked closely with fieldwork and lab work of ESR4 leading to a number of collaborative papers and over 5 collaborative submissions. ER1 published 8 papers in the field of palaeoenvironmental reconstruction and data analysis during time on the project from 1 November 2013 to 31 August 2015. One paper was specifically related to REAL project training event at the National Museums of Kenya, Nairobi, for REAL students and Kenyan researchers (Courtney Mustaphi et al 2014).^{vi} One of the main foci was late Quaternary vegetation and fire reconstructions using subfossil pollen and charcoal quantified from lake sediments and swamp peat cores. Data collected during the REAL project contributed to 5 published peer-reviewed journal articles and 3 manuscripts in preparation. Continued international collaborations on palaeoenvironmental databasing and syntheses produced 4 papers, one of which was an equal contribution primary authorship (Hawthorne et al, in press, QI).^{vii} During and continuing after the REAL project, ER1 participated in the Leverhulme funded Serengeti Fire Project lead by Dr. Colin Beale through the University of York's Tropical Ecosystems Network and participated in 6 field expeditions to the Serengeti and Tarangire National Parks in northern Tanzania and has produced 1 publication (Hempson et al, in press, *Ecography*)^{viii} and 1 high-impact submission (Beale et al, submitted, *Eco. Lett.*).^{ix} These papers show the importance of variability in savannah ecosystem fire regimes to increasing animal and bird biodiversity with implications for protected area management in Africa. Data collected by ER1 for the REAL project continues to be used for first author manuscripts and multi-author/multidisciplinary collaborations in palaeoenvironments, land cover change and management, and popular science digests. ER1 participated in the filming, editing and/or production of 4 video outputs available on Youtube. Currently ER1 has over 20 peer-reviewed publications and continues interdisciplinary research at the Department of Archaeology and Ancient History, Uppsala University.

Executive summary ER 2 (Franziska Bedorf)

In line with the tasks described for WP 5 (*Dissemination & Capacity Building for Sustainable Ecosystems and Livelihoods*) in the project proposal, ER 2 took a lead in creating and implementing the outreach and capacity building activities of the REAL project. In order to produce effective means of dissemination and outreach, ER2 also collated and synthesized data generated by the ITN and established cooperation with other research and outreach institutions in East Africa as well as in Europe.

On this basis, ER 2 developed several formats for communicating the REAL project's findings to a general audience in Kenya, Tanzania and Europe, as well as to secondary school students and policy makers. Besides restructuring and expanding the REAL ITN's online presence by remodeling the website, setting up a Facebook page and maintaining and updating both, the knowledge transfer included the production of a web documentary film, a film and poster exhibition (displayed at the Nordic Africa Days 2016), a collaboration with the Nordic Africa Institute regarding the publication of policy notes, the project's final conference and a travelling exhibition. ER 2 was in charge of developing both the idea and script for the web documentary "Changes" and the concept for the traveling exhibition "Getting Closer". For the production of the web documentary, ER 2 collaborated with the filmmaker Arghyro Paouri at CNRS/ EHESS in Paris, France, affiliated with the project through PI Benoit Hazard. The traveling exhibition (co-funded by "the Seedbox. A Mistra-Formas Environmental Humanities Laboratory based at Linköping University, Sweden") was curated and designed in cooperation with *Expology*, an exhibition design consultancy from Stockholm, Sweden.

For both the web documentary and especially the travelling exhibition, ER2 conducted extensive background research on issues such as entangled narratives of social and ecological crises in the Anthropocene and exhibitions as catalysts for social change. The aim of the exhibition is to make the very abstract concept of "climate change" palpable by breaking it down to something concrete and localized, showcasing ways of getting closer to what is happening on the ground in East Africa and presenting personal stories related to socio-environmental changes. The exhibition will be displayed at museums in Sweden, Germany and East Africa in 2018.

Apart from focusing on the dissemination of the research findings, ER2 also had a significant role in planning and facilitating the training events of the second project period (2015-2017) as well as the REAL project's final conference.

ⁱ ESR 3 and ESR 5 both investigated (pre-)historical interactions between climate change, landscape evolution and human activity in water-limited regions of equatorial East Africa, in order to produce a solid long-term reference frame for the modern-day and possible future use of those regions' natural land and water resources. These investigations used state-of-the-art paleolimnological techniques, which involved the extraction and interpretation of climate and environmental proxies from dated lake sediments. Originally, ESR 3 planned to focus on the longer-term history (the last millennium) using lake-sediment records from the sub-humid area around Mt. Kilimanjaro, and ESR 5 on a more detailed environmental reconstruction of the last 200 years using lake-sediment records from the semi-arid central Kenya Rift Valley. In consideration of the expertise of the ESRs hired for these two projects, as well as pre-existing research materials and data, and it was decided that ESR 3 would deal with the paleoecological aspects of environmental history in both regions, whereas ESR 5 would focus on impacts of past human activity on Kenya's Rift Valley landscape using sedimentological and geochemical proxies.

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