TUM School of Life Sciences

Human Acceptance and Ecological Outcomes of Conservation Strategies in Fragile Forest Ecosystems of South-Eastern Kenya

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To my daughter, Kendi.

“Until you dig a hole, you plant a tree, you water it and make it survive, you haven't done a thing. You are just talking.” (Prof. Wangari Maathai, 2006)

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Zusammenfassung

Die aktuellen Umweltveränderungen deuten darauf hin, dass anthropogene Aktivitäten die natürlichen Ökosysteme stark beeinträchtigen und einen beispiellosen Verlust der biologischen Vielfalt verursachen. Eine der größten Herausforderungen des Anthropozän ist die Vereinbarkeit von Biodiversitätserhalt und menschlichen Lebensgrundlagen. Diese Aufgabe ist von besonderer Relevanz für die Regionen mit tropischen Wäldern in Afrika südlich der Sahara. Verbleibende Wälder in Afrika sind oft Hotspots globaler Biodiversität und liefern wichtige Ökosystemdienstleistungen, die die Grundlage menschlicher Existenzen bilden. Heute sind diese Wälder zahlreichen sozioökonomischen Belastungen auf verschiedenen räumlichen und zeitlichen Ebenen ausgesetzt. Partizipative Waldbewirtschaftung (Participatory Forest Management, PFM) wird derzeit als Ansatz für den Schutz dieser zunehmend fragilen Wälder entwickelt. PFM baut auf breit angelegten Co-Management-Initiativen auf, die darauf abzielen, die Verwaltungsbefugnisse, Verantwortlichkeiten und Ansprüche gerecht unter den verschiedenen Interessengruppen zu verteilen. Die Anwendbarkeit, Akzeptanz und die sozio-ökologischen Auswirkungen von PFM werden in Afrika südlich der Sahara, einer Region, die sich durch sehr unterschiedliche Landschaften, Menschen und Biodiversität auszeichnet, kontrovers diskutiert.

Vor diesem Hintergrund bietet diese Dissertation eine zweistufige Analyse zum Verständnis von Faktoren, die die Akzeptanz und Legitimität von Waldschutzmaßnahmen in drei verschiedenen Waldtypen im Südosten Kenias beeinflussen. Die hier vorgestellten Studiengebiete umfassen die Kitui-Galeriewälder, den Arabuko-Sokoke-Tiefland-Küstenwald und die Taita-Hills-Nebelwälder. Im ersten Untersuchungsgebiet finden kaum Naturschutzvorhaben statt und daher ist PFM hier nicht existent. Die letztgenannten Untersuchungsgebiete dagegen sind als globale Biodiversitäts-Hotspots gelistet und erfahren

erhebliches Naturschutzinteresse, wobei sich PFM hier in verschiedenen Stadien der Umsetzung befindet. Zwischen 2016 und 2018 wurden Datenerhebungen in den Untersuchungsgebieten durchgeführt, wobei insgesamt 827 Anwohner dieser Wälder an strukturierten Umfragen teilgenonmmen haben. Diese Datensätze wurden durch insgesamt 37 Experteninterviews mit Vertretern staatlicher und ziviler Umweltorganisationen und Gemeindeinitiativen aus dem jeweiligen Untersuchungsgebiet ergänzt. Rückschlüsse auf ökologische Auswirkungen wurden aus aktuellen wissenschaftlichen Studien aus den jeweiligen Untersuchungsgebieten gezogen.

Die untersuchten Themenbereiche umfassen Biodiversitätsbewusstsein und -wissen, die Wertschätzung von Ökosystemleistungen, die Wahrnehmung des Artenschutzes, die Bereitschaft zur Umsetzung von Praktiken nach Umweltschutzgesichtspunkten, die Umweltkommunikation sowie die Einbindung und Beteiligung der Bevölkerung an Naturschutzmaßnahmen. Die wichtigsten Prädiktorvariablen waren Studiengebiet, Alter, Geschlecht, ethnische Zugehörigkeit, Bildung, Einkommen und Größe des Landbesitzes. Im ersten Schritt wurden die gebietsspezifischen Zielkonflikte, die den Waldschutz beeinträchtigen, untersucht. Im zweiten Schritt wurden dann die übergeordneten Trends und Zusammenhänge untersucht. Insgesamt konnten u.a. ein geringes Bewusstsein für Biodiversität, eine Neigung, Pflanzenarten gegenüber Tierarten als schützenswerter zu erachten, eine starke geographische Komponente und eine allgemeine Bereitschaft zum Biodiversitätsschutz bei unzureichender Umsetzung in die Praxis festgestellt werden.

Die Bedeutung dieser Faktoren war je nach Untersuchungsgebiet unterschiedlich. Gleichzeitig waren die sozio-ökonomischen Hintergründe, die diese Zusammenhänge hervorbringen, jeweils spezifisch für die einzelnen Untersuchungsgebiete. Zum Beispiel korrelierte die Befürwortung des Schutzes von Wildtieren im Kitui-Gebiet positiv mit zunehmendem Alter, während im Arabuko-Sokoke-Wald (ASF) und im Taita Hills-Gebiet das Gegenteil der Fall

war. Stattdessen stieg die Unterstützung für den Schutz von Wildtieren mit zunehmendem Bildungsniveau und ortsbezogenem Wissen, sowohl in ASF als auch in Taita Hills. Dabei wiesen die Bewohner von Taita Hills ein höheres Niveau an formaler Bildung und ortsbezogenem Wissen auf als die Bewohner der Region ASF. In der Folge zeigten die Teilnehmer aus Taita Hills ein hohes kollektives Verantwortungsbewußtsein für den Erhalt der Nebelwälder, während die Bewohner der Region ASF dem Erhalt der Wäder gleichgültiger gegenüberstanden.

Außerdem dämpften mangelnder Vorteilsausgleich, historische strukturelle Benachteiligung, ungelöste Mensch-Wildtier-Konflikte, willkürliche Durchsetzung von Umweltgesetzen sowie eklatante Ungleichgewichte in den Bereichen Kommunikation, Macht und Inklusion den Enthusiasmus der Bevölkerung für den Waldschutz, insbesondere in ASF und Taita Hills. Abschließend stellt diese Dissertation fest, dass ähnliche Zusammenhänge wie die oben erwähnten durch verschiedene sozio-ökonomische Wirkungspfade auf sehr feinen Skalen erzeugt und verstärkt werden können. Zweitens wird davor gewarnt, dass die Nichtbeachtung dieser feinskaligen Zusammenhänge und Interaktionen zugunsten verallgemeinernder regionaler Trends zu ineffektiven Naturschutzmaßnahmen führen kann, die sogar kontraproduktiv für die Schutzbestrebungen sein könnten. Drittens wird die Aufmerksamkeit auf die Vernachlässigung von Auwäldern und Ökosystemen gelenkt, die oft keine charismatische Megafauna oder Wirbeltiere beherbergen, aber wichtige Biodiversitätskorridore darstellen und die Erhaltung der Biodiversität auf Landschaftsebene unterstützen können. Außerdem zeigen die Bewohner dieser in ihrer Bedeutung für den Naturschutz unterschätzten Gebiete Bereitschaft für Waldschutz durch Co-Management. Die hier vorgestellten Kompromisse und PFM-Fallstricke sind Lektionen, die genutzt werden können, um das PFM in den Studiengebieten sowie in ganz Subsahara-Afrika zu verbessern.

Summary

Current environmental changes suggest that anthropogenic activities are severely impacting natural ecosystems and driving an unprecedented biodiversity loss. One of the biggest challenges of the Anthropocene remains the reconciliation of biodiversity conservation and human livelihood needs. This quest becomes notably relevant for tropical forests in sub-Saharan Africa. Most forest remnants in Africa are global biodiversity hotspots and supply essential ecosystem services that quality human livelihoods depend on. Today, these forests are under numerous socio-economic pressures at different spatial and temporal scales. Participatory Forest Management (PFM) is currently advanced as a viable approach towards conserving these increasingly fragile forests. PFM includes broad co-management initiatives that aim to equitably share the governing authority, responsibilities, and entitlements among different stakeholders. The applicability, acceptance and socio-ecological outcomes of PFM are highly debated in sub-Saharan Africa, a region characterised by highly diverse landscapes, people, and biodiversity.

Against this backdrop, this dissertation offers a two-step analysis into understanding the dynamics that impact forest conservation interventions' legitimacy and efficiency in three different forest types found in south-eastern Kenya. The study areas presented here include the Kitui gallery forests, the Arabuko-Sokoke lowland coastal forest and the Taita Hills cloud forests. The first study area attracts minimal conservation attention, and therefore PFM is non-existent. The latter study areas are listed as global biodiversity hotspots and attract considerable conservation interest with PFM at various implementation stages. Data collections were carried out from 2016 to 2018, whereby a total of 827 residents living within the vicinity of these forests participated in structured surveys. These datasets were complemented by 37 expert interviews with representants of the state, civil and community environmental organizations

from the respective study areas. Inferences on ecological outcomes are drawn from recently published ecological studies from the respective study areas.

The examined thematic areas include biodiversity awareness and knowledge, appreciation of ecosystem services, perceptions towards species protection, willingness to implement good environmental practices, environmental communication, and inclusion and participation in conservation action. The main predictor variables were area of study, age, gender, ethnicity, education, income, and landholding size. In a first step, the area-specific trade-offs that compromise forest conservation were investigated. In a second step, the overriding trends were explored. Overall, the results showed a low biodiversity awareness, an inclination to protect plant species over animals, high spatial bias, and a general willingness to conserve biodiversity but combined with underwhelming conservation action.

The degree of significance of each of these general trends differed with the study area. Simultaneously, the socio-economic pathways from which these overarching trends emerged were unique to each study area. For instance, local support for the protection of wildlife correlated positively with increasing age in the Kitui area, while in the Arabuko-Sokoke forest (ASF) and Taita Hills areas, reluctance to support wildlife protection increased with age. Instead, support to protect wildlife increased with increasing education levels and place-based knowledge in ASF and Taita Hills. In contrast, Taita Hills inhabitants recorded higher formal education levels and place-based knowledge than residents surrounding ASF. Consequently, Taita Hills participants demonstrated high collective responsibility towards conserving the cloud forests, where those surrounding ASF mostly showed indifferent attitudes.

Regardless, lack of benefit-sharing, historical resource disfranchisement, unresolved human-wildlife conflicts, selective environmental law enforcement, and glaring communication, power and inclusion imbalances curtailed forest conservation enthusiasm participants,

especially in ASF and Taita Hills. Conclusively, this dissertation contends that similar overarching trends (as listed in the preceding paragraph) can be produced and reinforced through different fine-scale socio-economic pathways. Secondly, it cautions that overlooking unique socio-economic interactions at the fine scale while favouring overarching regional trends may lead to untargeted conservation interventions in the respective forests that ultimately undermine conservation efforts. Thirdly, it draws attention to the neglect of riparian forests and ecosystems, which are often devoid of charismatic megafauna and vertebrates yet are important biodiversity corridors and may support biodiversity conservation at the landscape scale. Besides, the inhabitants of these undervalued areas for conservation demonstrate willingness for forest conservation through co-management. Lastly, the trade-offs and PFM pitfalls presented herein are lessons that can improve PFM in the study areas as well as across sub-Saharan Africa.

1. Introduction

1.1. Biodiversity conservation and human livelihoods

Biodiversity underpins human livelihoods quality (Mittermeier et al. 2011), and its loss undermines human resilience (Millennium Ecosystem Assessment, 2005). Healthy ecosystems are essential for the sustenance of ecosystem functions (Myers et al. 2000) such as climate regulation, water regulation and supply, soil formation, retention and nutrient regulation, pollination, dispersal, and genetic resources (de Groot et al. 2010; Meyer et al. 2015). Ecosystem functions directly or indirectly produce ecosystem services for the benefit of humans (Zhang et al. 2007) such as food, medicine, good air quality, favourable climates and precipitation, land productivity, pollination of crops, pests and disease control, fuel and energy, construction material, enjoyment, and spiritual values (de Groot et al. 2010; Meyer et al. 2015; Wangai et al. 2016).

In the endeavour to use, control, and maximise ecosystem benefits, anthropogenic-driven processes have simultaneously activated unintended and undesirable multifaceted trajectories (Hof et al. 2018) reverberating back through ecological landscapes (Jaeger 2000; Hof et al. 2018; Seibold et al. 2019) and socio-cultural landscapes in complex pathways (Berkes 2004; Cundill et al. 2017), especially in the tropics (Brockington 2004; Büscher & Whande 2007). Emerging understanding underscores that current economic growth models and consumption patterns are unsustainable and severely amplify biodiversity loss (Koh & Ghazoul 2010; Stoll-Kleemann & Schmidt 2017). Human-induced landscape modifications such as converting habitats into extensive agricultural fields and urban infrastructure drive habitat loss, fragmentation, and degradation, compounding into unprecedented global biodiversity loss (Hof et al. 2018; Habel et al. 2019; Bloomfield et al. 2020).

1.2. Challenges for forest conservation in Africa

The majority of the remaining global biodiversity reservoirs occur in tropical ecosystems (Myers et al. 2000; Millennium Ecosystem Assessment, 2005). Many of these biodiversity hotspots currently coincide with increasing human population pressures (Ahrends et al. 2010; Habel et al. 2019), accelerated and unsustainable land-use conversion (Koh & Ghazoul 2010; Aleman et al. 2017; Hof et al. 2018), high economic impoverishment (Ahrends et al. 2010; Mittermeier et al. 2011) and extreme climatic and weather changes (Mittermeier et al. 2011; Hof et al. 2018; Habel et al. 2019). These challenges become even more particular for Africa's tropical forests (Balmford et al. 2001; Aleman et al. 2017; Hansen et al. 2020). Recent statistics show that the continent lost 3.9 million hectares of forest annually between 2010 and 2020 (FAO 2020), driven by deforestation and selective logging (Aleman et al. 2017; Hansen et al. 2020) and accelerated land-use change (Hof et al. 2018; Habel et al. 2019).

Uncoordinated environmental governance (Nzau et al. 2020; Habel et al. 2020) and skewed environmental communication flows (Hohenthal 2018; Habel et al. 2019) exacerbated the fragility of African forest ecosystems (Balmfield et al. 2001; Berkes 2004). These challenges are compounded by historical injustices and legacies that reminisce colonial resource disenfranchisement (Brockington 2004; Githiru 2007), as well as international and national policies which may resort to counterproductive and maladaptive pathways (Teucher et al. 2020). Moreover, conservation action is often prioritised for African savannahs and bushlands, which are associated with megafauna and high tourism value (Githiru 2007; Riggio et al. 2019), while the conservation of forests and woodland is often sporadic (Balmford et al. 2001; Miles et al. 2006; Nzau et al. 2021a). Nonetheless, there are commendable efforts towards forest conservation and restoration in various diverse forest types across the continent (Gordon & Ayiemba 2003; Blomley et al. 2008; Matiku et al. 2013; Abiyu 2016).

1.3. Participatory Forest Management in Sub-Saharan Africa

Participatory Forest Management (PFM) is increasingly adopted as a progressive alternative to gated conservation approaches like national parks and strictly protected areas (Kellert et al. 2000; Schreckenberg & Luttrell 2009; Vyamana 2009) which exclude local people from the management and use of forest resources (Brockington 2002; 2004). PFM promotes the decentralisation of financial and administrative responsibilities and the transfer of decision-making authority and entitlements from the central government to local governments and civil society organizations, and ultimately to the local people (Kellert et al. 2000; Schreckenberg & Luttrell 2009; Vyamana 2009). It also includes a vital component of livelihoods diversification and improvement to reduce pressure on forest resources (Fabricius & Collins 2007; Vyamana 2009) and the inclusion of indigenous and local ecological knowledge systems in forest management (Kellert et al. 2000; Berkes 2012). PFM can be defined as a broad spectrum of diverse co-management strategies encompassing varying degrees of resource control by different actors from state to local level (Schreckenberg & Luttrell 2009).

The applicability, acceptance, and success of PFM on local livelihoods and ecological outcomes are highly debated in Sub-Sahara Africa (Kellert et al. 2000; Brockington 2004; Fabricius & Collins 2007; Nzau et al. 2020). Some of the challenges that undermine PFM in the region have already been pointed out in the preceding paragraphs. Several authors argue that the underlying assumptions of the PFM are either too naïve (Berkes 2004) or overestimate financial benefits (Fabricius & Collins 2007) for the co-management of forest resources to quickly persuade local people to support PFM (Nzau et al. 2020). These financial benefits are often elusive, reinforcing frustrations and distrust towards the conservation agenda (Berkes 2004; Githiru 2007; Nzau et al. 2020; 2021a). Additionally, increasing evidence points reluctance of states to equitably devolve management authority and entitlements to local people

(Igoe & Brockington 2007; Ming'ate & Bollig 2016). Numerous case studies find evidence for chronic asymmetrical power and knowledge imbalances between the state and local people (Hohenthal 2018; Magessa et al. 2020). In the meantime, ecological studies continue to find strong downwards trends in habitat quality and biodiversity (Aleman et al. 2018; Habel et al. 2019; Bloomfield et al. 2020). Nonetheless, there is positive evidence for improved ecosystem quality and human livelihoods in areas that have implemented participatory forest management (Blomley et al. 2008; Matiku et al. 2013; Burgess et al. 2017).

1.4. Emerging understanding in socio-ecological landscapes

Emerging understanding in forest ecology and management recognizes that socio-cultural aspects underscore successful biodiversity conservation in Sub-Saharan Africa (Githiru 2007; Burgess et al. 2017; Bloomfield et al. 2020). Natural resource management initiatives occur in complex socio-ecological landscapes and are subject to a multiplex of continually interacting in situ and ex-situ factors (Brockington 2002; Berkes 2004; Blomley et al. 2008). These factors can be grouped into five broad categories (Figure 1). They include: (1) Individual and social-cultural factors such as age (Kaltenborn et al. 2006), gender norms and dynamics (Vodouhê et al. 2010), ethnicities and their settlement histories (Steinhart 2000; Njogu 2004; Hartter 2010; Cundill et al. 2017), household wealth (Stern 2004; Mills & Waite 2009; Hartter 2010), formal school education (Reyes-García et al. 2010; Rieckmann 2018), practical environmental knowledge (Sternberg et al. 2001; Owuor 2007) and the persistence of indigenous ecological knowledge (Shizha 2006; Berkes 2012); (2) Economic factors such as domestic and international markets, commodification of nature (Githiru & Njambuya 2019), rapid urbanization (Nzau et al. 2020), livelihood insecurities and poverty traps (Berkes 2012; Igoe & Brockington 2007) and unclear land-tenure property rights (Bendzko et al. 2019; Djurfeldt 2020); (3) Environmental governance factors in the form of maladaptive international and

national policies (Teucher et al. 2020), lax enforcement of environmental laws and corruption (Nzau et al. 2020), historical land injustices and disenfranchisement (Njogu 2004), unclear benefit-sharing arrangements (Nzau et al. 2021a) and environmental communication disconnects (Hohenthal 2018; Habel et al. 2020); (4). Ecosystem and habitat structures and processes (Jaeger 2000; Hemp 2009) and their inherent biotic and abiotic interactions (Aerts et al. 2011; Meyer et al. 2015; Njeru 2016); (5). Available ecosystem services and goods (de Groot et al. 2010; Zhang et al. 2007) such as food, water, medicine, wood, and shade (Hartter 2010; Rülke et al. 2020) and the resorting exploitation dynamics (Wangai et al. 2016; Schmitt et al. 2019).

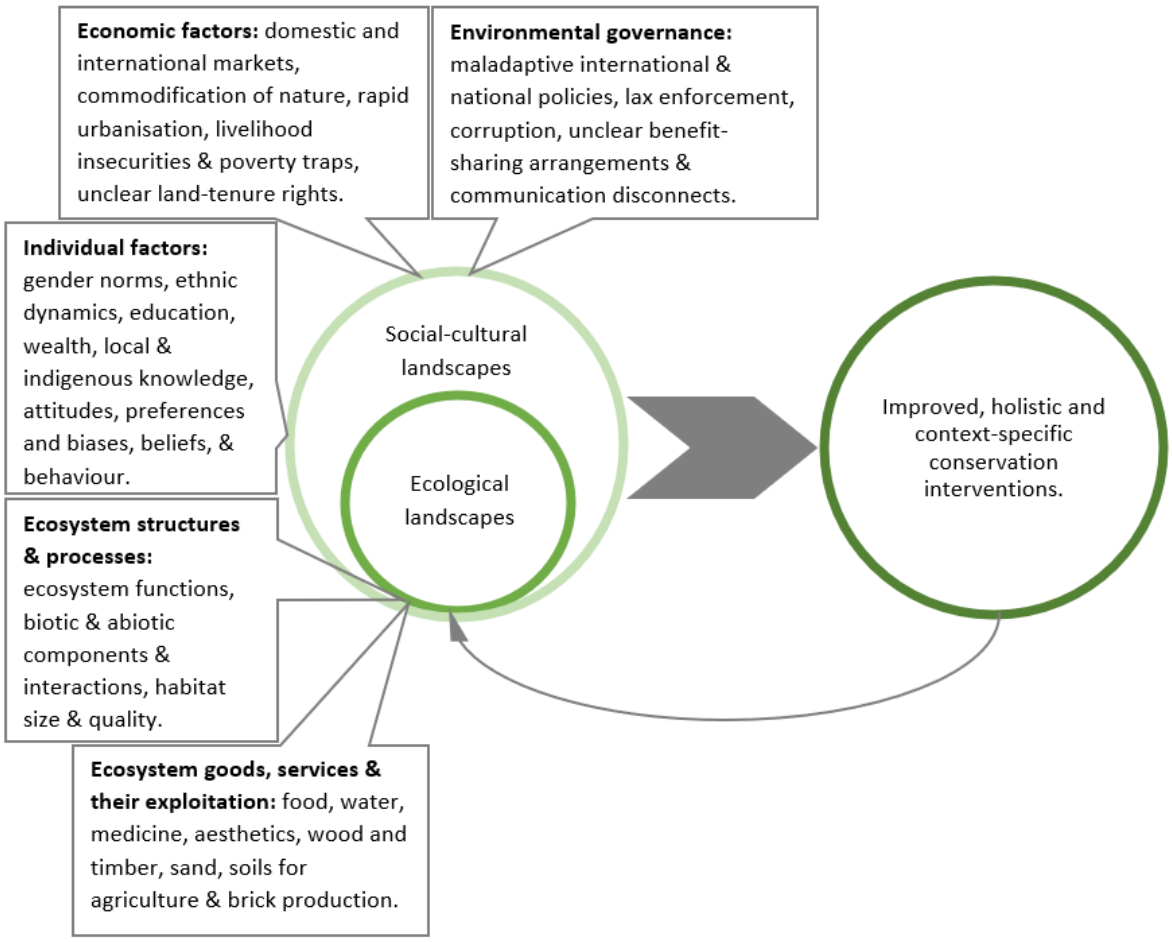

Figure 1: An illustration of the contextual framework. The figure shows that socio-cultural and ecological landscapes are intimately interconnected and interlinked in broader

multidimensional structures and processes that converge and diverge in predictable and unpredictable pathways over different spatial and temporal scales. These multifaceted interactions strengthen or undermine conservation strategies and livelihood strategies, which feeds back into social-cultural and ecological landscapes (Nzau et al. 2018; 2020; 2021a; 2021b).

1.5. Awareness, perceptions, and conservation behaviour

Socio-ecological interactions produce and reinforce perceptions and attitudes towards biodiversity conservation (Nzau et al. 2018; 2020; 2021a), impacting conservation behaviour and outcomes (Brockington 2002; Hartter & Goldman 2011; Berkes 2012). Research has shown that immediate beneficiaries of biodiversity conservation are likely to support forest resources' sustainable use compared to people who regard themselves as disadvantaged by biodiversity conservation measures (Holmes 2003; Vodouhê et al. 2010). Positive perceptions and attitudes do not automatically resort to positive conservation behaviour (Waylen et al. 2009; Nzau et al. 2018; Rülke et al. 2020). Perceptions and socio-economic realities may produce or reinforce negative trade-offs that undermine conservation outcomes (Sternberg et al. 2001; Brockington 2004). For instance, spatial bias regarding the severity of environmental problems has been shown to impair local commitment to conservation action (Weinstein 1980; Hatfield & Job 2001). Spatial bias tends to incorrectly assess global environmental conditions as worse than local conditions (Gifford et al. 2009; Schultz et al. 2014). Environmental communication sources and channels may strongly reinforce spatial bias (Hatfield & Job 2001; Schultz et al. 2014; Nzau et al. 2018).

1.6. Overall aims and approach

Against this backdrop, this dissertation is concerned with investigating and understanding the context-specific factors and overriding trends that impact forest conservation interventions' acceptance and legitimacy in three different forest types located in South-eastern Kenya. Considerable attention is focused on overlooked socio-economic trade-offs that undermine nature conservation efforts (Nzau et al. 2021b). The study areas are Kitui gallery forests (Nzau et al. 2018), Arabuko-Sokoke lowland coastal forest (Nzau et al. 2020) and Taita Hills cloud forest (Nzau et al. 2021a). In both the Arabuko-Sokoke forest and Taita Hills, Participatory Forest Management (PFM) has been implemented to varying degrees (Nzau et al. 2020; 2021a).

Nonetheless, pertinent conservation challenges crosscut these three regions (Nzau et al. 2018; 2020; 2021a; 2021b). They include agricultural encroachment, landscape fragmentation, logging, uncontrolled charcoal production, and urbanisation (Bendzko et al. 2019; Schmitt et al. 2019; Schürmann et al. 2019; Teucher et al. 2020) with negative impacts on biodiversity (Borghesio et al. 2017; Cuadros-Casanova et al. 2018; Schmitt et al. 2019) and human livelihood quality (Nzau et al. 2018; 2020; 2021a). This dissertation argues that although overarching trends in all three areas may be similar, the socio-economic interactions and pathways that produce and reinforce these trends are unique to each study site (Nzau et al. 2021b). The oversight or misdiagnosis of these fine-grain dynamics in implementing conservation initiatives may produce maladaptive trajectories that are counterproductive for nature conservation and human livelihoods (Teucher et al. 2020). This dissertation, therefore, attempts to answer the call of numerous scientists, who underscore the importance of understanding context-specific socio-economic dynamics in the quest to target conservation

interventions and improve conservation outcomes (Kellert et al. 2000; Berkes 2004; Büscher & Whande 2007).

Data collection was conducted between 2016 and 2018 using a structured survey which was administered to inhabitants living around Kitui gallery forests (Nzau et al. 2018), Arabuko-Sokoke coastal lowland forest (Nzau et al. 2020) and Taita Hills cloud forests (Nzau et al. 2021a). Expert interviews from governmental, non-governmental, and community representatives concerned with biodiversity conservation in each of the respective regions complemented this study. This dissertation attempts to answer the following research questions:

1. Do the inhabitants of three diverse socio-ecological landscapes in south-eastern Kenya present differentiated levels of biodiversity awareness, perceptions, and willingness for conservation action?
    a) Are there differentiating patterns for the appreciation of forests and biodiversity, various ecosystem goods and services and threats to forests?
    b) Do the conservation priorities of local people deviate from those of state and civil actors?
2. How does the credibility and legitimacy of available sources of environmental communication impact on conservation outcomes?
    a) Which socio-economic factors influence the credibility of different sources of environmental information?
    b) What are the implications of disparities in environmental communication?
3. How is inclusion and participation of the local people in forest conservation realised across the three study areas?

a) Which socio-economic factors determine inclusion and participation in forest management and decision-making?
b) Do differentiated inclusion and participation undermine conservation outcomes?

4. What inferences can be drawn concerning the acceptability of conservation strategies and ecological conservation outcomes across the three study areas?

2. Material and methods

2.1. Study areas

2.1.1. Kitui riparian gallery forests

The riparian gallery forests occur along rivers in Kitui County (Figure 2), a region characterized by semi-arid climatic conditions (Habel et al. 2018). This region receives two discrete annual rainfall seasons (a short rainy season from November till December, with 250–300 mm precipitation, a long rainy season from March till May with 400–450 mm of precipitation). The monthly mean temperature ranges from 15.7 to 27.2 °C. All the dominating soils (acrisols, luvisols and ferralsols) are low in soil fertility and agricultural productivity (Jaetzold et al. 2006). Once thought to have been an interconnected forest, today, the gallery forests occur as narrow and isolated riparian forest strips (Teucher et al. 2015; Schmitt et al. 2019) with adverse effects on biodiversity (Habel et al. 2018). Although dominated by exotic plant species, the remnant thickets are home to Kenyan endemic bird species like Hindes Babbler (*Turdoides hindei*) (Teucher et al. 2015).

The Kitui county recorded a 12% increase in the human population from about 1 million in 2009 and to 1.1 million inhabitants in 2019, occupying 30,430 km² (Kenya National Bureau of Statistics, 2019). The inhabitants of this region belong predominately to the Kamba ethnicity. The Kamba people settled in the region around the beginning of the 18th Century (Lindblom 1920). Today, the main occupation in this region is subsistence smallholder agriculture and small livestock keeping (Teucher et al. 2015; Nzau et al. 2018). Farmers produce mainly maize, pigeon peas, beans, cowpeas, and mangoes. Compared to the mainland, land near the rivers presents relatively fertile soils for agriculture and good soils for brick production as well as high-standing groundwater levels for human domestic needs (Teucher et al. 2015).

Consequently, these riparian zones attract high levels of human activities (Nzau et al. 2018). Land along the rivers is mostly privately owned by smallholder farmers, and therefore, conservation is individually driven (Nzau et al. 2018; Schmitt et al. 2019). There appears to be a lack of proper institutional regulation on conservation (Teucher et al. 2015; Nzau et al. 2018; Schmitt et al. 2019). The current landscape is highly degraded, representing a mosaic of agricultural fields and riparian thickets dominated by invasive exotic species such as *Lantana Camara* and human settlements (Habel et al. 2018).

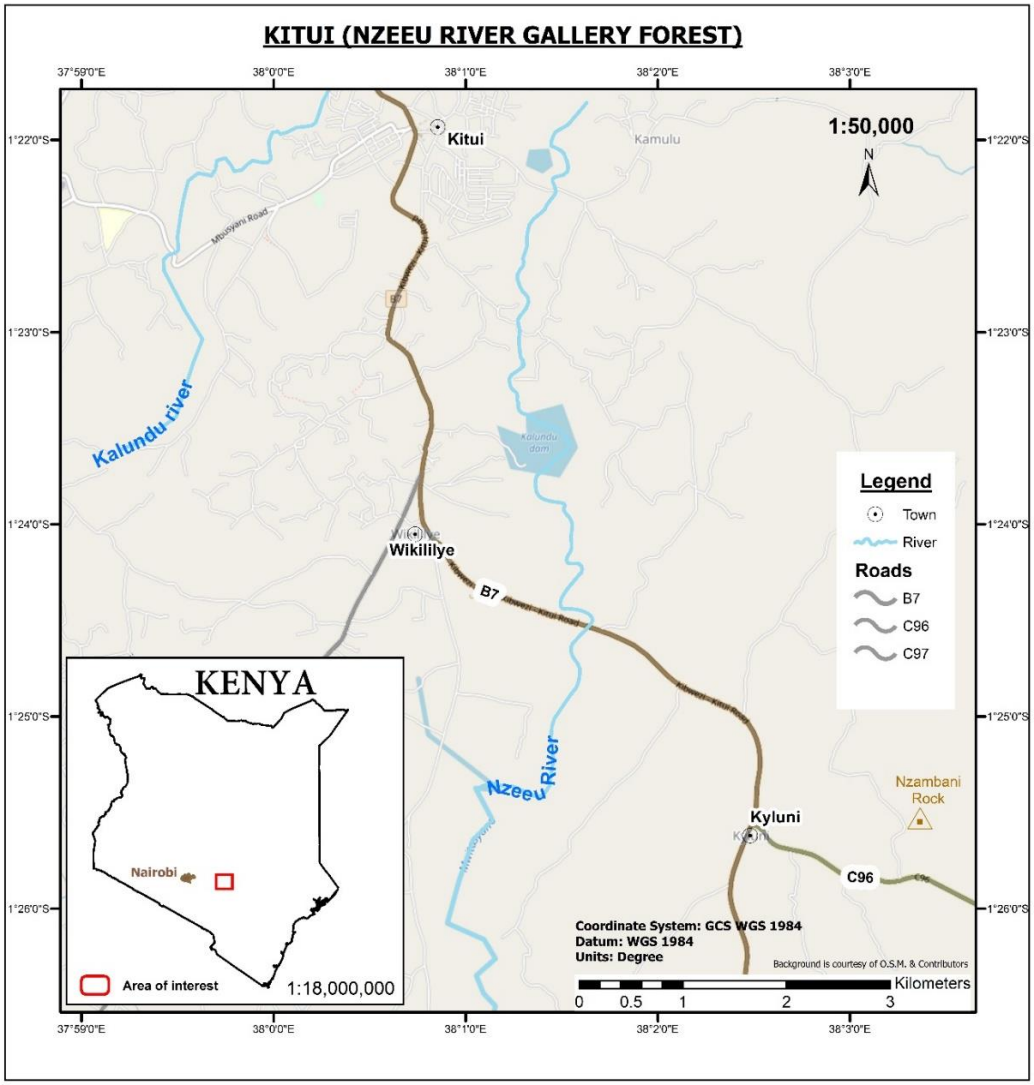

Figure 2: Kitui study area showing the *Nzeeu* river along which the studied gallery forests occur. The inset map of Kenya shows the location of Kitui County.

2.1.2. Arabuko-Sokoke coastal forest

Arabuko-Sokoke forest (ASF) is a gazetted, fenced and protected national forest reserve (Figure 3) found in Kilifi County on the Kenyan Coast (Kenyan Forest Service, 2021). The forest covers 42,000 hectares making it one of the most significant forest remnants along the east African coast (Arabuko-Sokoke Forest Management Team, 2002). A small section of the forest (6 km²) is designated as a National Park (Government of Kenya, 2002). ASF provides unique habitats for many endangered and endemic species and is part of global biodiversity hotspots (Gordon & Ayiemba 2003; Mittermeier et al. 2011; Habel et al. 2017).

Surrounding the ASF are 51 villages with more than 100,000 inhabitants (Gordon & Ayiemba 2003) with a 3.1 % annual population growth (Kilifi County Government, 2021). The principal inhabitants belong to the Giriama ethnicity. The Giriama settled along the forest's western margin in the early 1900s and moved eastwards in the 1950s and 1960s from coastal hinterlands (Gordon & Ayiemba 2003). Restricted in the forest's northern margins is a small ethnic minority, distributed across only 25 extended family households, known as the Waatha (Nzau et al. 2020). The Waatha, originally hunters and gatherers, are described as the indigenous people of the Arabuko-Sokoke forest (Gordon & Ayiemba 2003; Ming'ate & Bollig 2016).

Today, both the Waatha and Giriama depend on smallholder subsistence agriculture (Schürmann et al. 2020), producing maize, cassava, beans, cashew nuts, mangoes, and coconuts (Ming'ate & Bollig 2016; Bendzko et al. 2019). They also rely directly on forest resources such as firewood, poles for house construction, medicinal herbs, fruits, butterfly pupae and game meat (Arabuko-Sokoke Forest Management Team, 2002). Illegal logging, poaching and the unsustainable harvesting of most forest resources are rampant (Ming'ate & Bollig 2016; Busck-

Lumholt & Treue 2018). There is a strong presence of governmental and non-governmental environmental agencies that mediate forest conservation and human livelihood needs in the framework of Participatory Forest Management (PFM) (Ming'ate & Bollig 2016; Nzau et al. 2020). An electric fence was installed around the Arabuko-Sokoke forest in 2006 to minimize human-wildlife conflict (Kenyan Forest Service, 2021). Despite sustained forest conservation efforts, the forest habitat quality continues to decline with negative impacts on biodiversity (Cuadros-Casanova et al. 2018; Bendzko et al. 2019; Schürmann et al. 2020).

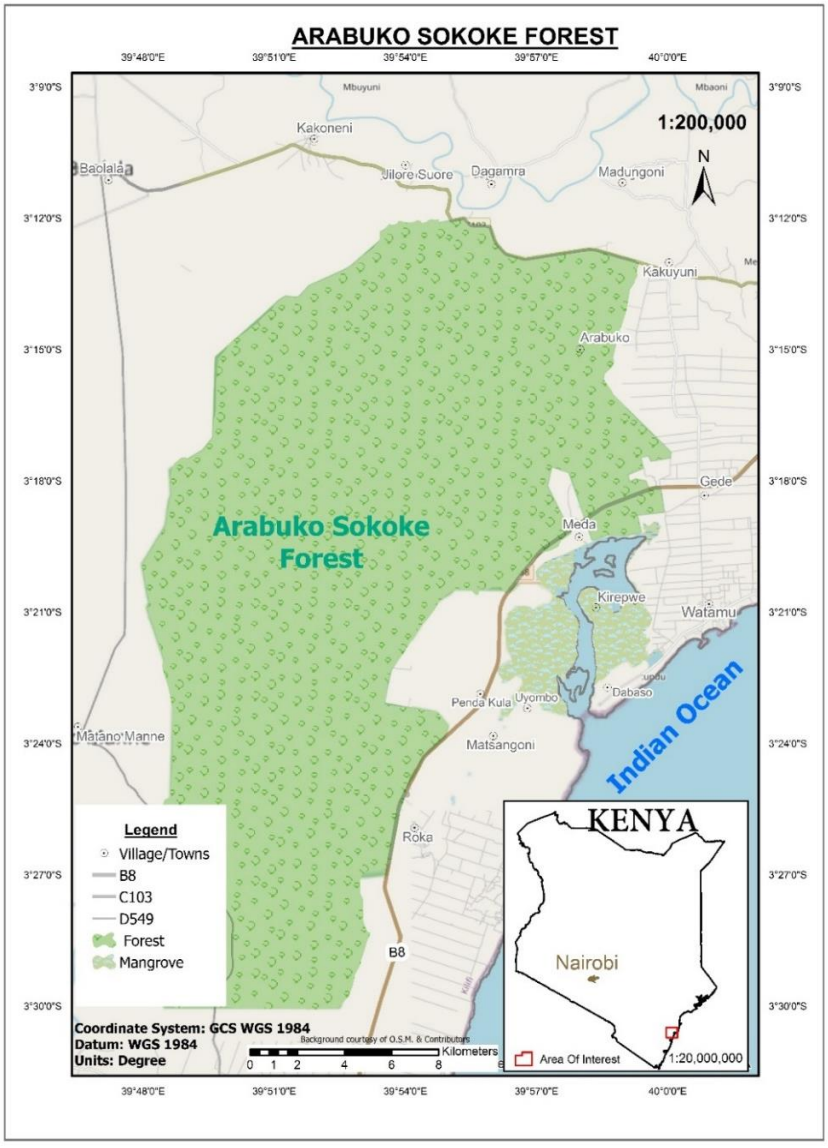

Figure 3: The map shows the second study are, the Arabuko-Sokoke coastal forest. The inset map shows the location of the Forest within the map of Kenya.

2.1.3. Taita Hills cloud forest fragments

The Taita Hills (Figure 4) rise from the middle of the Tsavo plains of the Taita-Taveta County in the Coastal Kenya (Maeda et al. 2010), cover an area of approximately 1000km² and reach up to over 2200 m in altitude (Jaetzold et al. 2012; Teucher et al. 2020). The Taita Hills represent the northernmost isolate of the Eastern Arc Mountains biodiversity hotspot (Mittermeier et al. 2011). The Taita Hills climate is cool and humid, recording annual rainfalls between 500 mm and 1400 mm, depending on the elevation and topography (Jaetzold et al. 2012; Njeru 2016), which offers suitable preconditions for smallholder farming and forestry (Maeda et al. 2010; Njeru 2016; Njeru et al. 2017). Up to 90 % of the indigenous forest has been converted into agricultural fields, human settlements, and exotic tree plantations with severe consequences for habitat quality and biodiversity (Githiru & Lens 2007; Borghesio et al. 2017; Teucher et al. 2020). Today, 12 highly degraded forest fragments remain (ca. 430 ha in total), scattered on hilltops and ridges distributed across the Taita Hills massifs (Aerts et al. 2011). Still, the forest fragments offer suitable habitat for many endemic and endangered species that are restricted into small forest remnants (Aerts et al. 2011; Githiru & Lens 2007), such as the Taita Thrush (*Turdus helleri*) and Taita Apalis (*Apalis fuscigularis*) (Mittermeier et al. 2011; Borghesio et al. 2017).

The Taita-Taveta County population was 340, 671 in 2019, representing a 1.97 % increase from 2009. This growth rate was slightly below the national average of 2.2 % (Kenya National Bureau of Standards 2019). Despite the comparatively slow population growth, the Taita sub-county, within which the cloud forests occur, had the highest population density of 117 persons per km². The inhabitants of the Taita Hills belong mainly to the Taita ethnicity. Their main occupation is smallholder agriculture (Teucher et al. 2020; Nzau et al. 2021a). The crops

produced include maize, beans, tomatoes, cassava, peas, cabbage, potatoes, mango, and banana (Jaetzold et al. 2012).

Of the 12 forest remnants, only six were gazetted as forest reserves under the management of the Kenya Forest Service (KFS), while four others were classified as community forests (Kenya Gazette Supplement, 2016). Regardless, most of the forest fragments' implementation of conservation strategies was ambiguous (Teucher et al. 2020; Nzau et al. 2021a). There have been sporadic efforts to implement Participatory Forest Management (PFM) around the Taita Hills cloud forests (Githiru & Lens 2007; Hohenthal 2018; Nzau et al. 2021a). Forest restoration efforts around the Taita Hills forest fragments have so far borne marginal success (Borghesio et al. 2017; Hohenthal 2018; Teucher et al. 2020).

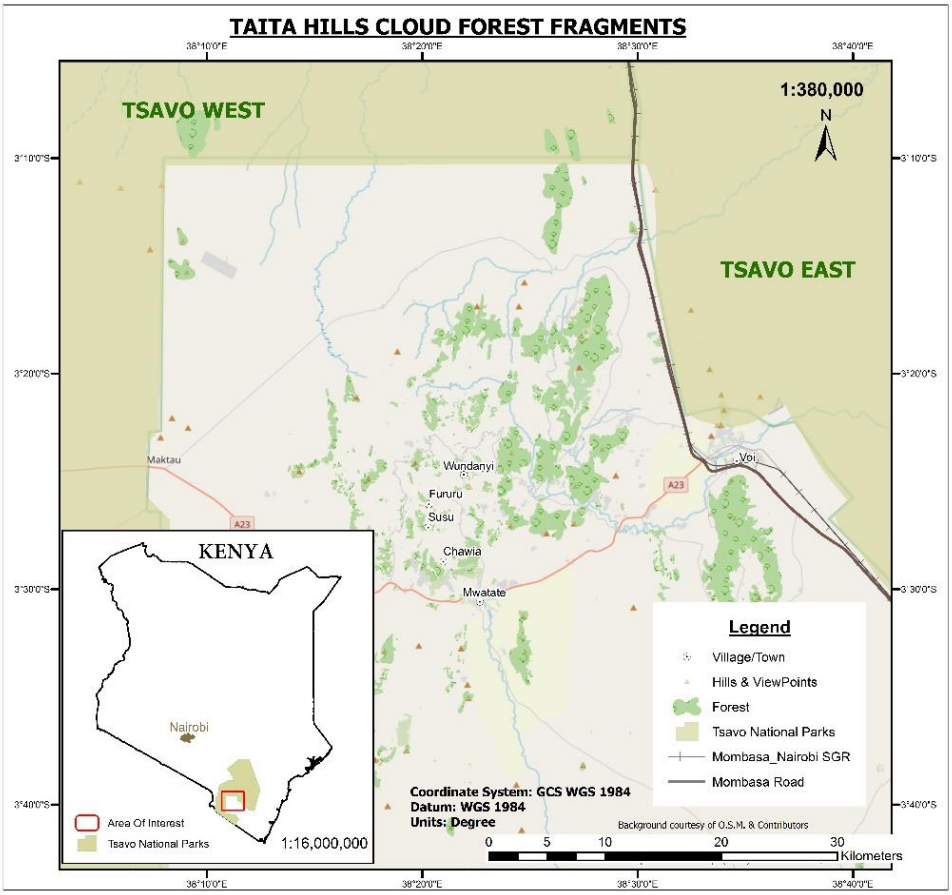

Figure 4: The map shows the forest fragments of the Taita Hills. Only three forest fragments are named within the map, i.e., Fururu, Susu and Chawia, where we collected the data for this

study. Wundanyi and Mwatate are the nearest towns to these fragments. The inset map displays the location of the Taita Hills in Kenya.

2.2. Data collection

Data was collected using a structured questionnaire for the respective local inhabitants and a semi-structured questionnaire guide for expert interviews. The original questionnaire used in the Kitui region was subsequently expanded and adapted for Arabuko-Sokoke and Taita Hills (Table 1). In all three areas, the respective version of the questionnaire was first piloted, reviewed and adjusted to locally specific characteristics of the local community of people and our research focus (see Nzau et al. 2018, 2020, 2021a; Rülke et al. 2020). The two last versions of the questionnaire borrowed specific components of questions from Shepheard-Walwyn (2014).

2.2.1. Survey

The three structured questionnaire versions were first designed in English and then translated into Swahili. The Kitui version covered four thematic sections: (1) Primary demographic data (age, gender, education, income, land ownership); (2) Land-use (production of goods and reasons for production); (3) Environmental awareness (reasons for living and cultivating along the river, perceptions towards the protection of species, knowledge of existing environmental rules and environmental communication); (4) Willingness (personal efforts in ecosystem conservation and willingness to adopt good environmental conservation practices). The expanded versions for Arabuko-Sokoke forest and Taita Hills covered six thematic sections: (1) Primary demographic data (age, gender, education, income, land ownership); (2) The existence and applicability of local ecological knowledge on forest conservation (cultural

identity and indigenous environmental rules); (3) Land-use and land tenure (landholding size and ownership, benefits of living and farming near the forest); (4) Environmental awareness and perceptions (attitudes towards the protection of species, environmental communication, laws and threats); (5) The willingness to apply sustainable practices in land management; (6) Everyday habits and behaviour (involvement in decision making, participation in conservation meeting, and alternative livelihood sources). Data collection was carried out between 2016 and 2018. Structured interviews were performed in April 2016 for the Kitui region, in March to April and September to October 2018 for the Arabuko-Sokoke forest region and in July to August 2018 for the Taita Hills forest regions (Table 1).

Structured survey (convenience Sampling)								
Region	**Sample size**	**Time stamp**	**Thematic areas investigated**					
Kitui	191	April 2016	Demographic data	Land use	Awareness, perceptions, and attitudes	Willingness for conservation action		
Arabuko-Sokoke forest	336	March-April & September-October 2018	Demographic data	Local ecological knowledge	Land use and land tenure	Awareness, perceptions, and attitudes	Willingness for conservation action	Conservation behaviour
Taita Hills	300							
Quantitative data analyses (SPSS): Descriptive statistics, *Pearson's* chi-square, ANOVA, *Kruskal-Wallis-Test*								
Semi-structured expert interviews guide (purposive & snowball sampling)								
Kitui	8	May-June 2017	Knowledge, awareness and understanding of the state of local ecosystems and human-ecosystem interactions;	Existing riparian protection laws, regulations/ policy implementation and barriers	Personal experiences from shortcomings of local ecosystems management			
Arabuko-Sokoke forest	20	March-April/ July 2017 & March, April/September 2018		Role of religion (Christianity, Islam and Traditional African) in forest conservation	Knowledge on Participatory Forest Management/ Environmental rules and implementation	Indigenous ecological knowledge application and systems	Knowledge and enforcement of existing environmental laws and rules	
Taita Hills	9							Land ownership dynamics
Qualitative data analyses: Thematic analysis (MAXQDA v. 2020)								

Table 1: Indicates the number of structured interviews and expert interviews, respective region, and data collection time. Furthermore, it shows the thematic areas investigated in each locality and a summary of statistical analysis employed.

2.2.2. Expert interviews

The semi-structured expert interview guide for Kitui focused on: (1) Experts' knowledge and understanding of the state of local ecosystems and human ecosystem interactions; (2) Existing riparian protection laws, regulations and policy and their implementation and barriers; (3) Personal experiences from shortcomings of local ecosystems management. The semi-structured interview guides for the Arabuko-Sokoke region and the Taita Hills were more elaborate than those previously used in the Kitui region (Table 1). These guides explored 5 and 6 themes, respectively: (1) Role of religion (Christianity, Islam and Traditional African) in forest conservation; (2) Knowledge on Participatory Forest Management (PFM) and implementation; (3) Indigenous ecological knowledge application and systems; (4) Knowledge and enforcement of existing environmental laws and rules; (5) Land ownership dynamics. Expert interviews were conducted from May to June 2017 for the Kitui region, in March to April and July 2017, and in March to April and September to October 2018 for the Arabuko-Sokoke forest region and July to August 2018 for the Taita Hills region (Table 1).

2.2.3. Selection criteria for participants

Participants for the survey were selected using convenience sampling throughout the three study areas. Convenience sampling is a non-probability sampling technique where participants are determined on specific practical criteria, such as geographical proximity, availability at a given time, or the willingness to participate (Dörnyei 2007). The population of interest was inhabitants living within a 3 to 5 km radius of Kitui gallery forests, Arabuko-Sokoke coastal forest and Taita Hills cloud forests. Household members nominated one participant for the interview, mainly either the male or female head of the household. We defined a *household* as all those people who cooked together every evening.

Purposive and snowball sampling techniques were employed in the selection of expert interviews (Dörnyei 2007). First, we selected all the key government, non-government and community representatives responsible for the three forest regions (purposive sampling). We then selected experts who were frequently mentioned during our surveys to be active in forest conservation (snowball sampling). The experts chosen were completely independent of the participants who answered the structured survey across the three regions. In total, 37 expert interviews were performed across the three study regions representing both civil and governmental officials engaged in environmental conservation and protection at the local levels. The following organizations were considered: Kenyan Forest Service (KFS), Kenya Forestry Research Institution (KEFRI), Kenya Wildlife Service (KWS), National Museums of Kenya (NMK), Ministry of Environment Kitui County and Taita-Taveta County, National Environment Management Authority (NEMA), and Water Resource Management Authority (WRMA), Nature Kenya, among others. Interviews were either voice recorded, and/or notes written down depending on the consent of individual experts.

2.3. Data analyses

Data were analyzed using the software SPSS v. 21.0 and v. 24.0 (Nzau et al. 2018; 2020; 2021b). Statistica 12 was mainly used in chapter 3 (Nzau et al. 2021a). In general, the analyses compared six main dependent variables (awareness, value for ecosystem services, spatial bias, environmental communication, protection attitude and willingness) against seven main predictor variables (area, gender, age, formal education level, monthly income, occupation, and landholding size). To compare groups, we used t-tests and ANOVA, using Cohen's *d* to measure effect size. *Pearson's* Chi-square tests, including *Cramer's V,* were also performed, and interpreted to show the context's strength. *Cronbach's alpha (α)* was employed to measure variables' reliability before computing them into a single variable (Nzau et al. 2018; 2020;

2021a; 2021b). In some cases (Chapter 4), non-parametric tests such as *Kruskal-Wallis-Test* and *Spearman's rho correlation* (R_s) were preferred because of violation of normal distribution (Nzau et al. 2021b).

Thematic analysis was used to explore the qualitative data. In the first two chapters (Nzau et al. 2018; 2020), thematic analysis was done manually, while in chapter three and four (Nzau et al. 2021a; 2021b), MAXQDA version 2020 was utilized. *Thematic analysis* is used to identify, analyze, and report themes within qualitative data (Braun & Clarke 2013). The themes developed were data-led, meaning that the coding process did not try to fit into a pre-existing coding framework. Six thematic data analyses steps were followed as described by Braun and Clarke (2013): (1) Familiarization with the data and marking potential patterns; (2) Generation of possible codes; (3) Sorting the different codes into broader themes; (4) Reviewing themes to ensure they were representative of the actual data; (5) Defining the generated themes with accompanying narratives from the data; (6) Producing the reports.

3. Manuscript overview

Manuscript 1

Smallholder perceptions and communication gaps shape East African riparian ecosystems

Joslyn Muthio Nzau, Rebecca Rogers, Halimu Suleiman Shauri, Marco Rieckmann & Jan Christian Habel

Biodiversity and Conservation volume 27, pages 3745–3757 (2018),

doi:10.1007/s10531-018-1624-9

Summary

There is often an inverse relationship between nature conservation and human livelihood needs. Healthy ecosystems are an essential prerequisite to good human life quality. Human agencies alter ecosystems functions and ultimately impact the accrued ecosystem services quality in their daily interactions with nature. Understanding the dynamics of socio-economic systems offers critical insights into the management of socio-ecological trade-offs. Inferring from the semi-arid regions of East Africa, this study seeks to understand the complexities of human perceptions towards nature conservation, underpinning the success of nature conservation strategies. Ecosystem degradation is apparent along rivers in semi-arid regions of southeast Kenya by transforming pristine riparian forests into agricultural fields and settlements. We conducted a structured survey with 191 smallholder farmers and semi-structured expert interviews with eight representatives from six governmental institutions that directly mandated the management and conservation of the *Nzeeu* River in south-eastern Kenya. We analyzed the socio-economic factors that influence smallholders' willingness for conservation engagement. We tested for spatial bias to understand smallholders' perceptions on environmental challenges and probed the impact of the environmental communication on these attitudes and biases.

Smallholders perceived land division due to land inheritance practices as not problematic. However, smallholders owning < 1 acre of land property were less willing to spare some of their land for conservation than those holding land plots above 1 acre. There was a mismatch between a high level of general willingness to conserve ecosystems and actual engagement in conservation action. We further recorded a communication disconnect between local smallholders and environmental practitioners, which was further manifested through locals' overconfidence in environmental information gathered from mass media instead of environmental officials' information. Our study underlines the importance of sustainable land management and practices and an urgent need to bridge knowledge gaps between local people and conservationists, a crucial polarizing barrier to nature conservation.

Author contributions

JMN participated in the conceptualization of the study and in defining the methodology for data collection together with RR, HS, MR and JCH. The original structured questionnaire was prepared by RR and MR. JMN translated it into the local dialect of Swahili. All authors conceptualized and translated the semi-structured expert interview guide. All authors piloted the structured survey assisted by Christine Geelhaar, Vinzenez Eichinger, Jane Evelyn Mutunga, Mary Cheruto, Mwanzi Obeka Bonventure and Agnes Kwamboka Ombati. RR and MR, together with the students as mentioned above, completed the survey process. JMN revisited the Kitui study area to perform further expert interviews. JMN, in consultation with RR and JCH, did the statistical analysis. JMN wrote the original draft, including all tables. All authors contributed by writing, reviewing, editing the subsequent drafts and approved the final manuscript. Gesine Heinrich gave essential insights into manuscript’s original development. Mike Teucher provided the map.

Manuscript 2

The illusion of participatory forest management success in nature conservation

Joslyn Muthio Nzau, Elizabeth Gosling, Marco Rieckmann, Halimu Shauri & Jan Christian Habel

Biodiversity and Conservation volume 29, pages1923–1936 (2020),

doi:10.1007/s10531-020-01954-2

Summary

Participatory forest management (PFM) has been advanced as a sustainable approach towards reconciling nature conservation and human livelihood needs. PFM entails diverse co-management strategies encapsulated in varying degrees of resource control among different actors such as the state, local people, and civil organizations. The success of PFM is highly debated, especially in Sub-Saharan Africa, a region characterised by broad diversities in landscapes, biodiversity, and people. A prominent example of PFM is in the Arabuko-Sokoke Forest (ASF), a biodiversity hotspot and the largest remaining forest block of the East African coastal forest found in southern Kenya. Whereas land cover studies show that the forest's cover has remained stable, there is evidence for persistent selective logging with negative impacts on habitat quality and a steady decline in biodiversity. In total, 336 individuals participated in the structured surveys and 20 semi-structured expert interviews were conducted to investigate the efficiency and acceptance of PFM by local people. Two ethnic groups were considered: The Waatha, who were hunters and gatherers and are considered the first known occupiers of the ASF, and the Giriama, who are the dominant ethnicity yet are recorded to have begun settling in this area around the 1900s. We analysed the prevalence of awareness based on indigenous and modern ecological knowledge systems, people's attitudes towards forest conservation, and their willingness to adopt sustainable environmental practices. Local people generally

demonstrated low awareness regarding the uniqueness of biodiversity in ASF. Significantly higher awareness was recorded among male participants, people with higher formal education or indigenous knowledge and long-term residents. Only a minority of the local people expressed personal responsibility towards the conservation of the forest. Nevertheless, most participants maintained that the forest was of high socioeconomic relevance. The indigenous people of Waatha ethnicity scored significantly higher than the recent settlers, the Giriama in traditional ecological knowledge, willingness for conservation action and personal responsibility towards forest conservation. Further results showed that during the inception of PFM in ASF, and oversight of inter-ethnic dynamics in the region had occurred. The indigenous people, Waatha, were reportedly alienated from the process of implementation. This alienation has contributed to a subtle but polarising force on the legitimate rights of forest resource use, benefit-sharing, and control which, unintentionally or deliberately, undermine PFM in the region. Furthermore, we recorded contestations for forest control among the governmental conservation organizations and pervasive corruption, which contributed to scepticism among the local people towards the PFM agenda.

Author contributions

JMN modified the original questionnaire used in the previous study, and MR provided crucial insights into the questionnaire, while Lozi Maranga, research assistant, translated the questionnaire into the local Swahili dialect. JMN, with the assistance of Lozi Maranga, piloted and corrected the questionnaire and administered the survey and conducted 14 of the expert interviews. JMN and Tobias Bendzko processed the dataset. JMN and EG performed the data analysis. JMN wrote the original manuscript. All the co-authors wrote, reviewed, and edited the subsequent drafts. Mike Teucher created figure 1. All authors approved the manuscript for publication.

Manuscript 3

Lacking benefit-sharing undermines support for nature conservation in the Eastern Afromontane biodiversity hotspot

Joslyn Muthio Nzau, Werner Ulrich, Marco Rieckmann, Halimu Shauri, &

Jan Christian Habel

Currently under review in Ecology and Society

Summary

Tropical forests occur in complex biophysical and socio-economic landscapes with inherent challenges such as climate change, user-rights disputations, governance barriers and environmental communication disconnects. Mainstream conservation in Africa tends to focus more on the conservation of Savannahs and bushlands than forests and woodlands. The continent continues to face unprecedented forest area loss, which is mainly human-induced. For instance, deforestation, selective logging, and forest degradation exacerbate habitat fragmentation with detrimental consequences for biodiversity and human livelihood quality. Addressing long-standing systemic weaknesses in environmental governance institutions and mainstreaming environmental policy and adaptation is urgent, especially for the cloud forest fragments of Taita Hills, which are part of the Afromontane biodiversity hotspot. These highly fragmented and degraded forest remnants, driven by unsustainable land-use practices, still host unique and critically endangered plant and animal species and provide essential ecosystem services to local people. Using a structured survey with 300 participants living along with three forest fragments in Taita Hills and 9 expert interviews with environmental conservation officials from both government and civil sectors organizations, we aim to build on existing research on the socio-economic complexities that underplay nature conservation and fragment rehabilitation in the Taita Hills. We found an inverse trade-off between formal education and

practical environmental knowledge which provides critical insights into the low levels of knowledge concerning endemic and endangered plant and animal species among the local people. We recorded grievances arising from human-wildlife conflicts and lack of benefit-sharing arrangements, which offer important clues into why local people show less enthusiasm towards wildlife conservation than plant protection. Further evidence showed communication disconnects and asymmetrical knowledge relations between environmental officials and the local people, influenced by a historical lack of government accountability on previous accounts of resource appropriations. The local people demonstrated enthusiasm towards the restoration of the Taita Hills water towers, an opportunity for local people and conservationists to pursue conservation of the forest fragments in cognizance of previous injustices.

Author contributions

JMN participated in the adaptation and translation of the questionnaire into the local Swahili dialect. JMN together with MR, Lozi Maranga, Jana Rülke, Anna Nies, Althea Dyer-Preibusch, Slas Neguse, Timothy Musa and Tobias Bendzko performed the fieldwork. Jana Rülke and Anna Nies, with the assistance of Tobias Bendzko, processed the dataset. JMN performed the preliminary analysis and wrote the original manuscript. WU confirmed the key trends and edited the figures, tables, and results section. All authors wrote, edited, and reviewed subsequent manuscripts. Mike Teucher provided figure 1. This publication builds upon Rülke et al. 2020, where this dataset was first published.

Manuscript 4

Socio-economic trade-offs in the conservation of fragile forest ecosystems in Kenya

Joslyn Muthio Nzau, Marco Rieckmann, &

Jan Christian Habel

Manuscript prepared for submission.

Summary

We present a fine-grain comparative study of three study areas representing distinct social-ecological landscapes in Southern-eastern Kenya. Overall, we recorded low awareness of biodiversity, high spatial bias, heightened preference to protect plants over animals, high willingness to conserve biodiversity but missing conservation action. The magnitude of these general trends and trade-offs and the socio-economic pathways from which they emerged differed significantly according to the area of study. For example, older generations in the Kitui area demonstrated positive protection attitudes for wildlife, while the opposite occurred in both Arabuko-Sokoke forest (ASF) and Taita Hills. Externally driven conservation agendas were generally met with scepticism in both Arabuko-Sokoke forest and Taita Hills. However, ASF inhabitants exhibited indifference towards forest conservation, whereas those in Taita Hills demonstrated collective responsibility towards the restoration of the Taita Hills cloud forests, which are viewed as essential water towers. These examples underline important site-specific distinctions that are beneficial for targeted conservation interventions such as environmental outreach campaigns. The critical negative socio-economic trade-offs identified herein include a strong correlation between higher education and old age (>51 years old) with increased scepticism for governmental and non-governmental sources of environmental information. However, educated people were often critical opinion-shapers while older people were key decision-makers and custodians of land resource and indigenous and local ecological

knowledge. Secondly, high willingness to implement good environmental practices was concentrated among young people, who often did not possess the land capital and decision-making authority to implement long-term investments such as land-sparing to plant indigenous trees. Third, the inclusion of local people in forest governance lacked robust structures and legally binding agreements, which created confusion and allowed for corruption to thrive in the enforcement of forest resource use while aggravating existing distrust towards the conservation agenda. Fourth, we established discrepancies between the alternative livelihoods projects implemented in the framework of Participatory Forest Management (PFM) and the livelihoods diversification priorities considered viable to alleviate forest use pressure by the local people. Fifth, there was evidence for malignant exclusion of groups of people who formed a majority representation such as women, people with low incomes and low formal education, and recent immigration from decision-making on resource-use and ultimately the marginalisation of these groups in alternative livelihoods participation. We argue that lack of benefit-sharing from the perceived benefits of tourism from the Arabuko-Sokoke forest and the Tsavo National Park surrounding the Taita Hills overrides the local people's positive attitudes and intentions to support ecological conservation actively. There is also a clear trend that conservation interests from both governmental and non-governmental organizations followed charismatic megafauna. Lastly, we contend that to improve ecological outcomes, it is paramount to not only consider the geographical scale trends but also to investigate and address the context-specific heterogeneity through which these trends are produced and reinforced.

Author contributions

JMN processed the dataset, performed formal analysis, wrote the original draft, and produced all statistical figures. Amos Maranga Atima assisted in processing the dataset and offered critical advice in the dataset's initial exploration. John Kanyingi produced figures 2, 3 & 4. All authors edited and reviewed subsequent manuscripts.

4. Discussion

4.1. Main findings

This study established that irrespective of the study area, the awareness and knowledge regarding biodiversity was underwhelming. Factors such as gender, ethnicity, and histories of migration into the forest regions, combine with traditional socio-cultural customs and practices such as sacred forests and hunting, affected place-based experiences and knowledge on biodiversity. The unprecedented loss of megafauna contributed to loss of intricate connection to wildlife. Unresolved human-wildlife conflicts, lack of benefit-sharing and corruption allegations fuelled attitudes of indifference towards conservation, especially that of wildlife (Table 2). Biophysical characteristics such as climatic conditions and household wealth determined the appreciation and utilisation of tangible or intangible ecosystem services and goods. For instance, the residents of the semi-arid area of Kitui held a high appreciation for tangible ecosystem services. However, most tangible ecosystem services, such as water, were available beyond the Arabuko-Sokoke forest and Taita Hills forest fragments. Therein, the respective inhabitants insisted on intangible benefits such as shade.

There existed a wide willingness-action gap. Several socio-economic trade-offs could provide plausible explanations into this trend. For example, young people demonstrated the highest willingness to undertake sustainable conservation practices. However, they lacked the decision-making authority to implement these long-term practices. Environmental information from mandated sources such as government and non-governmental agencies was met with scepticism, especially among full-time farmers and older people (>51 years old) who are key decision-makers in implementing conservation strategies. Environmental information from local chiefs was highly trusted across the three study areas, yet local chiefs had received no environmental training. Besides, local people's inclusion into forest governance was ambiguous

and lacked a legitimate framework or memorandum of understanding. Large groups of people were excluded from decision-making, such as women, recent immigrants, and people without formal education. Furthermore, the local inhabitants' ideas and priorities differed considerably from most of the implemented alternative livelihood projects. The significance of these general trends and their socio-economic pathways varied across the three study areas.

Qualitative data results			
Region	**Area-specific themes**	**Crosscutting themes**	
Kitui gallery forests	• Conflicts between traditional land laws and constitutional laws • Overlap and confusion of mandate between the environmental jurisdictions of the County and National government. • Insufficient environmental personnel	• Corruption and lack of transparency. • Missing benefit-sharing arrangements. • Slow uptake of alternative livelihood activities. • Lack of interest among governmental agencies to support participatory forest conservation.	• Insufficient resources for outreach and environmental law implementation and enforcement. • Skewed knowledge and powered relations between the local people and environmental officers. • Climatic challenges such as drought, erratic rainfall, and climate change.
Arabuko-Sokoke coastal forest	• Poor coordination among key government, civil and local stakeholders • Rapid urban sprawl • Forest user legitimacy contestations		
Taita Hills cloud forests	• Confusion caused by overlapping short-term projects. • Lack of land use plans • Lack of clarity gazettement status of different forest fragments • Weak indigenous resource management institutions		

Table 2: A summary of area-specific and crosscutting themes that undermine positive conservation outcomes in the respective study areas. These themes were derived and summarized from qualitative data using thematic analysis.

4.2. Awareness and knowledge

The awareness of endemic and endangered flora and fauna, and the knowledge on threats to forest fragments differed significantly according to the geophysical locality of our study areas (Nzau et al. 2020; Rülke et al. 2020; Nzau et al. 2021a). The inhabitants of Taita Hills recorded a relatively medium score on the awareness of endemic and endangered plants, endemic animals, and threats to the forest (Nzau et al. 2021b). The residents surrounding the Arabuko-Sokoke forest exhibited slightly higher knowledge on endangered animals occurring in the forest than those living in Taita Hills (This trend for the ASF will be explained in detail in a following paragraph) (cf. Nzau et al. 2020; 2021b). Meanwhile, the differentiated scores on awareness can first and foremost be understood in the context of divergent histories of migration and settlement into the Taita Hills (Mkangi 1983; Nzau et al. 2021a) and around the Arabuko-Sokoke forest (Ming'ate & Bollig 2016; Nzau et al. 2020). Compared to recent settlers (who are the majority) around the Arabuko-Sokoke forest, the settlement of the ethnic majority living in the Taita Hills can be traced several centuries back (Njogu 2004; Nzau et al. 2021a). The Taita people of the Taita Hills also record a long pre-historical interrelationship with sacred forests, which are locally known as *fighis* (Mkangi 1983; Njogu 2004; Hohenthal et al. 2017). On the other hand, most of the current inhabitants surrounding the Arabuko-Sokoke forest immigrated from coastal hinterlands within the last four to seven decades (Gordon & Ayiemba 2003; Ming'ate & Bollig 2016; Nzau et al. 2020).

Research has shown that longer-term inhabitants usually possess higher place-based knowledge and experience than newcomers (Hartter et al., 2014; Nzau et al. 2020; 2021a). Congruently, the indigenous ethnic minority (the Waata) living around the Arabuko-Sokoke forest manifested higher knowledge and awareness on biodiversity than the majority ethnic group (the Giriama), who are more recent arrivals into the area. In both the Arabuko-Sokoke forest and Taita Hills study regions, there was a positive relationship between indigenous ecological knowledge and endemism and endangered species awareness (Nzau et al. 2020; 2021a). The importance of indigenous ecological knowledge in nature conservation in Africa has been emphasized by numerous scientists (Kellert et al. 2000; Owuor 2007; Berkes 2012; Shepheard-Walwyn 2014). At the same time, indigenous ecological knowledge is no longer as prevalent among local people in the advent of formal education (Shizha 2006; Nzau et al. 2020). Formal education in many school setups currently lacks robust and practical environmental education (Owuor 2007; Reyes-García et al. 2010), which widens the practical knowledge gap (Sternberg et al. 2001; Shepheard-Walwyn 2014).

Overall, this study advances four plausible reasons why the residents surrounding the Arabuko-Sokoke forest showed a heightened knowledge of endangered animals (Nzau et al. 2021b). Primarily, the Arabuko-Sokoke forest still records charismatic megafauna such as African Elephant, Buffalo, Civet, lesser Galago (bushbaby) (Kenya Forest Service 2021), unlike the forest fragments of Taita, where mostly smaller wildlife such as birds and invertebrates occur (Githiru & Lens 2007, Aerts et al. 2011). Therefore, the Arabuko-Sokoke forest residents can easily observe these species (Arabuko-Sokoke Forest Management Team (ASFMT), 2002). It also explains why the Arabuko-Sokoke forest residents acknowledged the aesthetic value of wildlife (Nzau et al. 2021b). Additionally, there is a comparatively higher interest and presence of national and international conservation agencies in the Arabuko-Sokoke forest than in Taita

Hills (Nzau et al. 2020; 2021a). For instance, there is a strong presence of Kenya Wildlife Service (KWS) in the ASF, which is hardly noticeable in Taita Hills cloud forests. Residents around the ASF are likely to associate the numerous consented efforts to protect wildlife in the forest with endangerment. Moreover, the comparatively expansive size of the Arabuko-Sokoke forest block (Cuadros-Casanova et al. 2018) may foster confidence among the surrounding inhabitants that ASF faces lesser existential threats (Nzau et al. 2020; 2021b). On the other hand, due to the longer-term place-based experiences (Cundill et al. 2017), people living adjacent to the Taita Hills forest fragments acknowledged more threats to the forest fragments (Nzau et al. 2021b). For example, local people strongly associated diminishing water sources in the Taita Hills with the steady degradation and deterioration of their forest fragments (Hohenthal 2018; Nzau et al. 2021a).

In both ASF and Taita Hills, men of intermediate education showed the highest awareness of endangered and endemic plants and animals (Nzau et al. 2020; 2021a). Intermediate education for the Arabuko-Sokoke forest area denotes attaining primary education, while for the Taita Hills area, it means at least high school education (Nzau et al. 2021b). Men of average education living in rural Kenya often possess a combination of theoretical knowledge learnt in school, practical environmental knowledge acquired through livelihoods interactions with local ecosystems and increased levels of place-based experiences compared to women (Sternberg et al. 2001; Owuor 2007; Nzau et al. 2021a). These dynamics can be understood in the contexts of local migration flows, job-market dynamics, gender norms, and patriarchal land inheritance practices in Kenya (Suda 2002; Djurfeldt 2020; Nzau et al. 2021a). For instance, in cases where men of intermediate education are not absorbed in the casual labour market in urban areas (Suda 2002), they are likely to fall back to their rural home, where they were born and brought up because they have a higher probability of inheriting ancestral land (Owuor 2007; Djurfeldt

2020; Nzau et al. 2021a). On the contrary, women with similar formal education levels are likely to settle in other varied regions through marriage, domestic work, or casual labour (Suda 2002; Ginsburg 2016; Nzau et al. 2021a).

Illegal logging was highlighted as the leading threat to the local forests by residents surrounding ASF and Taita Hills cloud forests (Nzau et al. 2020; 2021b). Extensive research has been advanced on the complex dynamics and impacts of selective logging in all three study sites (Githiru & Lens 2007; Cuadros-Casanova et al. 2018; Schmitt et al. 2019). Both legal and illegal logging were associated with pervasive corruption and historical disenfranchisement through the lack of precise benefit-sharing arrangements in the Arabuko-Sokoke forest and Taita Hills (Nzau et al. 2020; 2021a). This discontentment combined with ambiguous environmental laws and policies at the national and county level (Nzau et al. 2018; Teucher et al. 2020), together with lax and selective enforcement of environmental rules (Nzau et al. 2020; 2021a) to further undermine support for forest conservation. For example, in Taita Hills, forest fires were particularly emphasized as an essential threat to the forest remnants (Nzau et al. 2021b). However, the forest fires' underlying causes could not be ascertained and warrant further research to establish if the fires occurred naturally, accidentally, or due to deliberate acts (cf. Nzau et al. 2021a).

4.2.1. Appreciation for ecosystem goods and services

Understanding how local communities perceive and prioritize ecosystem services and goods at local scales is vital for targeted and informed conservation interventions (Hartter 2010; Rülke et al. 2020). Additionally, perceptions towards ecosystem services and goods could offer critical insights into disgruntlement over forest resources management (Brockington 2002;

Rülke et al. 2020). Simultaneously, we may gain broader understandings of forests' intrinsic values to communities, which are often overlooked or misunderstood by conservationists (Hartter & Goldman 2011; Berkes 2012). Consistent with the findings of Hartter & Goldman (2011) in Uganda, we established significant inter-site and intra-site differences in the appreciation of ecosystem services and goods (Nzau et al. 2018; 2021b). Explanations for these differences are drawn from the inherent biophysical differences of our three study areas (Jaetzold et al. 2006; Jaetzold et al. 2012; Njeru 2016), as well as diverging efforts by various local, governmental, and non-governmental stakeholders into resource-use management (cf. Nzau et al. 2018; 2020; 2021a).

Among the three study regions, inhabitants along the Kitui gallery forests recorded the highest appreciation for ecosystem services and goods (Nzau et al. 2018). Most of the participants living along the Kitui gallery forests emphasized the value of tangible ecosystem services and goods such as access to water, fertile soils for agriculture, good soils for brick production and good pastures for their livestock (Nzau et al. 2021b). The Kitui gallery forests occur in a semi-arid climatic zone where river ecosystems are often a lifeline for both biodiversity (Teucher et al. 2015; Habel et al. 2018) and local people (Nzau et al. 2018). Contrastingly, the inhabitants of the Arabuko-Sokoke forest area and the Taita Hills highlighted non-material ecosystem benefits such as shade availability and perceived higher precipitations, fresh air, and water catchment (Nzau et al. 2021b). The Taita Hills region is an Afromontane zone (Aerts et al. 2011) where access to water and fertile soils beyond the forest fragments is less scarce (Njeru 2016; Njeru et al. 2017).

Moreover, the inhabitants surrounding the Arabuko-Sokoke forest displayed the slightest appreciation for ecosystem services and goods, regardless of socio-economic differentiation (Nzau et al. 2021b). Forest resource extraction from the Arabuko-Sokoke forest is strictly regulated by governmental agencies (Arabuko-Sokoke Forest Management Team, 2002; Nzau et al. 2020), unlike in Kitui (Nzau et al. 2018; Schmitt et al. 2019) and Taita Hills (Teucher et al. 2020; Nzau et al. 2021a). Most residents around the Arabuko-Sokoke forest claimed limited access to tangible ecosystem services and goods from the forest (Busck-Lumholt and Treue 2018; Nzau et al. 2020). Regardless, the illegal access to forest products was reportedly rampant (Ming'ate & Bollig 2016; Cuadros-Casanova et al. 2018). However, local inhabitants reiterated corruption allegations surrounding forest resources exploitation by outsiders and cartels in both ASF and Taita Hills (Nzau et al. 2020; 2021a).

Charcoal production and its intricate value chain necessitate deeper scrutiny in all three study sites (Nzau et al. 2021b). Despite the high prevalence (Njenga et al. 2013; Kiruki et al. 2017; Kamwilu et al. 2021) charcoal production was hardly mentioned as a significant ecosystem good. It was a highly guarded and lucrative business (Kamwilu et al. 2021) with unprecedented negative impacts on biodiversity in all three forest regions (Kiruki et al. 2017; Cuadros-Casanova et al. 2018; Schmitt et al. 2019; Teucher et al. 2020). Participants may have downplayed the significance of charcoal significance because of a national ban on charcoal production at the time of data collection (Kitui County 2014). A general observation was that charcoal production was driven by a high demand for charcoal in adjoining towns and Mombasa and Nairobi's cities (Njenga et al. 2013; Kiruki et al. 2017). It was a thriving business interjected by many curtails and go-betweens with the enabling of few local people (Njenga et al. 2013; Kamwilu et al. 2021). Many economically impoverished residents across the three study sites tended to use firewood as the primary energy source to cook (own observation). Our

results indicate that firewood was emphasized as an essential ecosystem good in ASF and Taita Hills forest fragments. Wealthier households in the same localities often had access to diversified energy sources such as charcoal, biogas, and liquefied petroleum gas (own observation).

4.3. Protection attitudes

The findings herein further illuminate a preference for the protection of flora over fauna (Rülke et al. 2020; Nzau et al. 2021a), albeit to varying degrees in all our three study areas (Nzau et al. 2021b). This dissertation advances two broad contexts to understand this bias. Firstly, the fauna was often associated with large 'dangerous' and 'destructive' wildlife such as snakes (in Kitui), elephants (in ASF) and monkeys (in Taita) (Kihiko 2013; Nzau et al. 2020; Nzau et al. 2021a). Secondly, the inhabitants of Arabuko-Sokoke forests and Taita Hills associated the protection of plants with increased access to provisional ecosystem services (cf. Nzau et al. 2021a; 2021b), while the protection of wildlife was associated with tourism (cf. Nzau et al. 2020; 2021b). To most local people in ASF and Taita Hills, tourism was synonymous with historical land disenfranchisement and elaborate exclusions from forest access and resource use (Nzau et al. 2020; Rülke et al. 2020; Nzau et al. 2021a).

Of the three study areas, residents along the Kitui gallery forests demonstrated minor support to protect fauna and recorded the least responses regarding the importance of protecting both flora and fauna (Nzau et al. 2021b). The little interest towards animal protection in Kitui may have been in response to severely constrained land sizes per capita in the area (Teucher et al. 2015; Nzau et al. 2018), as well as an increased disconnect and impersonality with nature following the acute loss of biodiversity in the region in the last century (Habel et al. 2018;

Steinhart 2000; Schmitt et al. 2019). There was also a minimal presence of governmental and non-governmental environmental agencies and conservation campaigns in Kitui (Nzau et al. 2018). The lack of environmental outreach campaigns in this area may contribute to the low awareness of biodiversity conservation benefits, especially among the young people in the locality (Hartter 2010; Hartter & Goldmann 2011).

It is not surprising that older adults with no formal education showed the most support for protecting animals in Kitui (Nzau et al. 2021b). This juxtaposition may be understood in the context of the pre/post-colonial histories of the Kamba people as revered hunters with advanced human-wildlife interactions and skills (Lindblom 1920; Steinhart 2000). Today, the Kamba are the principal inhabitants and the Kitui gallery forests (Nzau et al. 2018). It is, therefore, possible that the older generations still harbour memories of wildlife abundance and benefits, contributing to their positivity towards wildlife conservation (Steinhart 2000). Contradictorily in Taita Hills and around the Arabuko-Sokoke forest, there was a negative relationship between older generations and the support to protect wildlife (Rülke et al. 2020; Nzau et al. 2021a). Consistent with findings in neighbouring Tanzania, the fear of wildlife increased with age (Kaltenborn et al. 2006).

Furthermore, positive attitudes towards wildlife conservation coincided with increasing formal education levels in both the Arabuko-Sokoke forest and Taita Hills regions, especially among men with intermediate education (cf. Nzau et al. 2020; Rülke et al. 2020; Nzau et al. 2021a). Kaltenborn et al. 2006 find a similar correlation between men and positive attitudes towards wildlife in Serengeti National Park in Tanzania. With the extensive erosion of indigenous ecological knowledge (Wane & Chandler 2002; Shizha 2006; Berkes 2012), pervasive loss of practical ecological knowledge due to rapidly changing socio-economic landscapes (Steinberg

et al. 2001) and unprecedented biodiversity loss, especially for fauna (Myers et al. 2000; Steinhart 2000), educated people tend to possess higher theoretical environmental knowledge (Owuor 2007; Reyes-García et al. 2010) and therefore understand better the contemporary contexts of protected areas for conservation (Brockington 2002; 2004; Githiru 2007; Rieckmann 2018). On the other hand, women (who were generally likely to have lesser education) demonstrated the least support to protect wild animals (Nzau et al. 2021a; 2021b). Women possibly assumed most of the negative impacts from human-wildlife conflicts. Women were often responsible for chasing away monkeys from their farms (Nzau et al. 2021; Rülke et al. 2020). If crops were destroyed by wildlife, women were likely to suffer more from food insecurity given their role as primary caregivers (Wane & Chandler 2002).

The effective mobilization for conservation action is likely to occur among people with intrinsic sentiments of personal responsibility towards forest conservation (Cundill et al. 2017; Nzau et al. 2020). Overall, the Arabuko-Sokoke forest inhabitants exhibited a comparatively higher indifference towards forest conservation and often underscored that the primary responsibility to protect the Arabuko-Sokoke forest was vested with the government (Nzau et al. 2020). Exceptionally, long-term residents surrounding the Arabuko-Sokoke forest, especially those from the indigenous ethnic minority (Waatha), expressed positive attitudes towards forest conservation (Nzau et al. 2020). A similar trend occurred in Taita Hills, where most residents (These people have a comparatively longer settlement history living neat the forest) acknowledged that all conservation actors (government, civil and local) had an equal responsibility in the conservation of the Taita Hills cloud forests (Nzau et al. 2021b). People with an extensive history of living near forests often demonstrate stronger relationships with forests (Hartter 2010; Cundill et al. 2017).

4.4. Willingness-action gap

The inhabitants of all three study areas demonstrated a high willingness to undertake good environmental practices such as observing forest buffer zones, land-sparing to replant indigenous trees, engaging in agroforestry and adopting zero-grazing (Nzau et al. 2018; 2020; 2021b). However, the transition of willingness into action was strongly constrained by divergent socio-economic realities across the three study areas (Nzau et al. 2021b). In Kitui, willingness was significantly influenced by the size of landholdings per household, whereby inhabitants with at least 1-acre land property showed a higher willingness to adopt good conservation practices (Nzau et al. 2018). Further investigation revealed a negative correlation between willingness and age in Kitui (Nzau et al. 2021b). Herein, older people were less willing to adopt suitable conservation measures (Nzau et al. 2021b), yet they were likely to possess legal land property rights (Bendzko et al. 2019; Schürmann et al. 2020). Research has shown that legal landowners often demonstrate an upper hand in land-use decision-making, especially regarding long-term investments (Cotula et al. 2011; Djurfeldt 2020), such as land-sparing for planting indigenous trees (Nzau et al. 2018). Therefore, the younger generations who are highly willing to implement sound conservation practices are unlikely to do so without the older generations' support (Nzau et al. 2021b).

For the inhabitants surrounding the Arabuko-Sokoke forest, willingness was positively correlated with intermediate school education (Nzau et al. 2020). Intermediate education also positively correlated with being young and a non-farmer (Nzau et al. 2021b), often lacking legal land property rights (Cotula et al. 2011). These preconditions frequently resorting to similar negative trade-offs as described for Kitui in the previous paragraph (Nzau et al. 2021b). In Taita Hills, willingness positively correlated with men of intermediate education who were also highly likely to have off-farm employment and therefore not spent significant time on

everyday management of land-use unlike full-time farmers (Nzau et al. 2021b). On the other hand, full-time farmers demonstrated the least willingness to adopt sustainable environmental practices, yet they were likely to be older and, therefore, legal custodians of land property rights (Cotula et al. 2011; Djurfeldt 2020), leading again to a negative trade-off as in Kitui and Arabuko-Sokoke forest (Nzau et al. 2021b). Moreover, most participants across the three study areas are heavily reliant on ecosystem services such as firewood for cooking fuel (Nzau et al. 2021b). The fulfilment of immediate livelihood needs may take precedence over positive conservation intentions (Nzau et al. 2018).

4.4.1. Divergent conservation priorities

Alternative livelihood projects constitute a significant component of participatory forest management strategies (Kellert et al. 2000; Schreckenberg & Luttrell 2009). Alternative livelihoods projects seek to substitute a livelihood strategy that exerts unstainable biodiversity pressure (Roe et al. 2015). The long-term impacts of alternative livelihoods on local people and biodiversity conservation are debated (Igoe & Brockington 2007; Fabricius & Collins 2007; Blomley et al. 2008; Vyamana 2009; Roe et al. 2015). In both Arabuko-Sokoke forest and Taita Hills, numerous alternative livelihood activities have been implemented to this effect (Arabuko-Sokoke Forest Management Team, 2002; Gordon & Ayiemba 2003; Hohenthal 2018). Some of the critical alternative livelihood activities in these two study areas include tree planting, butterfly farming, beekeeping, medicinal herb collection and eco-tourism (Nzau et al. 2020; 2021b). These initiatives are largely missing in the Kitui region, attracting minimal conservation interest (Schmitt et al. 2019; Nzau et al. 2020).

Interestingly, alternative livelihood opportunities were marginally listed as priority strategies towards conserving the three fragile forest fragments (Nzau et al. 2021b). Indeed, despite

consented efforts to implement alternative livelihood projects in both the Arabuko-Sokoke forest and Taita Hills, this study recorded deficient active participation levels into the available alternative activities in both areas (Nzau et al. 2020; 2021b). Instead, participants surrounding the Arabuko-Sokoke forest prioritized off-farm employment opportunities and quality water availability to engage in profitable agriculture. Availability of water for agriculture was also highlighted in Kitui and the sustainable extraction of resources from the river systems (Nzau et al. 2021b). Taita Hills residents reiterated the need for reforestation aimed at restoring their water towers and catchment areas (Hohenthal 2018; Teucher et al. 2020; Nzau et al. 2021a). Overall, participants across the three study areas also ranked the co-management of natural resources, education and awareness and streamlining and enforcement of environmental laws as necessary towards the sustainable conservation of their forests (Nzau et al. 2021b).

4.4.2. Inclusion and participation

In general, the inclusion of local people in forest governance was ambiguous and largely asymmetrical across all three study regions (cf. Nzau et al. 2018; 2020; 2021a; 2021b). Gender, length of a participant's residence in the area, higher formal education and higher incomes were determinants for participants' inclusion and participation in forest management and decision-making (Nzau et al. 2021b). However, these predictors play out differently depending on the locality (Nzau et al. 2018; 2020; 2021a). In the Arabuko-Sokoke forest, men and longer-term residents were more likely to be included in making forest resource utilisation rules (Nzau et al. 2021b). Nevertheless, women were significant custodians of indigenous knowledge and skills regarding flora and fauna (Wane & Chandler 2002; Berkes 2012; own observations). Long-term residents surrounding the Arabuko-Sokoke forest demonstrated higher biodiversity knowledge (Nzau et al. 2020). It would be prudent to streamline knowledge flows in this region

to include and pass this knowledge to the recent immigrants into the area, who are the majority of the population (Ming'ate & Bollig 2016; Nzau et al. 2020; 2021b).

In Taita Hills, inclusion in decision making increased with higher education and higher incomes (Nzau et al. 2021b). However, inhabitants with higher incomes and education were less likely to have land property rights across our study areas. Research has shown that legal landowners have a higher potential to implement long-term investments, such as decisions regarding the types of trees to plant on their farms (Bendzko et al. 2019; Schürmann et al. 2020). At the same time, residents with higher income and education are more likely to be engaged in off-farm activities, while their counterparts were likely to interact daily with their local ecosystem in pursuit of fulfilling their livelihood needs (Stern 2004; Vyamana 2009; Nzau et al. 2021b). Therefore, the exclusion from forest management and decision making of whole sections of local populations, who are likely to be the majority potential implementers and targets for resource-use rules, fosters negative trade-offs culminating in poor conservation outcomes (Nzau et al. 2018; 2020; 2021a).

As already indicated in the preceding discussion, participation in alternative livelihood activities was overwhelmingly low in both the Arabuko-Sokoke forest and Taita Hills, where these projects have been implemented (Nzau et al. 2021b). Generally, women in both the Arabuko-Sokoke forest and Taita Hills were less likely to participate in all the other alternative livelihood activities such as beekeeping, herb collection and ecotourism (Nzau et al. 2021b). The low participation of women in alternative income activities may be linked to gender norms where women often assume the roles of primary caregivers (Wane & Chandler 2002; Rülke et al. 2020; Nzau et al. 2021a), with little time and resources (Djurfeldt 2020) to invest into long-

term alternative livelihood activities (Vyamana 2009; Cotula et al. 2011). This study found one exception whereby the inhabitants surrounding the Arabuko-Sokoke forest were likely to be actively involved in butterfly farming irrespective of gender (Gordon & Ayiemba 2003; Nzau et al. 2021b).

However, many of the butterfly farming groups around the Arabuko-Sokoke forest were marred by a lack of transparency (Nzau et al. 2020), akin to elite capture of proceeds (Blomley et al. 2008; Nzau et al. 2020), as well as low representations of women leadership (own observations). Butterfly group leaders (primarily men) acted as intermediaries between the butterfly farmers in the village and the butterfly project officials in Gede town (Arabuko-Sokoke Forest Management Team, 2002; own observations). For example, group leaders collected pupae from individual butterfly farmers in their respective groups. They transported the pupae to the butterfly collection centre in Gede town (Arabuko-Sokoke Forest Management Team, 2002), where the pupae were carefully sorted according to a strict set criterion. Only the pupae that met the criterion were compensated monetarily. Payments were handed directly to the respective group leaders, who in turn redistributed the amounts of money (often very minimal) to their group members back in the villages according to each farmer's accepted pupae. The described process was cumbersome and riddled with corruption allegations (own observations).

4.5. Environmental communication and spatial bias

Overall, the most common and highly trusted sources of environmental information were the local chiefs (Nzau et al. 2018; 2020; 2021a). Chiefs are locally appointed state agents who primarily hold a transitional role in maintaining order and crime control in rural Kenya

(Government of Kenya, 2009). Chiefs across our study areas were hardly trained as environmental experts, neither through formal education nor indigenous ecological knowledge systems (own observations). Contrastingly, there was a mixed reception of governmental and non-governmental environmental experts across the three study areas (Nzau et al. 2018; 2020; 2021a). For example, NGOs' information was more prevalent in Taita Hills than around the Arabuko-Sokoke forest but was thoroughly distrusted in both localities. Generally, people around the Arabuko-Sokoke forest exceptionally recognized information from government environmental experts as highly credible. Strikingly, residents with higher education around the Arabuko-Sokoke forest (who were the minority) showed a deep distrust of the government's expert information (Nzau et al. 2021b).

Across the three study areas, full-time farmers, who were likely to be older and legal landowners (Bendzko et al. 2019; Schürmann et al. 2020), showed a general distrust of sources of environmental information except for the local chiefs (Nzau et al. 2021a). Thereby marked a crucial negative trade-off impacting the uptake and implementation of environmental information in these fragile forest regions. Particularly in both Arabuko-Sokoke forest and Taita Hills where educated residents, who are important rural opinion shapers (Sternberg et al. 2001; Owuor 2007) and older people, who are vital decision-makers as landowners and custodians of indigenous ecological knowledge (Owuor 2007; Berkes 2012) demonstrated high scepticism towards expert information from government and non-governmental conservation practitioners. These distrust sentiments may point to deep-seated structural imbalances between environmental management agencies and local inhabitants (cf. Nzau et al. 2018; Nzau et al. 2020; Rülke et al. 2020; Nzau et al. 2021a). The inclusion of local people in natural resource governance was, in practice, ambiguous and asymmetrical (Ming'ate & Bollig 2016; Hohenthal 2018; Habel et al. 2020).

Spatial biases were consistently evident across our three study sites (Nzau et al. 2021b). Overall, participants assessed environmental problems as less severe in their immediate environments than in distant places (Nzau et al. 2018; 2021b). Previous research has shown that when local people underestimate the magnitude of immediate environmental problems, they are less likely to implement environmental conservation measures (Weinstein 1980; Gifford et al. 2009; Schultz et al. 2014). For instance, land-splitting, which occurs due to land inheritance practices, is positively perceived, yet emerging ecology research underlines the negative impacts of landscape fragmentation on biodiversity conservation (Githiru & Lens 2007; Seibold et al. 2019; Bendzko et al. 2019; Schürmann et al. 2020).

Spatial biases are closely related to environmental communication (Schultz et al. 2014; Nzau et al. 2018). The legitimacy of different environmental communication sources impacts the uptake of environmental information and ultimately affects environmental behaviours and conservation action (Hatfield & Job 2001; Gifford et al. 2009; Schultz et al. 2014). For instance, by giving predominance to global environmental concerns, mass media may misguide people to underestimate immediate vulnerabilities and delay the uptake of good conservation practices (Schultz et al. 2014; Nzau et al. 2018). Residents living along the Kitui gallery forests recorded the highest levels of spatial biases, which also corresponded with heightened trust in mass media (radio) as a source of environmental information (Nzau et al. 2018).

On the contrary, the inhabitants surrounding the Arabuko-Sokoke forest demonstrated the most negligible spatial bias, coinciding with minimal use of mass media (Nzau et al. 2021b). Furthermore, local people surrounding the Arabuko-Sokoke forest often perceived the forest as an infinite resource and under minimal threats due to its comparatively expansive size and

protected status (Nzau et al. 2020). Interestingly, residents of Taita Hills recorded heightened usage of external channels of environmental communication, and at the same time, displayed a general scepticism towards the begotten information (Nzau et al. 2021a). This scepticism may offer insights into the relatively moderate spatial bias in Taita Hills (Nzau et al. 2021b), which may also be impacted by the ongoing and observable landscape deterioration (Teucher et al. 2020) and diminishing water sources (Hohenthal 2018) as well as pronounced historical injustices around natural resources in the region (Njogu 2004; Nzau et al. 2021a).

Study limitations

Despite the significant trends and interesting coherences presented herein, I would like to stress the following limitations of this study; (1) convenience sampling techniques used in this study have strengths and drawbacks. One inadequacy is that they may not represent the target populations accurately; (2) Although a lot of caution was taken in administering the surveys, by asking questions in local Swahili dialects (which was a second language to most participants) and explaining terminologies such as endangerment and endemism, as well as encouraging participants to answer some of the questions in their first languages such as names of animals and plants where they did not know Swahili or English names, it is still possible that there were translation oversights which could affect the quality of our data; (3) The two latter versions of questionnaires administered in Arabuko-Sokoke forest and Taita Hills were expanded versions of the first survey done in Kitui area. Therefore, some of the comparative analyses were not done for the Kitui area.

5. Conclusions

Attempts to implement Participatory Forest Management (PFM) in fragile forest regions of southern-eastern Kenya were sporadic with mixed results. The case studies of the Arabuko-Sokoke forest and Taita Hills positively affirmed local people's interest in forest conservation. Indeed, many of these inhabitants recorded a long co-evolution history with forest conservation. In the riparian gallery forests of Kitui, there were hardly any implementation of PFM or enforcement of environmental laws despite the high value of these riparian ecosystems for human livelihoods and ecological significance. Nonetheless, the people living along these riparian forests demonstrated interest in implementing interventions on co-management of riparian resources. This dissertation provides a blueprint of how often overlooked context-specific trends and trade-offs may covertly or overtly hinder positive conservation action.

The mismatch between positive attitudes and intentions and conservation action is often reinforced by the reluctance to address historical land injustices, pursue equitable benefit-sharing, and persistent power imbalances in local people's involvement. Furthermore, the decentralisation of management responsibilities and entitlements in ASF and Taita Hills was vague and lacked a legitimate memorandum of understandings between local people and other state and civil conservation actors. Alternative livelihood projects such as butterfly farming and beekeeping had stalled mainly due to corruption, elite capture, short-funding streams, insufficient end-product processing, and lack of continuous impact assessment. Inconsistencies between the conservation priorities of local people and conservation practitioners were evident. The erosion of indigenous and local ecological knowledge systems and formal education's failure to integrate practical ecological knowledge continued to contribute to a pervasive vacuum in local biodiversity awareness. The ongoing unprecedented loss of biodiversity in these study areas further exacerbated attitudes of impersonality with nature, especially wildlife.

Ultimately, this dissertation draws attention to how different socio-economic factors such as gender, age, and education, can take heterogeneous pathways to produce and reinforce

overarching homogenous trends and trade-offs at the regional level. I contend regional generalizations may mislead many conservationists to apply one-fits-all assumptions leading to serious misdiagnosis of area-specific dynamics and, therein, maladaptive forest conservation interventions.

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