Norges miljø- og biovitenskapelige universitet

Master's Thesis 2017 30 ECTS
Noragric

Dynamic forests: Investigating resource use and social-ecological resilience within two communities in Unguja, Zanzibar

Tess Katherine Espey
M-IES

tess.espey@gmail.com

Noragric
Department of International Environment and Development Studies
The Faculty of Landscape and Society
P.O. Box 5003
N-1432 Ås
Norway
Tel.: +47 67 23 00 00
Internet: https://www.nmbu.no/fakultet/landsam/institutt/noragric

Declaration

I, Tess Katherine Espey, declare that this thesis is a result of my research investigations and findings. Sources of information other than my own have been acknowledged and a reference list has been appended. This work has not been previously submitted to any other university for award of any type of academic degree.

Signature: _____

Date: May 15, 2017

Abstract

Coral rag forests in Zanzibar are terrestrial environments with high diversity, providing multiple ecosystem services and attracting significant conservation interest. Over the past twenty years, forest management responsibilities have transitioned from the central government to local communities, where many people engage in resource-based livelihoods. Harvesting forest resources has been an important activity in rural areas for generations, but environmental, economic, and socio-political factors drive change and introduce disturbances in forest areas. This thesis investigates how forest harvesting and management strategies relate to social-ecological resilience in two communities. Kitogani and Muyuni A served as case studies to explore the dynamics of forested social-ecological systems on the island of Unguja. Data was collected through semi-structured interviews with multiple key stakeholder groups, including community members and leaders, government employees, NGO staff, and academics. These discussions covered a variety of related topics: resource harvesting patterns, observed changes in forest environments, important ecosystem services, and the community-based management approach. Subsequent forest surveys provided complementary information about the characteristics and condition of forest ecosystems. This process included measuring trees, classifying vegetation communities, identifying plant species, and recording patterns of disturbance and recovery encountered at sampling sites. Data were also cross-referenced against satellite imagery and results from recent forest inventories and research. Applying the resilience lens in this context revealed that Muyuni A and Kitogani featured complex and changing conditions as a result of multi-scale interactions, feedbacks, and variables. Coral rag forests (low to high) existed as patches on landscapes that also featured small-scale agriculture plots, shrublands, agroforests, and barrens. Vegetation in both locations exhibits high diversity and rapid growth capacity, supporting system resilience. Wood harvesting and land clearing served as the main disturbance types, however, and high harvesting rates currently hinder regeneration of woody shrubs and trees in some areas. As a result, wood and other services have declined in quality. Socio-economic and political drivers are primary detractors from system resilience: poverty, lack of institutional support for alternative livelihood strategies, high demands for biomass energy, and limited participation in forest management are major factors. Opportunities to improve resilience within these social-ecological systems begin with fostering more participatory input, bottom-up learning and knowledge sharing, monitoring, and cross-scale connectivity within the current governance framework.

Acknowledgements

My deepest thanks to everyone – in Zanzibar, at NMBU, and elsewhere – who provided academic guidance, assisted during fieldwork, participated in interviews, shared resources, gave feedback on drafts, and offered encouragement during the research and writing period. I sincerely appreciate your generous help and support. To friends and family near and far: your good humour, patience, and love provided an enduring source of positive energy to motivate me through this process. *Asante sana*, *tusen takk*, thank you.

Table of contents

List of Tables

List of Figures

List of Acronyms

AIGA: alternative income-generating activity

CARE: Cooperative for Assistance and Relief Everywhere (NGO)

CDF: community development fund

CoFMA: Community Forest Management Agreement

DCCFF: Department of Commercial Crops, Fruits, and Forestry (succeeded by DFNNR)

DFNNR: Department of Forests and Non-renewable Natural Resources

HIMA: *Hifadhi ya Misitu ya Asili* ("Conservation of Traditional/Indigenous Forests")

ICDP: international conservation and development project

JCBCA: Jozani-Chwaka Bay Conservation Area (succeeded by JCBNP)

JCBCP: Jozani-Chwaka Bay Conservation Project

JCBNP: Jozani-Chwaka Bay National Park

JECA: Jozani Environment and Conservation Association

JUMIJAZA:*Jumuiya ya uhifadhi wa Misitu wa Jamii Zanzibar* ("The Community Forests Conservation Association of Zanzibar")

KPFR: Kiwengwa Pongwe Forest Reserve

LULC: Land use land cover (zone)

MJFR: Muyuni-Jambiani Forest Reserve

NGO: non-governmental organisation

NMBU: *Norges miljø- og biovitenskapelige universitet* (The Norwegian University of Life Sciences)

NSD: *Norsk senter for forskningsdata* (The Norwegian Centre for Research Data)

REDD+: Reduced Emissions from Deforestation and Forest Degradation

RGZ: Revolutionary Government of Zanzibar

SEDCA: South Environment Development Conservation Association

SCC: *Shehia* conservation committee

sheha *(pl: masheha)*: the appointed leader in a *shehia*

shehia *(s/pl)*: local government unit in Zanzibar

SMOLE II: Sustainable Management of Land and Environment Programme

SUZA: State University of Zanzibar

URT: United Republic of Tanzania

WWF: World Wildlife Fund for Nature

ZWBS: Zanzibar Woody Biomass Survey

1. Introduction

1.1 Context for the research problem

Coastal terrestrial forests in East Africa stretch from Somalia to Mozambique. They form an eco-region that attracts high conservation interest and provides many ecosystem services, several of which include important cultural and practical values for human societies. Though no universal definition exists for these forests, they share several key characteristics: they have woody vegetative growth that provides at least some canopy cover; are highly biodiverse, especially within their plant communities; and often have been modified by human activities over time (Burgess et al., 1992; Burgess et al., 2000; UNEP, 2001; Revolutionary Government of Zanzibar [RGZ], 2013e). This eco-region is highly fragmented; the largest patches are estimated to be no greater than 500 ha in their extent, and many of them are not directly connected to other coastal forests (Burgess et al., 2000). At equatorial latitudes and low elevations near the Indian Ocean, these tropical forests are often spatially linked to other coastal ecosystem types such as mangrove forests, shrub- and grasslands, and agroforests (UNEP, 2001).

Coastal forests are often found in patches that exhibit high biodiversity and endemism. Burgess et al. (1992) remark that over fifty vegetative species – and often more – are found in most individual patches. Approximately 105 plant and 75 animal species are endemic to East Africa's coastal forests (UNEP, 2001) and, because several of these species are also threatened or endangered, this so-called *biodiversity hotspot* has drawn attention from conservationists (Myers et al., 2000; WWF, 2017). Other stakeholders with differing interests, however, also attribute important values to these ecosystems and their services. The complex social, political, and economic issues framing these forest environments require that managers balance conservation and resource harvesting activities, which help to sustain livelihoods in many coastal communities (Burgess & Mbwana, 2000).

Zanzibar, a Tanzanian archipelago within the coastal forest eco-region, features an interesting management approach: two decades ago it moved toward more participatory, community-based management to promote sustainable development and forest use. The most extensive forest ecosystem type there – covering 44.2% of the land area – is coral rag, a dry woodland with dense thickets of shrubs and small trees (Nahonyo et al., 2002; RGZ, 2013e). These forests and adjacent communities are social-ecological systems (SES) where human activities are tightly interlinked with the surrounding environment, which supports resource-based livelihoods and provides valuable ecosystem services. Coral rag forests support and regulate wider environmental processes (e.g. retaining and filtering water or cycling nitrogen)

and are a source of wood, fruits, wild game, charcoal, honey, and traditional medicines (Burgess et al., 2000; Nahonyo et al., 2002; Fagerholm et al., 2012). Community members harvest these products in accordance with Community Forest Management Agreements (CoFMAs), which decentralise many rights and responsibilities for forest areas from the state to local level. These agreements specify land use boundaries within each community, including areas for conservation, agriculture, settlement, and collecting various forest resources. The state forest authority, as well as local and international NGOs, have helped to initiate and support these agreements over the past two decades, sometimes in tandem with integrated conservation and development projects (ICDPs).

In spite of key stakeholder support and a firm legal basis for regulating land uses, the CoFMA framework – as an approach to sustainable forest management – faces some key challenges. Tourism has become a major industry on the islands, and clearing land for beachfront resorts and other developments has removed large tracts of coastal vegetation in recent years (Mustelin et al., 2010; Käyhkö et al., 2011). Illegal activities, such as poaching and overharvesting, also threaten plant and animal populations in some areas (Williams, Masoud & Othman, 1998; RGZ, 2013c; RGZ, 2013d; Suckall et al., 2014), while woodfuel demands from growing urban settlements require that large volumes of wood be cut to fulfil domestic energy needs (RGZ, 2004; Andersen, 2012). Forest products also provide materials for shelter and food, especially in rural areas and in impoverished households, which account for approximately half of the population (RGZ, 2007). Furthermore, climatic changes have made weather more unpredictable, increasing the frequency of droughts and floods, which can impair resource-based activities and disrupt ecosystem processes (Watkiss et al., 2012). Recent studies indicate that deforestation is occurring throughout Zanzibar and that some forest areas have become degraded, providing fewer ecosystem services (Mustelin et al., 2010; Haji, 2013; Kukkonen, 2013; RGZ, 2013e). These on-going changes in forest SES are vital considerations for long-term management of ecosystems and harvesting regimes.

Resilience is an appropriate concept for examining how SES in the coral rag zone respond to, learn from, and adapt to both sudden and gradual disturbances over time. Resilience describes systems' ability to regenerate and reorganise following disruptive events, requiring that SES preserve their essential functions and defining characteristics (Holling, 1973). This property can vary widely at different spatial and temporal scales because human activities and natural processes are unevenly distributed across landscapes (Berkes, Colding, & Folke, 2003; Moran, 2005). By defining allowable activities within forest areas, land use laws in Unguja regulate various human-mediated disturbances, such as

woodcutting, and shape systems' responses to them. Institutional frameworks also play a role in determining whether forest managers and resource users can collectively learn from and adapt to changes in these ecosystems. This thesis uses a case-study approach to examine events and forest-related initiatives to identify the key processes that build and detract from resilience in coastal forest SES.

1.2 Background information: Unguja and its terrestrial environment

1.2.1 Political, demographic, and geographic context

Zanzibar is a semi-autonomous state within the United Republic of Tanzania comprised of two main islands – Unguja and Pemba – and several smaller, mostly uninhabited islands and islets off the north-eastern coast of the Tanzanian mainland. Unguja[1] lies approximately 35 km from mainland Tanzania and – with an area of 1658 km^2 – is the largest island in the archipelago. During the 2012 census, Unguja's population was 896 721, distributed with an average density of 540 people per square kilometre[2] (NBS, 2013). Approximately two-thirds of Unguja's population, however, is concentrated in Mjini Magharibi, the fastest growing of the island's three regions (NBS, 2013). It includes Zanzibar Town – the economic, political, and cultural centre – and several contiguous peri-urban areas. As the largest city, it is the seat of the Revolutionary Government of Zanzibar and features Unguja's main sea port, several large markets, an international airport, and various businesses and industries. Several other towns and villages are also located on the island, especially along its coastline. Growing at an average rate of 2.8% per annum (NSB, 2013), Unguja's population uses the island's natural resources for necessary food, energy, building materials, and other products (RGZ, 2007; RGZ, 2012).

Many resource-based economic activities are centred around and influenced by the variations in the island's climate and physical geography. Lying between 4 and 6°S in the western Indian Ocean, Unguja's climate is tropical and has two rainy seasons: *masika* (the long rains, lasting from March to May) and *vuli* (the short rains, from November to December). In general, its western side receives more precipitation than the east (Hettige, 1990, as cited in WCS, 2012). Average temperatures are hottest in February (23-32.7°C) and coolest in September (22-29°C) (TMA, 2011 as cited in RGZ, 2012). These seasonal fluctuations impact resource use patterns and agricultural strategies (e.g. cultivation periods), but the underlying geology across the island is also an important factor. Soil profiles feature

[1] Sometimes informally called Zanzibar Island.
[2] For comparison, the average across all of Tanzania is 60 people per square kilometre (World Bank, 2016).

limestone bedrock formed from fossilized corals, which are most visibly exposed on the eastern side of the island (Johnson, 1987). Soil depths there are generally shallow; the landscape is predominantly flat and sometimes limestone is exposed directly at the surface. Despite the rocky, shallow substrate, this region hosts the largest proportion of forest area – primarily low and intermediate coral rag – in Unguja (Kukkonen, 2013; RGZ, 2013e). Conversely, the western side of the island features deep, sandy soils, and much of the land has been converted to productive agricultural areas consisting of crops and plantations.

Farming is the main occupation among Unguja's rural residents (NBS, 2014). Domestically grown crops supply much of Zanzibar's food, although yields can decline significantly – and must be supplemented by imports – after drought or flood events (RGZ, 2007). Common crops include sweet potato and cassava; vegetables[3]; and several tropical fruit varieties, including pineapple and citrus, among others. Plantations also contribute timber (hardwood), coconuts, and spices, such as nutmeg and cloves. The spice plantations are particularly mature and renowned; Zanzibar is known as the "Spice Islands" for its centuries-old role in the spice trade, contributing towards the archipelago's historic importance as a trading centre in the West Indian Ocean region (Sheriff, 1987). Today, coconuts and mangoes are the dominant cultivated tree species, being used for both their wood and their fruit (RGZ, 2013e).

Forestry operations account for only 4.5 billion TZS[4] in annual revenue (0.3% of GDP) for Zanzibar (RGZ, 2012), but other economic sectors benefit substantially from different provisioning services in forest ecosystems. For example, firewood and charcoal supply nearly all of the island's energy needs (RGZ, 2007), so wood collection is a major income-generating activity in many rural communities (RGZ, 2004; Andersen, 2012). By GDP, however, the services sector comprises the largest share (45.3%) of economic activities in Zanzibar (RGZ, 2012). The tourism and hospitality industry, in particular, has expanded rapidly in the last two decades, with many tourists seeking to experience the island's natural environments and cultural heritage (SNV, VSO & ZATI, 2010). In constructing new beachfront accommodations, coastal forest extent has been reduced in several areas (Mustelin et al., 2010; RGZ, 2013e). Some communities and companies, however, have turned to an ecotourism-oriented approach to explore opportunities for generating income from conserved forest areas, particularly near Jozani-Chwaka Bay National Park (JCBNP) (Fig. 1).

[3] Vegetables are sometimes hand-irrigated, but this technique is not often used for most other crops.
[4] At the time of writing, approximate exchange rates were 1 USD = 2200 TZS and 1 NOK = 250 TZS.

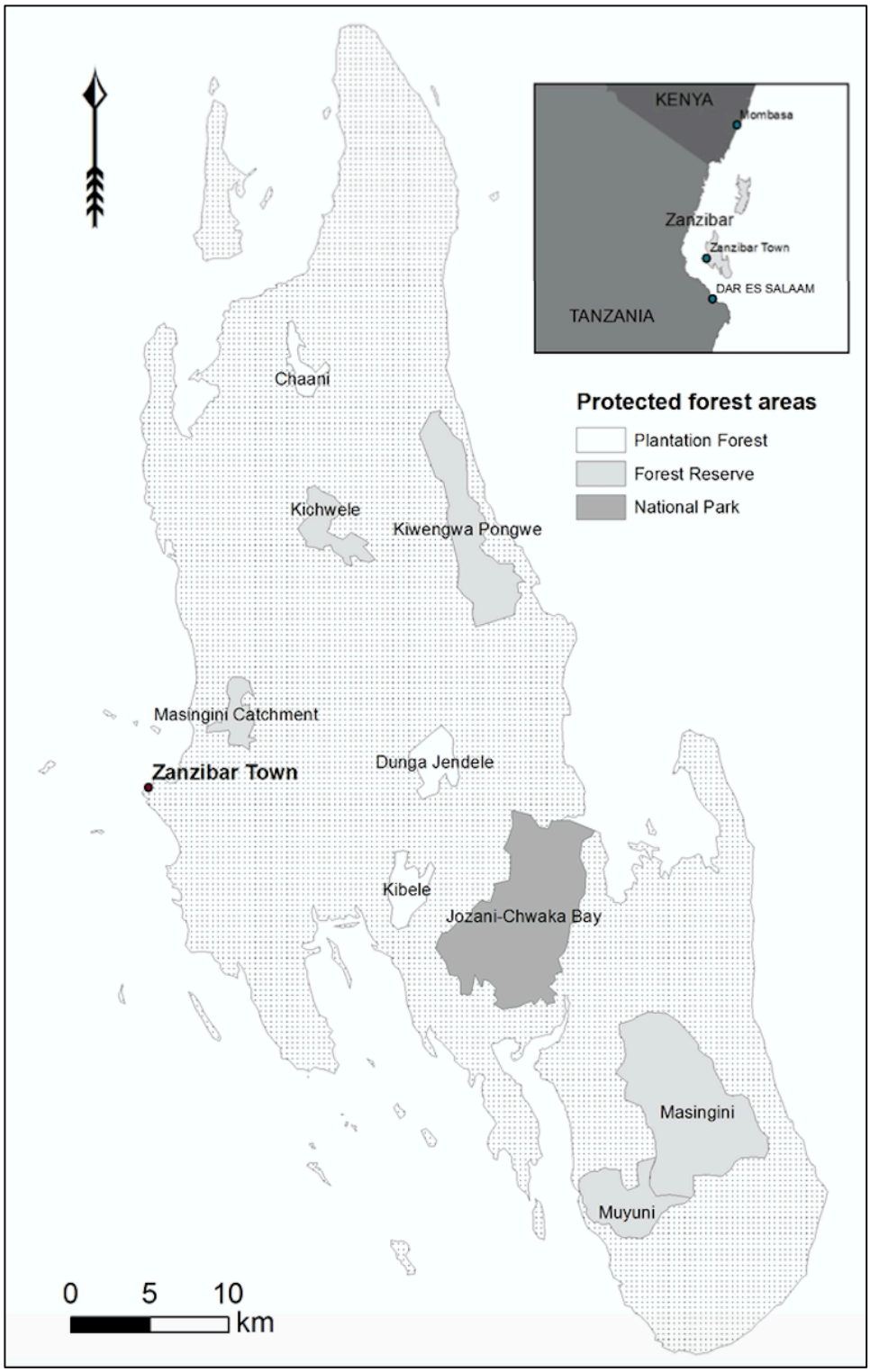

Figure 1. Map of major forest areas in Unguja, Zanzibar. Outside of protected areas, many forests are governed by CoFMAs. Data adapted from WCS (2012).

In spite of growth in tourism and in other economic sectors, poverty remains a major socio-economic issue in Zanzibar. Approximately half of the population lives in poverty[5], lacking access to support, services, and suitable employment opportunities to improve their quality of life (RGZ, 2007). Many people cannot access or afford basic necessities for survival. In a recent socio-economic survey, for example, 46% of respondents in Unguja said they faced food shortages throughout the year (RGZ, 2013d). To meet their needs and sustain income, many people combine several occupations; often this strategy involves informal activities in marine and terrestrial environments, taking advantage of periods of productivity in each (Andersson & Ngazi, 1998, Suckall et al., 2014). Fishing and seaweed farming, fuelwood collection, handicraft-making or sewing, small business operation, and livestock herding are just some examples of these income-generating strategies (NBS, 2014).

1.2.2 Ecological characteristics of coastal terrestrial forests in Unguja

Diverse patches of coastal forests and other terrestrial ecosystem types on Unguja result from uneven distributions of human-induced disturbances as well as environmental variations. Clarke and Burgess (2000) remark that these forest environments "consist of highly heterogeneous and diverse assemblages of forest types which have hitherto eluded a comprehensive description, even at the broadest level" (p. 83). Classifying plant communities has proven a challenge for biologists due to high variability in species assemblages and plant community structures between patches (Clarke & Burgess, 2000; Lowe & Clarke, 2000). Only four known species of endemic plants are found in Unguja (Burgess & Clarke, 2000), but its forests are highly biodiverse; botanists participating in the 2012-2013 Zanzibar Woody Biomass Survey (ZWBS)[6] identified some 386 species during surveys for the project (RGZ, 2013e). The majority of species are common to mainland East Africa. Exotic plants that have been introduced for cultivation or other purposes have also established wild populations on the island and, in some areas, they are dominant parts of vegetative communities (RGZ, 2013e).

Disturbances at a variety of scales have created mixed landscape patches of ecosystems at different stages of growth (Clarke & Burgess, 2000; Menzies, 2007). Jozani Forest, for example, was a hardwood plantation in the early twentieth century, but it has been preserved within JCBNP and today features the only large stand of tall forest remaining on

[5] RGZ (2007) uses a broad and qualitative definition: "not merely the lack of income but also the lack of accessibility to the basic needs of the people" (p. 28).
[6] Though there have been previous woody biomass surveys in Zanzibar, ZWBS hereafter always refers to the 2012-2013, unless otherwise stated.

the island (Nahonyo et al., 2002; RGZ, 2013e). Other areas feature current and former spice plantations as well as agroforests that contain trees and shade-tolerant species. The ZWBS indicates that Unguja's land cover[7] is comprised of coral rag forests (44.2% of the total land area), agroforests (16.1%), plantations (including coconut) (7.5%), and high forest (0.2%) (RGZ, 2013e).

Coral rag forests are mixed-height evergreen woodlands in areas with coralline limestone substrate. These forests grow under harsh conditions: shallow, rocky soils; exposure to strong ocean breezes; significant local variation in seasonal rainfall; and – in many cases – semi-regular disturbance by intentionally set or natural brushfires (Clarke & Karoma, 2000; Kotiluoto, Ruokolainen & Kettunen, 2008). They are visually distinct from other woodlands in Zanzibar due to their relatively low canopies and thick vegetation, often sharing edges with shrublands and coral barrens. Secondary growth comprises nearly all coral rag forests because humans have inhabited the island and harvested forest resources for centuries (Menzies, 2007). Current distributions of some fruit-bearing species – such as baobabs (*Adansonia digitata*) – may result from human efforts to facilitate access and harvesting (Karoma, 1993, as cited in Clarke & Karoma, 2000).

Common tree species within the wider coral rag forest zone include *Euclea racemosa*, *Diospyros consolatae*, *Ficus* spp., and *Maytenus mossambicensis* (Nahonyo et al., 2002). Where land has been burned by fire or abandoned after a shifting cultivation cycle[8], immature trees and shrubs such as *Euclea natalensis, Annona senegalensis*, and *Polysphaerea parvifolia* may be particularly abundant. Cycads (*Encephalartos hildebrandtii*) can withstand being charred by fire and can be seen growing new fronds in the months afterward. In many coral rag forests, vegetation can become exceptionally dense because "bushes are generally interwoven with climbers, lianas and twiners" (Nahonyo et al., 2002, p. 27). Some hardy non-native plants, such as *Acacia* spp., have been able to establish here after their introduction to the island for plantation-style harvesting (Kotiluoto et al., 2008). Conservationists recognize coral rag forests as important habitat for wildlife, especially the endemic Aders' duiker (*Cephalophus adersi*) and the endangered Zanzibar red colobus monkey (*Procolobus kirkii*), which has served as an emblem for preserving forest habitats in Zanzibar (Menzies, 2007).

---

[7] This most recent inventory uses broad structural and ecological characteristics to classify the island's forest environments into distinct Land Use Land Cover (LULC) categories, refining the categorization system used in the preceding 1997 survey. The values reported here include only forests and not shrubland areas.

[8] Remnants of wild pig exclusion walls (*bigili*), made from piles coral blocks, can often be seen as evidence of former farms that have since been abandoned and left to re-vegetate.

Coral rag forests also provide an array of important ecosystem services to the communities, or *shehia*[9], that are situated near them. They directly support and regulate broader environmental processes, such as maintaining soil and atmospheric moisture, storing carbon, retaining floral and faunal biodiversity, and serving as sinks for nutrients, among other benefits (Burgess et al., 1992; Nahonyo et al., 2002; Mustelin et al., 2010). Direct benefits to humans are more evident through provisioning services from forests. Though few trees in low and intermediate coral rag forests may reach a size large enough to become merchantable timber (Burgess & Mbwana, 2000), trunks and large stems are often suitable for use as poles and firewood. After harvesting these items, remaining lianas and stumps can be collected to make charcoal, a valuable commodity on Unguja because of its widespread use as a cooking fuel (Andersen, 2012). Residents of some communities also visit forests regularly to collect a variety of products for domestic consumption, including wild fruits, medicines, and honey (Nahonyo et al., 2002; Fagerholm et al., 2012). They may also come to forest areas for spiritual and traditional practices (Nahonyo et al., 2002; Käyhkö et al., 2011; Fagerholm et al., 2012; Fagerholm et al., 2013). Agricultural livelihoods, too, are often closely integrated with coral rag forest environments; farmers practicing shifting cultivation may fully or partially clear forested land for cropping, and then leave it to naturally re-vegetate after a few seasons. In some cases, livestock herders take their animals into more sparsely vegetated areas to graze. Though legal (and, to some extent, customary) systems strictly regulate these land use activities (Andersen, 2012; Benjaminsen, 2014), it appears that many forest areas suffer from gradual degradation.

In recent years, coral rag forests have declined in size. The areal extent of coral rag forests in Unguja decreased by 17.8% between 1991 and 2013 while, during the same period, the area covered by settled areas, home gardens, and crops increased by over 95% (RGZ, 2013e). This change represents a significant loss of services provided by these ecosystems, even though less biomass has been lost there in comparison with other forest ecosystem types (RGZ, 2013e). Forest cover loss has been particularly great on the island's east coast, where the majority of large tourism developments are situated (Mustelin et al., 2010; Kukkonen, 2013). Changes in land cover, as shown by satellite images from 1996 and 2009, indicate that

[9] The smallest division of government in Zanzibar. Each one is usually comprised of a main village – or a cluster of small villages – and surrounding areas. It is used interchangeably with "community" in this paper. Note: *shehia* connotes both singular and plural forms of the term.

the majority of the island's "deforestation hotspots" are located within the coral rag zone[10] (Kukkonen, 2013). Land clearance and degradation have also served to further fragment coral rag forests over time (Haji, 2013; Kukkonen, 2013).

The structures and compositions of some forests, too, are changing. In the Matemwe area, for example, the fifty-year aerial photograph record indicates that canopy cover in closed forests has been opening up (Käyhkö et al., 2011). Käyhkö et al. (2015) also cite a case where members of one community harvested nearly all their wood and other forest products from one area, reducing the quality of that ecosystem and the services it had previously provided. Overharvesting of preferred woody species, in particular, has reduced these populations substantially in some land use areas (Mustelin et al., 2010; Haji, 2013). But the ZWBS highlights that forests are responding to this intensive harvesting; stem densities have – on average – are increasing around the island because canopy gaps left by vegetation removal are promoting growth of new seedlings (RGZ, 2013e).

In many cases, declines in extent and quality of forest ecosystems are further exacerbated by other factors. Fuelwood and charcoal demands on the island, for example, are particularly high because 97% of Zanzibar's population uses wood biomass fuels – charcoal and firewood – for household energy and cooking (RGZ, 2013c). Urban residents consume, on average, 0.74 m^3 of woody biomass per year, and rural residents use 0.66 m^3 (Owens, 2011, as cited in RGZ, 2013e). Though 500 to 1000 ha of coral rag forest are thus cleared each year to supply household energy needs (RGZ, 2004; RGZ, 2007), the demand for wood still exceeds its supply (RGZ, 2013c). The state government acknowledges that access to woodfuel alternatives could reduce this harvesting pressure and that better agricultural efficiency could further slow the rate of forest loss from shifting cultivation (DCCFF, 2008). In some areas, poaching and unsustainable hunting have been persistent problems. Permit systems for certain mammals allow regulated hunting, but poaching has threatened the stability of some species – including the Aders' duiker, whose population declined precipitously in the 1980s and 1990s (RGZ, 2004). Clarke and Karoma (2000) and Haji (2013) posit that man-made fires may also be an important source of disturbance in some areas, although no studies have yet quantified the effect of fires on Unguja's forest landscapes. These human-induced changes exist alongside other environmental variations. Extreme weather events are now occurring more frequently in Zanzibar, with both severe

[10] Kukkonen (2013, p. 97) also identifies several "reforestation hotspots", which mostly fall within protected areas. However, deforestation is occurring over a much larger area compared to these small pockets of net regrowth.

droughts and floods occurring in recent years (Watkiss et al., 2012). Based on trends in existing climate data, Watkiss et al. (2012) predict that average temperatures will continue to rise in Zanzibar and that both seasonal and annual rainfall patterns may vary more than they have in the past. These changes in ambient temperature or moisture could be problematic for forests should they exceed species' ability to tolerate them.

1.2.3 Forest management in Unguja: Historical institutional context

State-level management

National government agencies have responsibility for several aspects of broader planning, management, and regulation of forests in Unguja. Prior to the 1990s, the state government (whose agencies have changed in name and duties through several phases of reorganization) held centralised forest management authority. During that period, the government managed coral rag and other ecosystem areas in a top-down fashion and, especially in forest reserves, "rigorously excluded residents of communities surrounding the forests" (Menzies, 2007, p. 30). This trend has eased in the past 25 years, with more benefits and responsibilities for forest areas devolving to community governments that work cooperatively with actors at the state- and region-levels.

Today, the Ministry of Agriculture, Natural Resources, Livestock and Fisheries is the authority that collectively governs Zanzibar's natural, agricultural, and marine resources. Beneath it, the Department of Forestry and Non-Renewable Natural Resources[11] (DFNNR) works most directly with forest-related activities and environments. It maintains forest inventories, manages national park and reserve areas (e.g. the new Muyuni-Jambiani Forest Reserve (MJFR) in Unguja Kusini), oversees tree plantation agriculture, and coordinates large-scale fire-fighting efforts. Related to these roles, the DFNNR is responsible for reporting on Zanzibar's forest ecosystems and facilitating concerted action on crosscutting social and environmental issues with other national agencies. For example, *The National Adaptation Plan for Action* (United Republic of Tanzania [URT], 2007) addresses strategies for responding to the effects of climate change. Contributing to state policy documents and operating within major national directives are ways that this department integrates forest issues within the contexts of sustainable development and resource use.

[11] Formerly known as the Department of Commercial Crops, Fruits, and Forestry (DCCFF), the Department of Forestry (DF), and the Commission on Natural Resources (CNR). Note that the DFNNR is independent from Tanzania Forest Services (TFS), whose jurisdiction is mainland Tanzania.

The DFNNR works under the Forest Resource Management and Conservation Act[12] (RGZ, 1996), the main legal framework governing forest-related activities in Zanzibar. It defines management responsibilities for government agencies, specifies legal activities within different forest areas, and describes the process for establishing CoFMAs. This act builds on the National Forest Policy of 1995, which outlines statewide objectives for forest use and conservation and is the first forest policy document to underscore the importance of greater community participation in planning and management of forest areas. It portrays communities and resource users as allies who can foster sustainable harvesting systems and preserve ecosystem integrity. Together, these documents lay the foundation for transitioning many of the responsibilities for forest areas (outside of reserves) from centralised government management to communities.

CoFMAs and community-level governance

CoFMAs, legal agreements between the DFNNR and communities, assign local-level responsibilities for forest management. To date, fifty-four *shehia* in Zanzibar have negotiated these agreements (DFNNR, 2017), which are unique within Tanzania. The National Forest Policy refers to community forestry as "the involvement of target groups (at village, group, and individual level) as the principal actors in the planning and implementation of sustainable forestry programmes" (RGZ, 1999, p. 5). CoFMA documents outline – for each signatory (*shehia*) – specific responsibilities for all aspects of forest management, including setting harvest quotas, enforcing laws and punishments, and designating specific land use zones. In effect, Menzies (2007) explains, these agreements have returned rights to communities whose traditional use of forest environments was cut off during decades of centralised management. Negotiation helps to define each agreement's terms, which are included in a legally binding document co-signed by the community and the Director of the DFNNR (Menzies, 2007; Royal Norwegian Embassy in Dar es Salaam [RNEDS], 2015).

The terms apply for a period of thirty years, over which the community also has the right to earn profits from its forest products. Retaining these economic benefits requires that communities work to sustain vital ecosystem services and processes. Two alternative – but not mutually exclusive – approaches include harvesting resources in a way that allows forests to regenerate and sustain them or preserving these ecosystems to attract revenue through, for example, ecotourism activities. Securing land tenure within communities comes as an added

[12] Henceforth referred to as the Forest Act of 1996.

benefit; CoFMAs precisely define land use areas by law, clarifying ownership (RNEDS, 2015).

Community leaders – or *masheha*[13] – and *shehia* conservation committees (SCC) bear primary responsibility for ensuring that each community works to uphold the terms of the CoFMA. As the appointed local government representative, each *sheha* holds community meetings about forest-related issues, works to implement national environment programs at the local scale, and may be called to help resolve disputes regarding misuse of local resources (Andersen, 2012; Benjaminsen, 2014). He or she works closely with the SCC, a group of elected community members who ensure that the rules of the CoFMA translate into practice. They administer harvesting activities and set long-term forest management objectives. SCCs sometimes receive additional support for their activities and initiatives from their respective district forest offices, or from the DFNNR itself.

NGOs and other key stakeholders

Other groups, such as non-governmental organisations (NGOs), have also worked on a variety of forest issues ranging from alternative income-generating activities (AIGAs) to poverty reduction to conservation. CARE, an international NGO, has worked on several projects in Zanzibar since 1993. It started the Jozani-Chwaka Bay Conservation Project (JCBCP), which aimed to conserve rare forest ecosystems (e.g. groundwater and high evergreen forests, as well as large tracts of mangroves) and their constituent species in and around the Jozani Forest area. Both terrestrial and marine ecosystems achieved high-protection status, becoming Jozani-Chwaka Bay National Park in 2004.

In the years since the establishment of JCBNP, local NGOs have also advanced sustainable development projects in nearby coastal forest areas. The Jozani Environmental Conservation Association (JECA), for example, works to continue JCBCP directives in south-central Unguja. It puts revenue from national park entrance fees toward community development funds (CDFs) and wider development efforts around the park, while also spreading awareness about the benefits of healthy forest ecosystems and facilitating training for park staff. The South Environment Development Conservation Association (SEDCA) has, since its establishment in 2007, worked on various projects to support sustainable forest use in the southern part of the island. Its members are representatives from 11 SCCs in that

[13] Note: *masheha* is the plural form of *sheha*.

region. Some small micro-credit and women's collective groups are also active in supporting AIGAs that reduce the need to harvest new forest resources.

These Zanzibari NGOs worked in tandem with CARE and DFNNR staff on a statewide project called HIMA (*Hifadhi ya Misitu ya Asili*, or "Conservation of Traditional/Indigenous Forests") between 2010 and 2014. As the first REDD+ (Reducing Emissions from Deforestation and Forest Degradation)[14] project in Zanzibar, HIMA aimed to set up a framework for carbon forestry in the archipelago, providing trial payments to communities as an incentive for conserving forest biomass stocks. A new NGO, JUMIZAZA (*Jumuiya ya uhifadhi wa Misitu wa Jamii Zanzibar*, or "The Community Forests Conservation Association of Zanzibar"), was established to manage the carbon crediting system among participating *shehia*. HIMA's broader aim to preserve forest environments (and their carbon-storing capacities) included securing rights, benefits, and enforcement authority for local communities by signing or updating CoFMAs in 45 *shehia* (RNEDS, 2015). It also introduced some AIGAs and instituted trials of alternative cooking fuel (liquid gas) sources (RNEDS, 2015).

Much of the development aid for forestry projects in Zanzibar has, in recent years, come from Northern European countries. The Royal Norwegian Embassy in Dar es Salaam funded HIMA, placing Zanzibar within the global REDD+ network, which includes tropical forests in developing regions around the world. Finland, too, has funded various projects in sustainable forest management in Zanzibar over the past three decades. Most recently, its government contributed to improving environmental monitoring, planning, and mapping through the Sustainable Management of Land and Environment Programme (SMOLE II), which operated from 2010 to 2015 (Embassy of Finland Dar es Salaam, 2017). Academic groups from both of these countries – in addition to the Netherlands, Denmark, Sweden, and others – have also worked alongside DFNNR staff and NGOs through various research projects and collaborations, contributing to the body of knowledge on the social and ecological dimensions of forest areas in the archipelago.

1.3 Literature review

Diverse sources contribute to current knowledge about Zanzibar's coastal forest SES, including reports and surveys from state government agencies, primary academic literature

[14] Since 2010, the added "+" in the program's title has represented additional benefits through improving forest carbon storage as well as conserving and sustainably managing forest areas.

from several disciplines, and ICDP reports. Findings from several key publications are summarised below.

1.3.1 Ecological characteristics, ecosystem services, and forest-based livelihoods

In Zanzibar, inventories and coarse-scale forest survey projects provide the most extensive available data regarding structural characteristics, species assemblages, and major ecosystem changes over time in coral rag and other forests. The government has commissioned statewide forest surveys approximately every 15 years, with the most recent being the ZWBS (RGZ, 2013e). The resulting *Zanzibar Woody Biomass Survey Inventory Report* provides an extensive plant species list, proposes revised forest ecosystem classifications (land use land cover [LULC] categories) for Zanzibar, and describes land use changes since the preceding 1997 survey. It indicates that coral rag forest areas are incrementally declining – by approximately 1% per year – around the island. New seedling recruitment, however, appears to be significantly higher on Unguja than Pemba, showing that the populations of some species are regenerating quickly in disturbed areas, particularly stress-tolerant ruderals.

Nahonyo et al. (2002) provide an earlier – but complementary – record of forest structure, vegetation communities, and ecological succession in the coral rag zone. Their work is particularly relevant to south-central Unguja, having focused on the flora and fauna within the area proposed to become JCBNP. The *Jozani-Chwaka Bay Proposed National Park Biodiversity Inventory Report* serves to describe the baseline conditions of the forests there. Beyond serving as taxonomic resource and inventory of different coastal forest ecosystem types, this report points out important indicators for ecosystem health and succession. In particular, the authors discuss species that evidence disturbance or regeneration; several exotic species are likely to come from past farming or timber plantation operations, while a select group of light-seeking and pioneer species are indicators of regrowth following vegetation removal. Because local guides helped to identify species and their traditional uses, this report also reveals ecosystem services that nearby communities benefit from and value for various purposes.

More information about ecosystem services and their importance to Zanzibari communities stems from a research collaboration between the University of Turku and University of Dar es Salaam (*Changing land use and forest management practices and multidimensional adaptation strategies in Zanzibar, Tanzania, 2010-2013*). Fagerholm et al. (2012) examined community members' use of different services in two *shehias* (Cheju and

Unguja Ukuu Kaebona) in central Unguja. Using semi-structured interviews and mapping exercises, they studied spatial distribution of and perceptions of different services. Communities inherently conserved sites of spiritual and cultural importance, and respondents placed the highest value on food and fuel among the ecosystem's various provisioning services. Familiarity with these services also increased with the amount of time respondents had spent living in the area, and some of them travelled over 1 km from home to acquire forest products. In the same two *shehias*, Fagerholm et al. (2013) used the landscape characterization method to better understand how community members valued forest patches of different types. They harvested resources from 35% of the landscape and put another 43% of the area toward mixed uses, such as agroforestry. These case studies show that terrestrial forest ecosystems play vital roles in local economies, food systems, spiritual practices, and traditional medicine (Fagerholm et al., 2012; Fagerholm et al., 2013).

Other scholars have examined forest-based livelihood strategies and discuss how community members modify and adapt their activities during times of stress and uncertainty. Andersson and Ngazi (1998) studied economic activity in coastal communities on Unguja and on Mafia Island, noting that many respondents partook in a variety of activities for generating income and meeting sustenance needs throughout the year. Selectively using different marine and terrestrial resources helped respondents to reduce the risk of unexpected disturbances on individual resources or areas. Rural community members report that adverse changes often follow land conversion for construction or agriculture, overharvesting of fuelwood, and irregular weather patterns (Suckall et al., 2014). Though some participants in Suckall et al.'s (2014) study in three rural Unguja communities had attempted to diversify their resource harvesting strategies, over time they invested increasing effort to collect the same resources. Furthermore, resource users and farmers had received little or no information from the government about how to adapt new technologies and approaches in tandem with traditional activities. As a result, the authors argue that some on-going activities – such as continually clearing new land to farm in increasingly remote areas – constitute "maladaptive coping strategies" (p. 209). They have reduced quality of natural resource stocks and made people's livelihoods more vulnerable to future climatic changes.

Both Kukkonen (2013) and Haji (2013) describe how Unguja's forest ecosystems have responded to different human-mediated disturbances. Kukkonen undertook his research with the aforementioned Finnish project, a multi-year initiative to study the spatial attributes of and changes in Zanzibar's forests. He collected and analysed remotely sensed images of vegetation cover on Unguja and validated them through point sampling. Many forest areas

had been cleared to make way for settlements, agriculture, and tourism developments, causing forest areas to decline by 0.82-1.18% per year between 1996 and 2009. Losses were greatest near the coast, outside of protected areas, and close to expanding settlements. Rather than examining areal extent, Haji's (2013) research at Kiwengwa Pongwe Forest Reserve (KPFR) focuses on the structure and characteristics of forests, placing a special emphasis on biomass changes. His findings indicate that this protected coral rag forest is frequently disturbed by resource harvesting activities. Forest edge areas, in particular, featured thinner, lower-biodiversity vegetation due to firewood and pole collection, and the majority of biomass removed from forests (measured from cut and damaged trees) was taken from narrow-diameter trees and species with good quality wood. Compared to the previous government inventory (in 1997), the forest had declined in biodiversity, carbon sequestration potential, and biomass. The author, however, did not investigate the root causes of deforestation or connect it to prevailing forest regulations and management frameworks (e.g. CoFMAs) in the area.

1.3.2 Forest governance, policy, and management trade-offs

Through its recent policy frameworks and directives, Zanzibar's government stresses the crucial relationship between forest environments and sustainable development, rural economic stability, biodiversity and habitat conservation, and resilience to climate change. The National Forest Policy (RGZ, 1999) makes this sentiment clear in an opening statement: "forest resources are deeply woven into the fabric of Zanzibar's national well-being, in a way that cuts across sectors and social and economic categories" (p. 1). The *Zanzibar Strategy for Growth and Reduction of Poverty* (ZSGRP) (RGZ, 2007) recognizes that the state government's inability to provide adequate services and support to citizens has contributed to conditions of poverty, which may help drive unsustainable resource use as people seek to meet basic survival needs. This document seeks to address the general root causes of poverty and to improve agricultural techniques so that less land must be cleared to sustain farming activities. But, surprisingly, it mentions no forest-specific directives. Tanzania's *National Adaptation Programme of Action* (URT, 2007), however, outlines strategies that directly engage the nation's forest sector in mitigating and adapting to climate change. Its objectives include improving management of wildlife populations and forest fires, starting reforestation programs, adopting more efficient farming techniques to reduce land clearance, and securing land tenure (URT, 2007, p. ix). Energy, water, and agriculture sectors also have assigned mandates relating to forests, such as finding alternatives to wood biomass as an energy

source. Zanzibar's Environmental Policy (RGZ, 2013c) also identifies deforestation as a major issue. This document relates this trend to the fact that there is "inadequate capacity for effective coordination, law enforcement and environmental management practices" in forests (RGZ, 2013c, p. 40).

In working toward a sustainable, long-term balance between forest use and conservation in Zanzibar, the DFNNR and communities have received support from the aforementioned NGOs in projects that have attracted scholastic interest. During the period when Jozani-Chwaka Bay Conservation Area (JCBCA) was proposed to become a national park, Myers (2002) researched perceptions and political developments in Chwaka village, which lies on the northern margin of the protected zone. He notes that internal divisions in the community – rooted in neighbour disputes, multi-party politics, and general lack of social cohesion – detracted from the success of community-based resource management efforts up to that point. Many people were unhappy with the execution of the national park initiative and did not want to participate in a system rooted in shared responsibilities of common resources. Menzies' (2007) study on trends in forest management in Zanzibar also focuses on this period, the 2000s, when more communities began to sign CoFMAs. He found that, as a legacy of top-down, "heavy-handed regulation of resource use" (p. 42) in Zanzibar's colonial and post-revolutionary past, some communities have struggled with new decision-making power over forest resources. People have often disagreed on priorities for forest management, placing different values on ecosystem services. This work indicates that a complex array of perspectives, interests, and values shape forest resource management and use in south-central Unguja, particularly surrounding JCBNP, a focal point for conservation on the island.

More recent studies of HIMA, the four-year REDD+ readiness program in Zanzibar, also highlight institutional weaknesses in how forest-related ICDPs have tailored the scope of their activities and engaged communities. In her stakeholder analysis of HIMA in Imani, a village in Unguja Kusini, Andersen (2012) argues that ascribing communities the responsibility for reversing forest loss is problematic because the project does not address external drivers of deforestation. In many cases, collecting fuelwood is the most profitable income-generating activity available; this demand for wood, though, is ultimately driven by a lack of energy alternatives, particularly in urban Zanzibar. A broader, more holistic view of island-wide development issues and resource economies may therefore help to refine targets for CoFMAs' long-term performance in guiding forest management on the island.

Benjaminsen (2014) also describes socio-political problems the project has encountered (and created), using one community as a case study. She argues that "[responses]

to the HIMA project are framed by structural – both historical and political – inequalities" (p. 392), making it difficult for community members to reach any consensus in negotiating a CoFMA with the government. This agreement did not receive full support from community members before being signed. Benjaminsen argues, therefore, that this situation creates opportunity for dissatisfaction and resistance that may undermine the agreement's efficacy in promoting sustainable forest use and conservation. It may further serve to further imbalance community power relations: "With its ahistorical and apolitical approach, the HIMA project risks consolidating existing alliances between local political elite and the central government, as well as the domination and control of certain groups in local decision-making" (p. 394).

Further insight on interactions, power relations, and representativeness in the CoFMA system stems from Yakub's (2016) work. He explored related issues in forest carbon crediting in Zanzibar, examining relationships between the main actors and groups managing the nascent system that the HIMA project initiated. JUMIJAZA – as the central managing group for carbon credits – seemed a well-equipped and authoritative body to fulfil its role of coordinating fair credit and fund distribution. However, he found that community-based forest management in Zanzibar faced some basic challenges. Some of his respondents were sceptical that the carbon crediting system would provide enough compensation to make pursuing non-forest livelihood strategies an attractive option. He saw that many communities had not yet become leaders in pioneering novel, locally-adapted management approaches within the CoFMA scheme. Instead, they allowed themselves to be lead by more powerful actors: the DFNNR and NGOs.

1.4 Research purpose

This thesis investigates two coral rag forest areas in southern Unguja to determine the characteristics, processes, and feedbacks that contribute to the system's resilience in adapting to externally-imposed and internally-driven disturbances. Simultaneously, it seeks to identify any behaviours that detract from resilience so that it can suggest improvements to strategies for resource harvesting, forest conservation, and sustainable development. To assess and compare social-ecological resilience within two community-managed forest SES, it employs a mixed-methods approach that focuses on data collection through parallel case studies. It examines features of these forest ecosystems – including their structures, compositions, and functional roles – and studies their responses to past disturbance events. Exploring the role of institutions, with focus on the CoFMA framework, is also an essential step in determining how they moderate harvesting activities and adapt over time to improve responses to change.

This is the first known study to apply the social-ecological resilience perspective toward research on terrestrial forest areas in Zanzibar. Field work was undertaken through the collaboration titled *Vulnerability, Resilience, Rights and Responsibilities: Capacity Building on Climate Change in Relation to Coastal Resources, Gender and Governance in Coastal Tanzania and Zanzibar*, which is run jointly by the Norwegian University of Life Sciences (*Norges miljø- og biovitenskapelige universitet* [NMBU]) and the State University of Zanzibar (SUZA). This study involves several sectors and disciplinary foci: forestry, development, agriculture, traditional land use, ecotourism, and resource governance. An understanding of resilience dynamics within these forest SES helps to gauge how they respond to disturbances and to highlight ways to strengthen their adaptive capacity in the future.

1.4.1 Research Question

How do forest harvesting and management strategies relate to social-ecological resilience in two village communities in southern Unguja, Zanzibar?

1.4.2 Research Objectives

1. Determine the characteristics of the terrestrial forest ecosystems in two communities.
2. Analyse forest resource use within the communities, including related livelihoods and ecosystem services.
3. Examine changes and disturbances in forest social-ecological systems over time and the ways that systems respond to them.
4. Examine the role of institutions in implementing management regimes that affect social-ecological resilience through shaping and regulating forest resource use.

2. Conceptual Framework

2.1 Resilience

Resilience provides a theoretical framework for looking at relationships between ecosystems and society from a comprehensive, multi-dimensional perspective (Holling, 1973; Folke, 2006). Having its conceptual roots in ecology, resilience employs a systems approach to examine responses to different disruptions including, for example, gradual climatic changes or individual disturbance events, such as fires or clear-cuts. These disturbances – and their subsequent effects – rarely have linear behaviour; system dynamics are significantly more complex because "periods of gradual change and periods of rapid transition coexist and

complement one another" (Folke, 2006, p. 258). Ecologists and social scientists have documented cases of non-linear and unexpected changes in different parts of the world (e.g. Holling, 1973; Adger, 2000a; Walker et al., 2004), contributing to more in-depth understanding of how complex systems react and adapt to disturbances.

The resilience perspective has broad utility: "the term and the concepts around it have significant resonance and the traction for current thinking and policy on global change, development and environment" (Brown, 2016, p. 5). Folke et al.'s (2002) report to the Swedish Environmental Advisory Council is one example of how resilience has been linked to goals for sustainable development and management of SES at a national scale. The resilience perspective challenges traditional ways of thinking about change; rather than being forces of destruction, disturbances are drivers of innovation that lead to new approaches, processes, and connections[15] (Berkes & Folke, 2003; Folke, 2006). Managers and scholars have adopted this term in different ways (Folke, 2006), so this chapter explains its use and relevance as a conceptual framework within the context of Zanzibar's coral rag forests.

Holling's (1973) *Resilience and stability of ecological systems* lays the foundations for modern resilience thinking in SES. In this paper, the author contests a traditionally-held view of ecosystem dynamics that assumes, apart from periodic interruptions, that these systems remain in stasis. Based on his own experiences in modelling ecosystem changes, Holling suggests that ecosystems trend toward different *basins of attraction*, which are distinct system states reinforced by internal feedbacks and key processes and separated by critical thresholds. If a disturbance event is severe enough, it may push an ecosystem into a qualitatively different state. For example, a landslide may remove a part of a forest and much of its underlying soil, allowing grassland species to establish an ecosystem with different functions, processes, and services. Considering fine- and coarse-scale disturbances across landscapes, ecosystems are highly heterogeneous. Rather than being stable and predictable, ecosystem patches continually respond to a variety of perturbations through feedbacks and internal processes. Holling (1973) thus defines resilience as "a measure of the persistence of systems and of their ability to absorb change and disturbance and still maintain the same relationship between populations or state variables" (p. 14). A growing body of resilience scholarship has continued to further develop this seminal definition.

[15] While resilience is often used with reference to building and improving beneficial qualities in a system, it is important to note that it is not a normative term. From a human perspective, it would be undesirable if, for example, a forest overtaken by disease were resilient to efforts made to control the outbreak (because internal feedbacks helped to keep it in the same state).

The concept of social-ecological resilience (SER) broadens Holling's initial focus, emphasising interrelationships and feedbacks between humans and the environment. SES are at the core of this concept, demonstrating that social and ecological realms are inherently connected because each of these systems enacts change within and shapes characteristics of the other (Berkes & Folke, 1998; Berkes et al., 2003; Folke, 2006). Berkes and Folke (1998) indicate that ecosystems strongly relate and connect through "property rights, land and resource tenure systems, [and] systems of knowledge pertinent to environment and resources" (p. 4). Social and ecological resilience can be linked particularly closely in communities where natural resource harvesting plays a dominant role in livelihoods and economies (Adger, 2000b). In these cases, resilient societies buffer the effects of disturbances by diversifying livelihoods and resource supplies, and institutions use flexible, learning-oriented, and participatory approaches to maintain the services and values that landscapes provide (Adger, 2000b; Folke, 2006; Biggs et al., 2012).

In Unguja's forests, SER relates to interchanges between coral rag forest patches, resource users' activities, and the existing governance framework. Community members harvest resources in accordance with CoFMA guidelines and, in doing so, they modify and impart some disturbance in forest ecosystems to take advantages of various ecosystem benefits. Characteristics of and changes within these environments influence the kinds of subsequent activities, developments, and management strategies undertaken there. The clear relevance of SES in this context makes it necessary to use SER, specifically, when examining interlinked systems' abilities to respond to change. In the context of this study, SER thus refers to resource user groups interacting with forest environments in a way that makes them able to endure disturbances and changes by facilitating processes for internal reorganization, adaptation, and learning to retain key ecosystem functions and services over time (Berkes et al., 2003; Folke 2006; Resilience Alliance, 2016).

2.1.1 Resilience, the adaptive cycle, and panarchy

The four-stage adaptive cycle (Fig. 2) depicts how SES behave over time. Holling (1986) first proposed this model[16], which likens major changes in organization and function within SES to phases within the two loops of a figure eight (Holling & Gunderson, 2002; Berkes et al., 2003). In the loop at the forefront, populations of r-selected (pioneer) species grow rapidly as they establish in area and take advantage of resources there. In this

[16] Holling (1986) initially called this model the *four ecosystem functions* (p. 307), but subsequent publications (e.g. Holling and Gunderson, 2002) refer to it as the adaptive cycle.

exploitation (r) phase, systems are resilient to change and disturbance. As resources become scarcer, however, the system enters a conservation (K) period in which energy and matter build up but population growth subsides. Here, "the tightly bound accumulation of biomass and nutrients becomes increasingly fragile" (Holling & Gunderson, 2002, p. 33), eroding resilience. Major disturbances can therefore initiate sudden, pivotal change in the system, forcing it into the back loop through release (Ω). Internal system processes are at work during the subsequent reorganization (α) phase. Holling and Gunderson (2002) explain that soil biogeochemical cycles play a key role in retaining the nutrients for subsequent primary succession (i.e. the next rapid growth phase). Depending on the outcomes of reorganization, the system may return to a state with the same qualitative characteristics and functions. Alternatively, it may "flip into a less productive and organised system" (Holling & Gunderson, 2002, p. 34) – i.e. a new state.

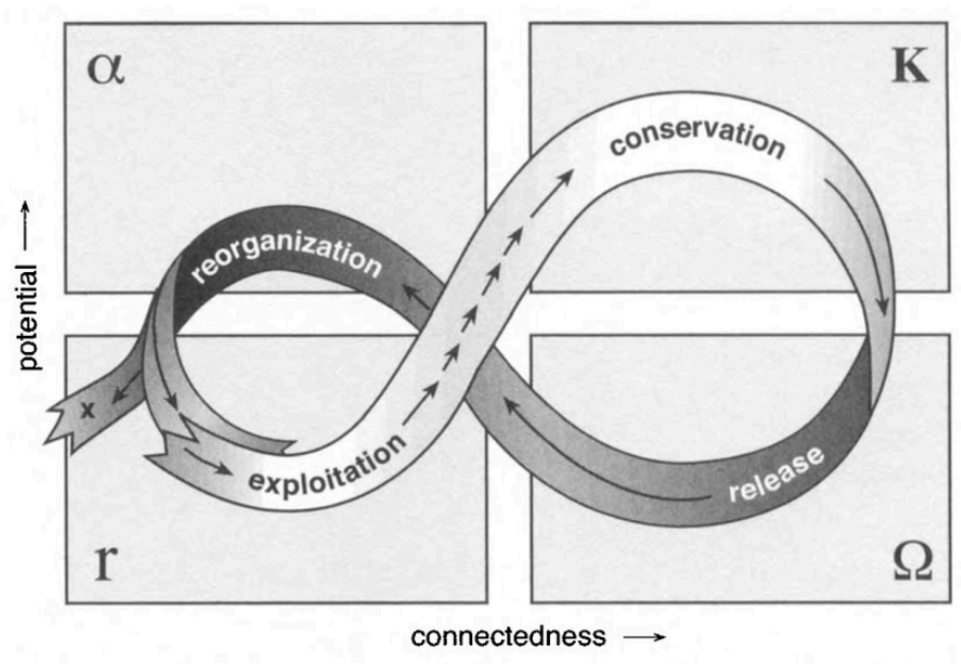

Figure 2. The four adaptive cycle phases (from Holling & Gunderson, 2002, p. 34).

Within this adaptive cycle, internal variables shape SES characteristics and affect resilience (Holling, 1986; Berkes & Folke, 1998; Holling & Gunderson, 2002; Folke 2006). Holling (1986) suggests that SES feature both "fast" and "slow" dynamics, with variables driving system feedbacks. Brown (2016) defines fast system variables simply, as "those on which the human use of the system is based" (p. 74). In forest environments, they may include, for example, wildlife populations or tree species harvested for timber. On the other hand, slow variables are major biophysical properties that influence fast variables, often

changing gradually over long time scales (e.g. geochemical cycles and soil profile formation). This second category most directly influences SER because slow variables can have thresholds that coincide with major tipping points in SES (Carpenter et al., 2001; Biggs et al., 2012). Monitoring and managing for slow variables, however, can be logistically complicated because of their vast temporal and spatial scales (Folke, 2006; Biggs et al., 2012; Brown, 2016).

Processes and changes outside SES can also have cascade-like effects on internal system dynamics. Holling & Gunderson (2002) put forward a multi-system concept called *panarchy* to describe the nested and interconnected nature of adaptive cycles for SES at different scales, ranging from fine to coarse. In a forest, for example, these scales could be delineated at leaf, branch, tree, and stand levels. Resilience Alliance (2017) explains the processes by which these different levels interact: "The smaller, faster, nested levels invent, experiment and test, while the larger, slower levels stabilize and conserve accumulated memory of system dynamics" (17.02). Disturbances and regenerative processes alike thus affect SES at multiple scales through revolt (ascending levels) or remembrance (descending) across these nested scales (Holling & Gunderson, 2002; Folke, 2006; Miller et al., 2010).

These cross-scale linkages make it important to spatially and temporally define an SES for a given context in order to understand the relative effects of internal and external processes. In employing resilience as a conceptual tool, resilience *of what, to what* must therefore be considered because different types of disturbance can coexist and/or synergise across diverse landscapes (Carpenter et al., 2001). Researchers and managers alike must base their investigations of SER on a relevant disturbance (or set of disturbances) within a defined area and time period to understand how a given SES responds (Carpenter et al., 2001; Walker et al., 2002; Folke, 2006). Conversing with resource users who possess experiential knowledge helps to identify relevant disturbances within a given SES towards defining appropriate research foci or management strategies (Resilience Alliance, 2010).

2.1.2 Applying resilience as a conceptual tool

To establish system boundaries and understand key disturbance types, this study draws on Walker et al. (2002) and Resilience Alliance (2010), who propose comprehensive frameworks to make balanced assessments of SER in different contexts. Both processes require setting spatial and temporal boundaries for an SES (the "focal system") and involving stakeholders to define system characteristics and identify important disturbances. Resilience Alliance (2010) also recommends examining how the system has responded to past

disturbance events in order to understand processes for reorganising, regenerating, and adapting. This information helps to estimate the approximate adaptive cycle stage for a given SES and to identify alternative system states, drivers of change coming from finer and coarser scales, and thresholds for key variables and processes (Resilience Alliance, 2010). The steps from these two complementary frameworks anchor the research methods discussed in the next chapter of this thesis, determining the approach for studying two terrestrial forest SES in Unguja.

This study puts particular emphasis on the related concept of ecosystem services as a means of classifying and understanding key biophysical characteristics and processes in coral rag forest SES. Ecosystem services are "the benefits people obtain from ecosystems" (Millennium Ecosystem Assessment [MA], 2005, p. v) and range from material products (e.g. wood) to non-tangible benefits (e.g. leisure opportunities). Four categories capture their primary functions: provisioning, cultural, supporting, and regulating (MA, 2005). Within a resilience framework, they indicate the values and products that human populations get from ecosystems (Biggs et al., 2012). These benefits, like the SES that produce them, are subject to disturbance events and can vary non-linearly (Biggs et al., 2012; Turner et al., 2013). Nevertheless, Biggs et al. (2012) argue that that SES must maintain essential ecosystem services, even in spite of shocks and disturbances, to be considered resilient. In forest ecosystems, biotic communities generally require diversity (in species, functions, landscape patches, etc), patch connectivity, functional redundancy, and sustained regeneration potential in order to retain these services (Thompson et al., 2009; Biggs et al., 2012). Their everyday importance to livelihoods and well-being makes these forest benefits logical starting points for connecting harvesting trends and resource governance issues to resilience within SES in Unguja.

This study also employs ideas about ties between SER and governance as explained by Lebel et al. (2006) and Biggs et al. (2012) to understand how political power distribution across institutions and actors shapes SES. Lebel et al. (2006) define governance, within the context of SER research, broadly; it includes actors involved in governmental and private-sector roles in addition to the processes that establish regulations, make laws, and set norms. Governance systems are resilient when they foster collaboration, participatory planning, learning, and connectivity between members of society (Lebel et al., 2006; Biggs et al., 2012). In contrast, actions and policies that marginalise certain groups of people or erode ecosystem benefits over time detract from a system's SER (Lebel et al., 2006). Resilient systems also "match governance levels to the scale of the problem" (Folke et al., 2007 as

cited in Biggs et al., 2012, p. 437), targeting adaptive management efforts and encouraging stakeholders' agency to best promote actions that reinforce SER within a system.

2.1.3 Perceptions of environment: Complementarity with political ecology

Political ecology lends opportunity for additional insight within this context by showing how power relations and socio-political forces shape people's perceptions of and interactions with forest SES. This discipline centres on the idea that people interpret environmental phenomena in diverse ways; unique social, political, historic, economic, and cultural factors contextualise events and changes, as well as the way people think about them and try to manage them (Robbins, Hintz & Moore, 2010; Robbins, 2012). This way of thinking implies that measured qualities of a system are sometimes overlooked in favour of "the accounts of environmental conditions and change that are held as true by decision-makers, local people, and competing interests" (Robbins, 2012, p. 127). It therefore encourages more "constructive-and-critical" (Zimmerer, 2015, p. 162) thought about key environmental discourses and the actors involved. This aspect makes political ecology especially suitable for the context of this study, which features competing narratives about the nature of on-going environmental changes (e.g. deforestation) and an institutional framework comprised of actors and sub-groups pursuing distinct objectives.

Forest SES in Unguja feature a great deal of social and ecological heterogeneity, so political ecology adds an additional – but necessary – dimension to analysing how human societies relate to terrestrial landscapes. Political angles to environmental change cannot be ignored because power relations permeate all human-environment interactions (Robbins, Hintz & Moore, 2010; Robbins, 2012). Most fundamentally, the ways that people name, categorise, and discuss ecosystems and their key features – i.e. socially construct them – bely important information about different norms and political objectives (Robbins, 2012). In this study, political ecology applies an added lens for deeper analysis into the connections between social, political, and ecological realms that are intrinsic to defining systems' resilience to disturbance and stress.

3. Methods

3.1 Study Areas

Field research focused on two *shehia* in Unguja Kusini, the island's southernmost district. Contacts from SUZA and the DFNNR who had long-term academic and professional experience working in this region helped inform the choice of appropriate study locations.

We selected Muyuni A and Kitogani (Fig. 3), two communities that signed CoFMAs in 2013 and have participated in HIMA project activities. They are geographically close; only one other *shehia*, Muungoni, separates them. For the purpose of this study, they represent distinct SES at the community scale, featuring legally demarcated forest areas governed by independent SCCs over the thirty-year durations of their current management agreements.

Both communities share notable similarities in their ecological features and in the ways that they govern and use resources from terrestrial forests. Each *shehia* has a stretch of coastline to the west side of forest and shrubland areas and is traversed by a paved road corridor, in addition to a network of unpaved tracks and paths. Coral bedrock (consisting of uplifted fossil coral reefs) limits vegetative growth in both areas, resulting in a spectrum of ecosystem types from closed-canopy forests to coral barrens. The SCCs in each community have, within the CoFMA area boundaries, divided this landscape into zoned areas intended for protection, agriculture, settlement, and low-impact use. Though the two *shehia* have relatively similar population sizes and areal extents, they can be compared and examined on the basis of their social-ecological characteristics, which are shaped by management decisions and resource use activities taking place there over time.

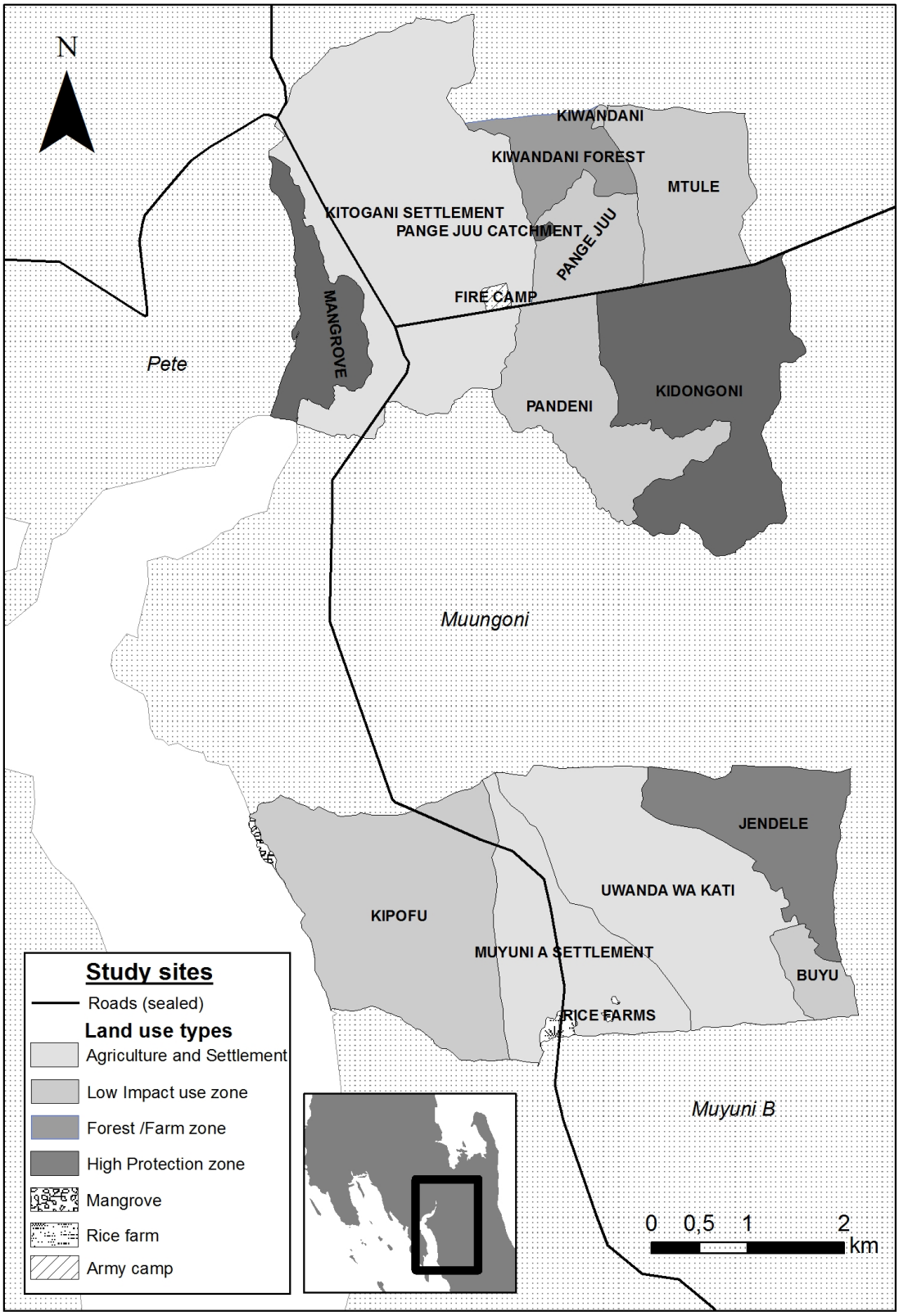

Figure 3. Kitogani and Muyuni A *shehia* and their respective land use areas.

3.1.1 Kitogani

Kitogani is a moderate-sized community of 1128 residents (National Bureau of Statistics, 2013) located at a junction where the road from Zanzibar Town splits east to Paje and curves to the south/southeast in the direction of Makunduchi. Some residents have capitalised on this location, developing small businesses to sell food and various wares to passing travellers; other community members practice irrigated and shifting cultivation, collect firewood and other forest products, and work in semi-formal or formal jobs, among other occupations (Andersen, 2012). Pange Juu Cave is an important natural feature and water source, used for both drinking and irrigating crops. It is currently being developed to attract tourists to the area.

Kitogani's CoFMA has helped to concretise the objectives of land use and forest-related activities in the community. The community has been engaged in conservation-oriented activities since the gazetting of JCBNP, northwest of the *shehia*, and has participated in regional forest initiatives through membership in both JECA and SEDCA. It can also put CDF monies from the national park toward initiatives that benefit sustainable development within the community. According to community leaders in Kitogani, the Kidongoni forest in the south-eastern portion of the *shehia* has recently been converted to central government management as part of the newly established MJFR. The *shehia* hosts a variety of terrestrial ecosystem types across its 1953 ha: active and abandoned farm fields, agroforest, mangroves, coral rag forest, and shrublands (RGZ, 2013e).

Much of the forest area in Kitogani features low to intermediate coral rag forests that have thick, intertwined vegetation, thin soils with moderate leaf litter layers, and canopies ranging from 1-3 m in height. Near the Pange Juu catchment, there are taller trees (≤ 8 m) and outcroppings of ragged coral limestone among some of the deepest and most moist soils in the *shehia*. Semi-open shrublands – abandoned farm fields left to re-vegetate – characterise areas close to the Paje road. Farmers practice small-scale commodity agriculture (primarily shifting cultivation) on a network of semi-contiguous plots, many of which feature root vegetable and fruit crops (such as cassava and papaya) growing in rocky soils. In areas cleared or burned within the past two years, mature cycads are often the only clear remains of previous growth (Fig. 4). Some irrigated vegetable fields are located near to the Pange Juu Cave area and elsewhere near groundwater well sites. Along the Mtule/Pange Juu land use area boundary, several plantations of casuarina (*Casuarina equisetifolia*) can be found.

Figure 4. Cycads on new agricultural land (left) and intermediate coral rag forest (right) in Kitogani.

3.1.2 Muyuni A

Muyuni A has slightly fewer residents – 1028 in the 2012 census (National Bureau of Statistics, 2013) – and its land area covers 1460 ha. Most settlement is clustered along the Zanzibar Town-Makunduchi road, with mixed land use areas stretching away to the east and west. Unlike Kitogani, Muyuni A has sandy beaches, where seaweed farming and fishing take place. Community members work in various occupations, including small businesses; farming; and harvesting forest products like firewood, charcoal, and timber. Much of the community's agriculture is based in the settlement zone and on the west side of the road, where there is a network of dirt tracks that stretches as far as the coast.

This community also belongs to SEDCA and signed its CoFMA in 2013[17]. Coral rag forest is the dominant ecosystem type here, although there are also small areas of mangrove forest and agroforest. A Zanzibar Town-based tour company runs tours here every week, showcasing local handicraft making and farming as well as Ngonga Cave, a large natural cavern with staircases built for access. The *shehia* features evergreen coral rag forest and shrubland, punctuated in several areas by shifting cultivation. Rice, a relatively uncommon crop in coral rag areas, is also grown here in a few specially designated plots. MJFR forms the eastern boundary of the *shehia*.

Denser growth and higher canopies, averaging 2-5 m tall with up to 90% canopy cover, characterise forest patches here. Interspersed with forest areas, extensive patches of shrubland have < 50% canopy cover, low growth (≤ 2 m), and mixtures of herbs, shrubs, climbers, and immature trees over shallow soils or exposed coral bedrock (Fig. 5). Centred

[17] Muyuni A, Muyuni B, and Muyuni C formerly had a joint CoFMA, but each *shehia* has now signed an individual agreement with the DFNNR.

around and west of the Kitogani-Makunduchi road there are some coral barrens that feature little – if any – soil and small clusters of shrubby vegetation. At some agroforest sites west of the main road, coconuts, bananas, and citrus trees are intercropped, reaching canopy heights up to 10 m. There are also several current and abandoned casuarina plantations. Soils in Muyuni A appear drier than in Kitogani, often featuring shallow layers of dead leaves that have not yet decomposed. Small-commodity agriculture here also features root and fruit crops; mature mango trees along the main road produce particularly large harvests every January.

Figure 5. Shrubland (left) and patch of intermediate coral rag forest (right) in Muyuni A.

3.2 Mixed methods research: Combining qualitative and quantitative approaches

To comprehensively answer the research question, this study takes a critical realist stance and employs a mixed methods research (MMR) design. Critical realism holds that valuable scientific knowledge can be gathered inductively – i.e. outside of the traditional scientific approach of hypothesis testing (Bryman, 2012). The complex social and ecological facets of resilience make it difficult to "test for"; I therefore work to build an in-depth understanding of the two SES and examine whether these systems demonstrate resilient characteristics. Ross and Berkes (2014) argue that "because abstract concepts such as 'resilience' defy direct observation (Carpenter et al., 2005), the combined insights of several methods are more likely to produce a robust understanding" (p. 789). In bringing together and analysing qualitative and quantitative data, I aimed to generate a comprehensive view of SES dynamics. Bryman (2012, p. 633) calls this objective *completeness*: using both data sets to complement each other in producing a comprehensive view of reality. Examining resilience requires an understanding of social phenomena between stakeholders, institutions and the

environment. Here, the critical realist approach entailed looking at processes shaping relationships between people and influencing how they perceived and constructed reality (Bhaskar, 2011).

I employed this MMR approach to examine how people's ideas about forests, governance, and socio-economic phenomena aligned with measured conditions in the two *shehia*. I used qualitative methods to elicit traditional ecological knowledge (TEK), which Berkes (2008) defines as a cumulative, context-specific understanding of the land, its processes, and communities' relation to it. I collected information about community members' perceptions of management, ecosystem health, harvesting activities, and environmental changes or disturbances over time. Quantitative data, which included measurements of forests' structure and composition, built on this data to show ecosystems' compositions, characteristics, and responses to past disturbances. Having these two sources of information also allowed for triangulation, the corroborating of results using data collected in different ways. This practice can help to minimize the risk that each method's inherent assumptions detract from the validity of results (Fielding & Fielding, 1986, as cited in Berg & Lune, 2012). Creswell et al. (2008) highlight another advantage of this technique: if the triangulated results are dissimilar, they can shed light on unexpected and interesting phenomena.

Though MMR designs have become increasingly common in interdisciplinary research, they remain contested by some scholars (e.g. Guba, 1985, Morgan, 1998, as cited in Bryman, 2012) who argue that qualitative and quantitative methods represent different philosophical paradigms in science. But Bryman (2006, as cited in Bryman, 2012) indicates that qualitative and quantitative research methods can be seen as independent from their epistemological roots, allowing each of them to be used to explore research questions within different disciplinary paradigms. I share this second view and argue that, so as not to omit any important human or environmental dimensions of SER in this study, both research methods must be used in tandem. As an added benefit, combining these methods can allow for efficient and comprehensive data collection (e.g. interspersing key stakeholder interviews with biophysical surveys) within the relatively short timeframe of thesis fieldwork (Creswell et al., 2008). The methods for this study are herein focused toward generating data that describe processes, drivers, and conditions relating to resilience in two SES within the coastal terrestrial forest of Zanzibar.

3.3 Qualitative data collection

3.3.1 Semi-structured interviews

I conducted 51 interviews with relevant stakeholders to collect qualitative information about the characteristics of these two SES, including resource use patterns, management activities, and observations of environmental change. To sample a range of different perspectives on these forests, I stratified the population of potential respondents into four stakeholder groups: community members, community leaders, businesses and NGOs, and other researchers. Purposive sampling allowed me to collect data from actors filling different roles in using, managing, and studying forests. I used a semi-structured interview questionnaire (Appendix A-1) to enquire about livelihoods, the forest environment, resources, and governance in ways relevant to the role of each group. Questions were based on Resilience Alliance's (2010) *Assessing resilience in social-ecological systems: Workbook for practitioners*, a practical guide for modelling and analysing resilience within SES. I designed questions to encourage discussion and reflection on forest issues and, where necessary, to allow for more detailed follow-up on interesting descriptions and anecdotes. Encouraging open dialogue while safeguarding respondents' anonymity was essential in this context where, for example, participants could potentially discuss illegal resource use or controversial management decisions. As a means of protecting confidentiality, I therefore decided neither to record the interviews nor to collect personal details (name, phone number, etc.) that could relate responses back to individual participants.

I spent the first two weeks of the fieldwork period meeting contacts from SUZA and DFNNR, obtaining the necessary permissions to conduct research, and scheduling interviews. Part of my preparations included reviewing my interview questionnaires together with the two translators who would be facilitating data collection in communities. This step ensured that we had a common understanding of questions' meanings and the desired response type for each. The translators also agreed on how to convert the questions from English to Swahili to allow consistent translations across all sessions. Responses from all interviews, however, were to be written in English on response forms to facilitate later data entry and analysis. Because they had previous work experience in both communities, the translators offered to make contact with the *masheha* to introduce the research project, obtain permission for fieldwork activities, and request participants for the interviews.

Community interviews

Interviews were held in the two communities in late October and early November 2016. In Muyuni A, the 26 respondents included six people in community leadership positions (including the SCC) and 20 community members. Here, the respondents were chosen purposively, having been invited to represent different livelihood types and forest resource user groups by the *sheha*. After introducing both the research and ourselves at a community gathering, we split into two interviewing teams to increase our efficiency and sample size. I reviewed the aims of the study with each interviewee and ensured that they were aware of their rights as voluntary participants. I sought oral consent to participate and recorded each affirmation on an anonymized consent form. After the first two interviews, the interviewers convened to discuss two problem questions that were drawing unsatisfactory responses. We agreed on slight adjustments to the wording of the questions to access the same information from different angles. Indeed, these revisions prompted appropriate answers with fewer misunderstandings.

We then visited Kitogani to interview 20 people: two members of local NGOs, five people in community leadership roles (again including the SCC), and 13 community members. Again, we interviewed in two teams; I alternated working with each translator. A community leader coordinated participant selection, which began purposively and then became convenience-based in order to achieve a large enough sample from community members who were available on interview days. I later interviewed another community leader while doing field reconnaissance in the community.

I gathered additional qualitative information from informal conversations and resource walks with community members in both locations throughout the fieldwork period. On the first day of interviews in Kitogani, a spontaneous field visit to two irrigated vegetable farms permitted more in-depth discussion about and observation of alternative agricultural and income-generating activities in that community. During two days of pre-survey field reconnaissance, a guide from each community identified, explained, and showed me different land use areas and significant forest features within both *shehia*.

I transferred all interview responses from the two communities to a password-protected spreadsheet for safekeeping and later analysis. Soon after completing the interviews, I recursively coded the data to draw out key themes in the responses. Where necessary, I cross-checked answers against each other and with each community's CoFMA document, which I obtained from the DFNNR. I kept physical copies of interview forms in a safe, secret place until after completing my analysis, when I permanently destroyed them.

Other key stakeholder interviews

I also sent interview requests to other stakeholders involved in forest resource management in the wider Unguja Kusini area. Though I had made a contact list prior to starting fieldwork, I was able to refine it once I arrived in Zanzibar and started meeting various actors involved in the forestry sector. Due to time constraints for interviewees, I sometimes had to conduct these interviews quickly or informally, focusing on questions most relevant to their scope of work. Because all these interviews were in English, I was the sole interviewer. I spoke to a tour company manager and two government employees, one having worked in community forestry for three decades. I also talked to a PhD student conducting research on the ecology and management of duikers in the coral rag forests of Unguja Kusini.

Unfortunately, some actors did not respond to my requests, so I could not cover all key stakeholders involved in forest-related projects and activities in Muyuni A and Kitogani. This situation was particularly true of international NGOs such as CARE, who had executed projects in these communities. I therefore gathered information about their activities and objectives from the detailed project reports and evaluations they have published online.

3.3.2 Limitations

The validity and generalizability of data collected during the interviews was limited by several key factors. Because I was a newcomer to both the language and culture of this region, my foreign background may have biased the way that I perceived social and natural settings or interacted with participants in the study. I endeavoured to be politely curious and to learn as much as possible about each community and its biophysical, social, and political context during my time there. I suspect, however, that I overlooked or did not fully understand some of the nuanced statements, actions, and situations that transpired during the interviews. Furthermore, though I tried to sample respondents purposively to get a wide spectrum of different stakeholders, some actors were unreachable during the interview period, so unique perspectives on forest issues may have been omitted. I also did not have full control over which community members were invited to participate; once the translators had made initial contact with each *shehia*, the communities chose the respondents themselves.

In Kitogani, not enough respondents initially came to the interview sessions, so a community leader went to find more people to come at the last minute. Some respondents, therefore, were chosen based on their location and availability at that time, rather than their knowledge of forest environments and related activities. As a result, a couple of respondents said they were unfamiliar with local forest management and use, and fewer community

members participated in Kitogani (13) compared to Muyuni A (20)[18]. A more balanced number of respondents within this stakeholder category could have introduced respondents involved in a wider range of forest-related activities, permitting easier comparison between the two communities.

After interviews concluded in Muyuni A, I also found out that respondents had been paid from the *shehia*'s CDF to participate. Even though I did not pay the respondents myself or know about the arrangement beforehand, this compensation may have biased the sample group (e.g. favouring individuals who were not occupied with formal employment that day) and/or made respondents feel obligated to favour the SCC, which disbursed the money, in their responses.

Some logistical aspects of the interviews – involving translation and measures to preserve confidentiality – may have further influenced the responses I collected. In working with translators who converted responses from Swahili to English, some expressions and phrases were probably altered from their original, intended meanings. Perfect translations were not always possible between the two languages, especially within this context, where word uses and phrases sometimes had very specific connotations. Across all the interviews, it was impossible to entirely standardise our practices; for example, if a participant needed clarification on a question, each translator would re-explain it in their own words in an attempt to evoke an appropriate response. The efficiency of working in teams for community interviews, however, seemed to outweigh these small variations, especially when we had agreed to a limited interviewing timeframe in each community. In trying to completely safeguard respondents' anonymity, I furthermore made it impossible to follow-up on responses once the interviews were finished. Because I did not record the interviews or take any personal details for later contact, I left only one-way communication open between the respondents and me (they had my contact details in case they wished to withdraw their answers from the study later). For this reason, I had to immediately clarify any discrepancies as they arose during the interviews. I also addressed a few gaps and inconsistencies from the interview responses during my pre-survey resource walks and reconnaissance.

[18] This imbalance was particularly problematic for assessing livelihood strategy differences between the two communities. I only assigned questions about occupations and personal resource use patterns to the community member stakeholder group. In retrospect, however, these questions should have also been posed to community leaders because many of these respondents also had first-hand experience in forest-related activities.

3.3.3 Ethical considerations

Through data collection and storage, I endeavoured to follow core ethical standards for social science research in trying to "do no harm" to participants in this study. As a student at NMBU, I was required by the Norwegian Centre for Research Data (*Norsk senter for forskningsdata* [NSD]) to submit my research proposal for clearance. I applied their suggested changes to my research plan once my application had been reviewed and approved. I based a participant information letter on the NSD's template and made a copy available to each respondent at the time of the interviews. With the help of the translators, I ensured that the *sheha* in each community knew about the timing and progress of interviews and surveys, and I left copies of my study plan and contact details. I did not ask respondents questions involving controversial or politically contested subjects; when participants raised these issues, however, I gave neutral responses.

But in spite of these measures to ensure openness and voluntary choice to participate, my or my translators' presence or actions may have unintentionally influenced or affected participants. For example, Banks and Scheyvens (2003) write that when researchers or field assistants are perceived to have different status within a social hierarchy, respondents may feel more pressure to participate or alter their behaviour accordingly. This situation may have played out during my research because both of my translators were well-respected government staff that already had professional relationships with the two communities. Furthermore, my presence as a foreign student seemed to evoke hope that my research would garner support for the communities to improve local livelihood alternatives and secure forest health in the future. Some community members requested that my results be used to attract grant money to fund various development activities in this area. I was honest in explaining the scope and purpose of my research, and I told community members that the research results would be available for the communities and DFNNR. However, my results were not fully analysed before I left the field, so I was unable to hold meetings in the communities to discuss them in further detail. This activity would have been an ideal way to share these preliminary findings and to see if community members wished to make further comments or clarifications about them. Holding such a meeting could have given both communities a greater sense of ownership over the information before receiving it in thesis format.

3.4 Quantitative data collection

3.4.1 Biophysical surveys

To supplement the data collected through semi-structured interviews, I planned forest survey activities in each *shehia* to gather biophysical data relating to resilience, including structure, composition, and function of forests and their responses to past disturbances. The CoFMAs define different land use zones – including settlement, agriculture, high protection, and low-impact use – but I focused my sampling on the latter. During community member interviews, respondents most frequently associated the community's key forest-based activities with those allowed in low-impact land use zones[19]. Concentrating on these areas was most practical given limited time and funds for conducting the surveys, especially after bureaucratic delays in securing the necessary materials, geospatial data, and permissions to carry out this fieldwork. Initial field reconnaissance further confirmed that these zones featured several land use strategies within qualitatively different forest environments.

The DFNNR provided map shapefiles of current land use zones in each *shehia*, providing the basis for laying out a systematic sampling plan. Using Google Earth Pro, I overlaid these map shapefiles with randomly-placed sampling grids[20]. The total low-impact use area available for sampling was 486 ha (49.9% of the land area of the *shehia*) at Muyuni A and 652 ha at Kitogani (50.3% of the land area)[21]. To obtain a comparable number of survey sites in each location, the grid had 400 m intervals in Muyuni A, while Kitogani had a grid scaled to 500 m to account for the greater land area sampled there. The relatively large gaps between sampling sites allowed me to sample across a large land area, but likely at the expense of overlooking some finer-scale environmental variations.

To determine how many of these intersection points to sample, I drew upon the UN Framework Convention on Climate Change's (UNFCCC, 2009) guidelines for estimating the number sample plots in forest biomass surveys. Biomass estimation is not the explicit purpose of this study, but this series of formulae has come to be used as an international standard applied across a variety of forestry projects[22]. Recent biomass data from the ZWBS (RGZ, 2013e) provided rough information (due to the data's display in low-resolution maps)

---

[19] These zones constitute 69.8% of the 82 754 ha covered by all the CoFMAs in Zanzibar (RNEDS, 2015), making them a key land use category for management and planning.

[20] All mapping programs used in the course of this study – including Google Earth Pro, Garmin BaseCamp, and ESRI ArcGIS (v. 10.4.1) – were set to use the WGS84 datum to ensure against distortion from datum shift. Where necessary, I transformed data to project correctly in this datum.

[21] I include the "forest/farm" zone in Kitogani within this sampling area; it shares most land use activities and regulations with the other low-impact use zones.

[22] These projects include many recent UNFCCC Clean Development Mechanism initiatives involving carbon forestry, such as the REDD+ program.

to run this exercise. Forest biomass across the two *shehia* is quite variable at 2-50 t ha^{-1}, with low coral rag forests having the lowest values. Based on the mapped areal extents of these different biomass values, at least 45 sample plots needed to be surveyed. I therefore used a random number generator to choose 24 grid intersection points as sampling sites in each community. (As a result, a few of these intersection points were randomly excluded from the total set.) All 48 sampling sites were then entered into a GPS unit as waypoints. Navigating to pre-mapped sampling sites (as opposed to measuring out transects in the field) allowed me to draw on satellite imagery to plan surveys in groups of sites that were close to common access routes within the same day. I worked with a field assistant who had extensive botanical and experiential knowledge in the study areas and had contributed to prior biological surveys, including the ZWBS.

Centring on the coordinates of each sampling site, a 10 m by 10 m (100 m^2, or 0.01 ha) quadrat marked the sampling area. I chose squared-shaped quadrats because they would be relatively simple to lay out and visualize (i.e. straight lines intersecting at right angles) in dense thicket areas. (String-and-anchor techniques for delineating circular plots would have been difficult to employ against the profuse tangle of branches and thorns in the workspace.) Though edge effects can increase counting errors in non-circular quadrats (Krebs, 1999), determining whether a given plant was inside or outside the boundary was relatively straightforward because any sites had small-diameter stems that were clearly separated from each other. When a multi-stemmed plant landed on the boundary, its location was considered to be the centre-point of the cluster of stems at ground level; it was then counted or left out accordingly. Within each quadrat, we further delineated a series of nested quadrats with 2 m, 5 m, and 8 m side lengths. Within the 2 × 2 m plot (henceforth "mixed vegetation plot"), all vegetation – including trees and other plants – were identified and enumerated. Inside the 5 × 5 m quadrat, we described and classified all evidence of disturbance and regeneration (including counts for saplings/seedlings and stumps). We also measured all trees with diameter at breast height (*dbh*)[23] from 5-10 cm. Within the 8 × 8 m plot, we recorded all trees from 10-20 cm *dbh* and in the 10 × 10 m plot all trees over 20 cm *dbh*. We also noted the growth form of all identified plants – classifying them using Rowe and Speck's (2005) categories: herbs, climbers, herbs, and trees – in order to document the structural composition of plant communities.

[23] Measurements were taken from a height of approximately 1.35 m from ground level.

My field assistant, who had extensive experience identifying native flora in Zanzibar and using them in traditional medicine, first identified species in the field using their Swahili names. We then cross-referenced Latin names using species lists from three previously published studies containing forest structure and composition data for Unguja: Nahonyo et al.'s (2002) survey of the JCBNP area, the ZWBS (RGZ, 2013e), and Haji's (2013) study of forest degradation in KPFR. We also referred to Vernon's (1987) *Field guide to important arable weeds of Zambia*, which contains several species found in Zanzibar and was particularly useful in identifying less common herbaceous species. For the remaining species that we could not identify ourselves, we collected specimens and/or photos and consulted with a knowledgeable botanist stationed at JCBNP. On two occasions, we asked community members for help in identifying unfamiliar species that we had found at sampling sites close to their farm fields. As a result, all species were identified – at minimum – with a Latin or local name, and in most cases both names were recorded. This satisfied the primary aim for identifying plants in this study: documenting species and functional diversity to understand how they relate to SER.

I recorded all field data on a project-specific form (Appendix A-2) at each site. I also used a small notebook to keep track of observations that I made while moving between sampling sites and after talking informally with community members who were harvesting forest resources when I was in the area. Information from all sampling sites was entered into a corresponding Excel spreadsheet and coded accordingly to calculate basic measures of central tendency for different variables and to facilitate visualising and comparing the data through various graphs and charts.

3.4.2 Field equipment

The biophysical surveys required standard field equipment for forest vegetation inventories, including tools for navigating and determining precise locations of sampling sites. We used a set of standard forestry instruments to lay out plots and measure trees within them. I delineated the quadrats and nested plots with a 50 m measuring tape, temporarily marking each plot interval with flagging tape. To measure the heights and diameters of trees, I used a Suunto PM-5/1520 clinometer and pair of Haglof Mantax Blue tree callipers, respectively. A Garmin eTrex 20x GPS unit was used to navigate to and between sites.

3.4.3 Limitations

I adopted methods that were simple and could be conducted efficiently but, as a result, my dataset is not as thorough as it could have been with techniques requiring additional time and resources. My strategy aligns with Nahonyo et al.'s (2002, p. 30) recommended approach for "rapid assessment" in the complex, high-diversity ecosystems in the JCBNP region, using indicators and capturing major characteristics of forest ecosystem patches. For example, I recorded disturbances, by type, in terms of their presence or absence at study sites. In large part I was not able to gauge their intensity or entire spatial extent; but naturally this information would be useful in a more comprehensive study to understand the relative effects of and responses to different disturbance types across the landscape over time. The resulting quantitative data therefore forms a preliminary overview of major system characteristics.

In reaching 46 of 48 predetermined locations, the representativeness of the sample declined. Extremely dense, thorny vegetation and heavily-creviced coral substrate prevented us from reaching two of the sampling sites in Kitogani, so I chose to sample at the closest representative areas instead (70 and 250 m from the original points, respectively) to maintain the same sample size. I decided to retain values from these two sites with the dataset, however, because they were within the same LULC category areas as the target locations and had similar qualitative features in terms of their structure and canopy cover. (From nearby high points, I was able to get a line of sight these unreachable locations, allowing me to roughly gauge similarities with the alternate sites.) By removing this data from subsequent calculations, I did not notice any significant deviations in the results; with only 24 sample sites, keeping the data seemed a more valuable way to capture and represent trends across the landscape in Kitogani *shehia.*

Ideally, I would have had additional time and funds to complete these surveys, permitting me to sample at more points and within more different land use zones (a larger proportion of total the land area) within each community. Visiting more sites would have helped to increase representativeness in the sample, especially because the ecosystems encountered during survey work featured less mature vegetation (and also less biomass accumulation) than expected. I had planned surveys – and calibrated the calculations for estimating the number of sample plots – using data on biomass and LULC types produced only a few years earlier in the ZWBS, supplementing this information with field reconnaissance observations. I realised, however, that during those visits I had been taken to see the most mature and lush forest areas, rather than the ones representing characteristics more common to many landscape patches in the low-impact use zones. During subsequent

field surveys, many sites had been recently disturbed and were in the process of regenerating; I encountered, for example, many wood harvesting sites and few mature trees.

For this reason, my sampling methods should have been adapted to better capture trends in low forest and shrubland ecosystems. For instance, I could have examined trees and woody shrubs with *dbh* <5 cm in greater detail than the (count-based) seedling/sapling category permitted. Had I been able to extend my sampling to more sites, it would have been particularly interesting to compare sites in high protection and low-impact use zones, and to measure more ecological variables. In coral rag zones limited by shallow soils, for example, I could have incorporated indicators for longer-term processes likely to affect vegetative growth, such as nutrient cycling or soil development. By focusing on the products of those processes – i.e. current floral communities – I collected a narrower set of data than could have been obtained with more resources and a longer research timeframe.

4. Results

4.1 Forest ecosystems

Based on survey evidence, a variety of qualitatively different terrestrial ecosystems exist within these two communities' low-impact land use zones. According to the ZWBS LULC classification scheme (RGZ, 2013e), both Kitogani and Muyuni A featured different coral rag forest types in addition to other land cover classes (Fig. 6). These proportions do not necessarily represent the total relative extents of different land cover types in each *shehia*, but they illustrate the conditions encountered during surveys.

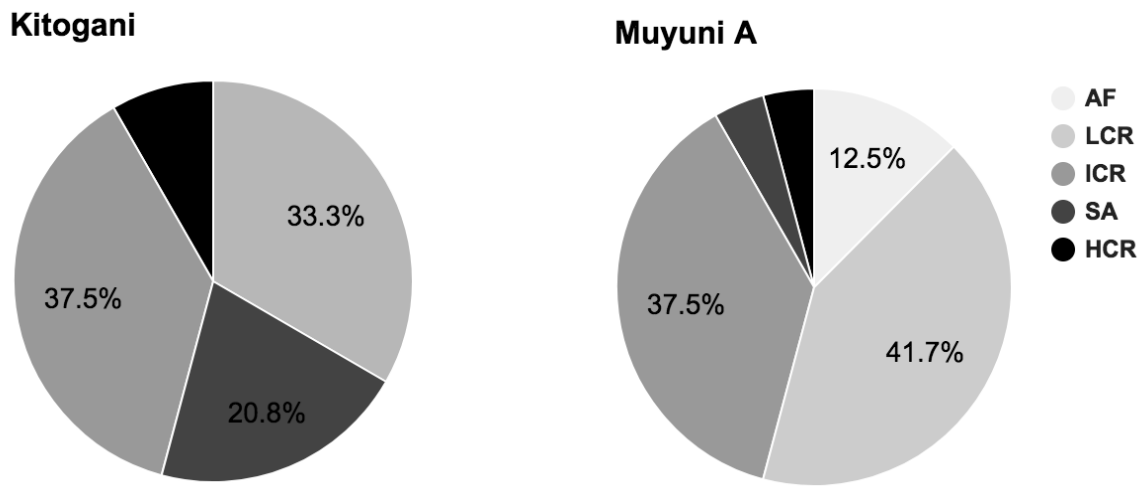

Figure 6. LULC classifications for sampled sites in Kitogani and Muyuni A. L/I/HCR=low/ intermediate/high coral rag forest (LULC 1.1-1.3), SA=small-scale agriculture (6.2), AF=agroforest (5.3).[24]

Across the 4 m^2 mixed vegetation quadrats at the 48 sample sites, we recorded 1129 individual plants (herbs, shrubs, trees, climbers) in Kitogani and 1252 in Muyuni A. In the nested tree quadrats (i.e. 5 × 5 m, 8 × 8 m, 10 × 10 m plots) ten trees were documented in Kitogani and 7 were found in Muyuni A. Information collected about these individuals provides the basis for examining the ecology of vegetative communities in greater detail.

4.1.1 Species diversity and community composition

During forest surveys, we identified a total of 82 plant species in the two communities between the nested tree quadrats and mixed vegetation quadrats (Appendix A-3). Thirty-two species (39%) grew in both *shehia*, but the remaining species were recorded in sample plots within only one community (Table 1). Shannon-Weiner index scores incorporate both richness and evenness parameters, but the magnitude of the contributions from each is evident through the species count and Simpson's index of diversity for each community. Muyuni A had the greatest species richness, with 65 species, but slightly lesser species evenness than Kitogani. Forest ecosystems in Muyuni A are the more biodiverse of the two communities – albeit by a relatively small margin. Overall, high *H'* values show that both communities exhibit moderately high biodiversity.

Table 1. Species diversity values for plant communities in Kitogani and Muyuni A.

Parameters:	**Kitogani**	**Muyuni A**
Total species (i.e. species richness)	50	65
Species (unique to *shehia*)	18	33
1-*D* (Simpson's index of diversity)	0.90	0.89
***H'* (Shannon-Weiner index)**	2.89	2.91

[24] "Agroforest" areas have over 30% canopy cover and comprise various tree species grown with other crop types (equivalent to ZWBS' 'mixture of trees and agricultural crops'). "Small-scale agriculture" describes low canopy cover (<30%) areas with small-scale crop production on plots less than 2.5 ha in size. The latter definition is equivalent to that of the ZWBS category "subsistence agriculture" but more accurately captures the type of farming I encountered in the field. Coral rag forest class definitions are summarised on p. 73.

Both study locations featured many light-demanding, stress-tolerant ruderal species. In Kitogani, species comprising the greatest proportions of identified plants included the grass *ndago* (*Mariscus dubius*) (23%), the shrub *mlapaa* (*P. parvifolia*) (16%), the shrubs *msiliza* (*E. natalensis*) (7%) and *mfungajama* (7%), the tree *mkonge* (*Psychotria bibracteatum*) (5%), and the shrub *mdaa* (*E. racemosa*) (5%). In Muyuni A, the most frequently encountered species included *M. dubius* (28%), *P. parvifolia* (9%), the grass *nyasi* (7%), the herb *Indigofera* sp. (7%), the grass *ukoka* (*Panicum trichocladum*) (6%), and *mfungajama* (5%). These common species were most often encountered in canopy gaps, in shrublands, or in vegetation clusters on coral barrens – as opposed to closed-canopy forests.

Several species we documented, however, were relatively rare within plant communities: the population sizes for 37 species (74% of the total number) in Kitogani each comprised ≤ 1% of the total number of recorded plants, while 52 species (80%) in Muyuni A comprised ≤ 1% of all the individuals identified there. For nine species in Kitogani, only a single individual was documented; in Muyuni A, single-individual identifications accounted for 14 species.

4.1.2 Forest structure

Each *shehia* also featured different proportions of plant growth forms, evidencing differences in community composition and structure. In Kitogani, growth forms were more evenly distributed among herbs, shrubs, and trees (Fig. 7). But there we only identified a single climber: *Cassytha filiformis*, a parasitic vine found in both study areas. In Muyuni A, shrub species were the most abundant growth form, followed by trees, herbs, and four climber species.

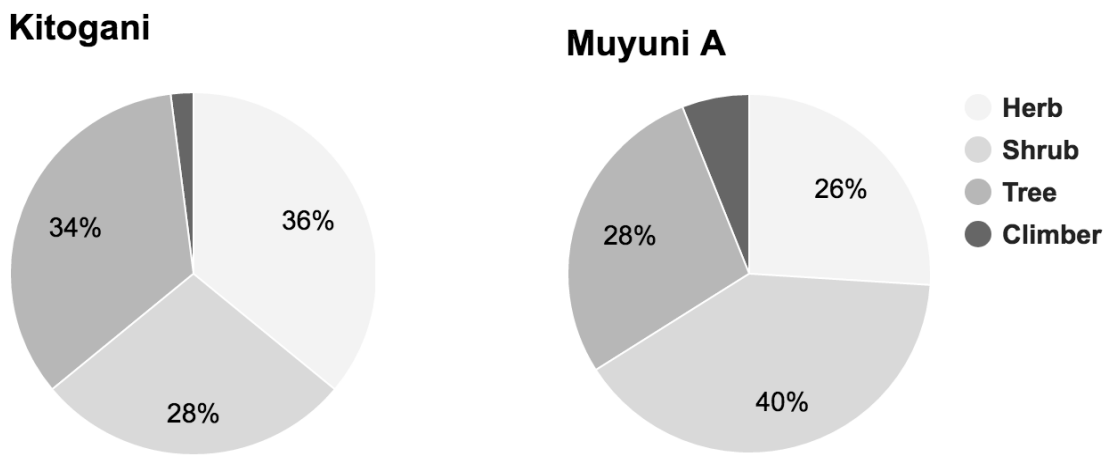

Figure 7. Percentage composition of plant communities by growth-form type between the two *shehia*. Climbers represent 2% of individuals in Kitogani and 6% in Muyuni A.

Though about a third of individual plants represented tree species, very few mature trees (with *dbh* ≥ 5 cm) existed within the concentric sample quadrats. We encountered only 10 of these individuals in Kitogani and seven in Muyuni A, limiting the size of the dataset. In Kitogani, small tree diameters were common (with the largest diameter specimen being a stout cycad). Trees were short to moderately tall (Fig. 8). Muyuni A featured more moderately tall trees, with diameters being positively skewed. The logarithmic relationships between tree diameters and corresponding tree heights in both communities (Fig. 9), therefore, were primarily supported by an abundance of relatively short, small diameter trees that characterised the sample. Trees in Kitogani, for the same *dbh* values, appear to attain their height more rapidly than they do in Muyuni A. These relationships, however, span multiple species that may build cambium at different rates. Having encountered few individuals and lacking reference allometric information for most of these species, though, the data can only point to general growth patterns within these plant communities.

This small number of tree measurements translated into low basal area (BA) and stand density values. Both communities have very low BA values – 1.71 m^2/ha in Kitogani and 1.41 m^2/ha in Muyuni A – revealing low contributions from trees toward area occupied by standing wood at breast height. Tree stand densities (i.e. stocking rates) were also low at 156 stems ha^{-1} in Kitogani and 127 stems ha^{-1} in Muyuni A. Though trees and shrubs with *dbh* < 5 cm also contribute some wood volume and stems toward BA and density, respectively, they were not specifically measured because they were below the size thresholds set for this study.

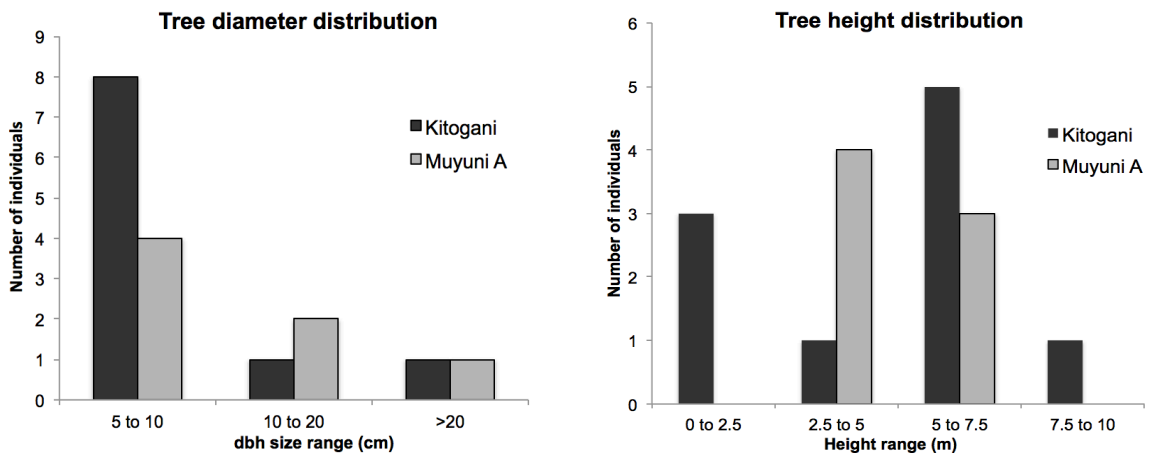

Figure 8. Diameter and height distributions for trees in Kitogani and Muyuni.

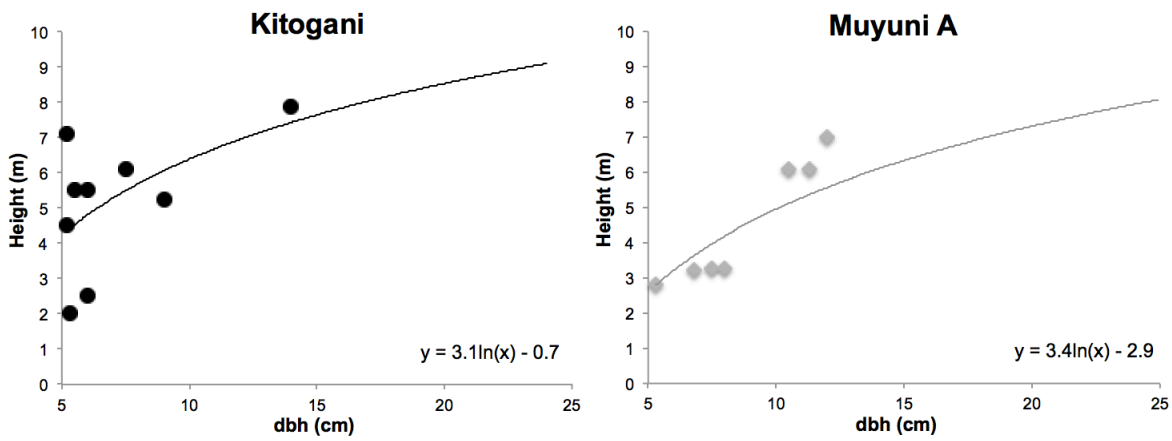

Figure 9. Tree height and diameter relationships in Kitogani and Muyuni A. Note: an individual cycad (dbh=29.2, h=1.46) encountered in Kitogani, as an extreme outlier, has been removed from the graph (but is included in Figure 8).

4.1.3 Fauna

Though we frequently saw insects and ants during field surveys, we recorded few birds and mammals. In Kitogani, we observed a lizard and a grazing cow in a shrubland site, while two forest sites had fresh duiker droppings from earlier the same day. Twenty-one sites featured ants, 13 had other insects, and nine had birds. In Muyuni A, 21 sites had ants and 15 had other insects. Birds were sighted from 6 sites and we did not see any mammals. This paucity of megafauna between the study communities is not surprising; surveys were mostly conducted between 8:30 and 15:30, when ambient temperatures were highest and community members were in forest areas to tend to fields, collect wood, or graze livestock. Interview data, therefore, provided extra information about common animals in both communities. Respondents said they had seen monkeys and some bird species in addition to various insects. Duikers were seen infrequently. Most respondents believed that mobile wildlife populations had moved to other areas (e.g. forest reserves) in recent years.

4.2 Forest livelihoods and ecosystem services

4.2.1 Community and other participant demographics

In both communities, interview respondents included women and men who had lived there for varying lengths of time and used different livelihood strategies. Among the community members and leaders who participated in Muyuni A, eight were male and 18 were female. Respondents had lived in the area for an average of 24.2 years, with residence times ranging from three to 52 years. In Kitogani, nine respondents were female and nine were male among the group of community and members and leaders. Participants had lived

there relatively longer: from 12 to 50 years, averaging 28.8 years. The majority of participants had first-hand experience harvesting forest resources. Some people who were not actively engaged in harvesting, however, still used products from forest areas in their daily lives and had well-informed perspectives about forest environments and activities in their communities.

4.2.2 Livelihoods

Many respondents in both communities used resources from terrestrial forest areas to support their livelihoods (Fig. 10). Ninety-five per cent of respondents in Muyuni A were engaged in some harvesting activities, compared to 61% in Kitogani. Male and female respondents participated in nearly equal numbers in these activities within each community.

Shifting cultivation was the most common primary occupation that respondents had on forested land; this activity was the main income source for 55% of respondents in Muyuni A and 46% in Kitogani. Seaweed farming was another main income source for four female respondents in Muyuni A, where they also harvested sticks from the forest to anchor rows of seaweed. The remaining primary income sources in this community included woodcutting and a few non-forest related occupations. In Kitogani, four respondents worked for various government branches, often supplementing this income with irrigated or shifting cultivation within low-impact and agricultural land use areas.

In both communities, all respondents had alternative income sources beyond their main occupations, representing a diverse spectrum of strategies in each community. In Muyuni A, the most common of these activities was woodcutting – for building poles, seaweed farming sticks, firewood, and to make charcoal. Both men and women there farmed seaweed for secondary income. Respondents also discussed several other supplementary income sources, although only some of these strategies involved forest areas or resources. The community hosts regular eco-tours, but no respondents said they were employed in these ecotourism activities. In Kitogani, both shifting cultivation and small businesses were the most common secondary income types. Pot making, stove making, and jobs in the tourism industry (hotels) were also novel activities in this community, which had more non-forest strategies for generating alternative income. Irrigated agriculture – specifically for growing vegetables like peppers and tomatoes – was not commonly practiced, but several participants expressed a desire to try it. Interestingly, despite the positive opinions that many respondents

expressed about beekeeping as a sustainable forest-based livelihood[25], only one respondent in Kitogani was a part-time beekeeper. Looking ahead, community leaders were optimistic about future income-generating opportunities from the Pange Juu Cave, but they did not indicate how many community members would be involved in running operations there.

Perhaps because of the relatively wider range of non-forest livelihood strategies in Kitogani, fewer community members reported selling forest products or using them at home. Sixty-one per cent of respondents used forest products at home and 38% sold them, compared to 85% and 60%, respectively, in Muyuni A. Both communities, however, reported firewood as being the most useful product for these two purposes, followed by crops and charcoal. In Muyuni A, one person did not use any forest resources at all, while five respondents reported the same situation in Kitogani.

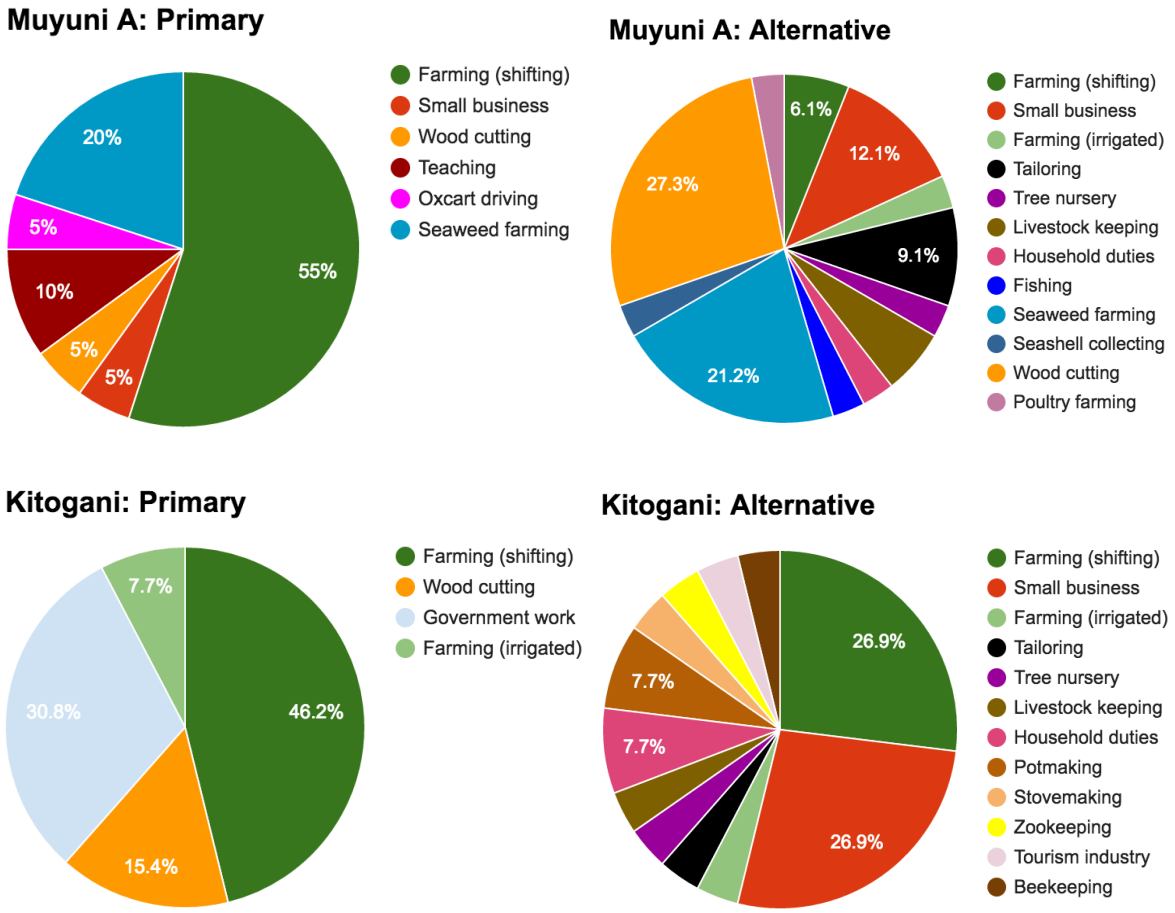

Figure 10. Summary of primary and alternative livelihood strategies identified during community member interviews in Muyuni A (N=20) and Kitogani (N=13).

[25] Bees are used in Kitogani not only to provide honey (for home use and sale) but to protect the forest; hives are kept in high protection areas to defend against people entering illegally.

4.2.3 Temporal and spatial patterns in forest resource harvesting

Community members in Muyuni A and Kitogani discussed how they change their activities daily, weekly, and/or seasonally to take advantage of good environmental conditions, get products to market at the best time, take care of regular household tasks, or schedule other activities around formal employment.

In Muyuni A, several community members split their time in daily rotations between marine and terrestrial environments. In most cases, respondents alternated seaweed farming with collecting sticks and firewood and doing other land-based activities. In this way, the tides created a daily cycle: during low tide, seaweed could be tended and harvested, while high tide proved a better time to work in the forest. These cycles nest within monthly tidal cycles, too, based on the fortnightly timing of spring and neap tides. One fisherman also explained that fish were more plentiful in the dry seasons, when no farming was taking place; in this way, he tailored his activities to seasonal environmental changes.

Respondents in both communities explained that seasonal wet and dry periods most strongly influence forest-based activities, particularly relating to shifting cultivation, agroforestry, and woodcutting – and their off-season alternatives. During the two dry seasons, permit holders cut forest areas to clear land for shifting cultivation. Farmers usually cultivate each plot for 2-3 years before leaving it to re-vegetate and moving on to a new area. Wet and dry seasons also influence activities among the few farmers with irrigated crops, affecting the varieties they choose to grow and the maintenance activities they undertake (e.g. focus is on weeding during rainy seasons). Apart from initial preparation of an irrigated plot, additional forest cutting is not necessary.

Over shorter periods of time throughout the year, members of both communities would gather different products from the forest before celebrating important festivals and holidays. One respondent explained that before Eid, weddings, and other ceremonies it can be hard to get enough money together using just what is available on the farm, so people sell forest resources to make extra cash. People sometimes come all the way from Makunduchi (southeast Unguja) to cut trees for the annual Mwaka Kogwa festival in July.

Young respondents with less work experience had more irregular patterns for strategically switching their incomes over time. These community members often reported taking on work opportunistically and trying new things as a way to make extra cash. When

harvesting forest resources – such as firewood – these respondents often aimed to make money from selling the products, as opposed to putting them toward domestic uses.

Overall, forest resource harvest in Muyuni A and Kitogani appears to be most heavily concentrated during the dry seasons. Most importantly, these periods are when people convert land for shifting cultivation and collect firewood opportunistically. Community members seek permits from their respective SCCs to undertake harvests; for some activities, such as firewood cutting, harvesters can collect a quota amount per year within the permit system. These permits specify the exact area in which they are valid. Misinterpreting the activity specified by permits, respondents said, would be difficult because the SCC shows where and how a harvest should be undertaken. Committee members also visit harvesting areas to ensure that quantities are within legal limits. In general, respondents felt that most people followed this system in both communities.

However, respondents in both communities expressed concern that some illegal woodcutting was done during the long rains – in spite of the risks from tree-falls at that time – when offenders were less likely to be caught by patrol parties. Respondents stated that offenders consciously violated the rules, disobeying allowable harvesting practices inside land use zones. Outsiders, often from Zanzibar Town or other communities, were usually at fault, but the extent and magnitude of the harvesting done illegally was unclear. A few respondents in Kitogani also expressed concern that young men from that community were overharvesting resources and would probably continue to do so without support to pursue other income-generating opportunities.

Community members agreed on the consequences of illegal and over-harvesting: many forest resources were farther away from settlement areas than they were in the past, requiring that people walk or cycle longer distances to harvest the resources they wanted. Respondents in Muyuni A said their travel distance has increased substantially within the past 10 years. In Kitogani, respondents remarked that the diameter of firewood logs had decreased close to settlements; larger wood had to be cut much farther away. A few respondents said they had illegally harvested wood (e.g. from high protection areas) and did so to obtain higher quality, larger diameter stems closer to settlements or roads.

4.2.4 Perceptions of forest ecosystems

In undertaking a wide range of activities in forest areas, community members in both Muyuni A and Kitogani perceive these environments – and their associated benefits – in diverse ways. During interviews, individuals often delineated “forest” from “non-forest”

areas based on the services they provided and the qualitative features they had. Perceptions varied between people engaged in different occupations and also within these groups. Some farmers, for example, talked about forests as places with rich soils that would improve crop productivity after land clearing; in contrast, some community leaders discussed them as places with high, full canopy cover (often referring specifically to high protection zones). During my forest surveys, I encountered community members who said I was going to a place where no forest existed, but other community members later referred to that same area as being a forest. This scenario took place in both communities, and often these contested areas featured patchy, mixed-height thickets or shrub-dominated vegetation. Though respondents did not possess a unanimous definition for what, specifically, qualified as forest, they agreed that these areas provide a wide range of materials and services to communities.

4.2.5 Ecosystem services and forest benefits

In describing the benefits of their local forests, community members spent the most time talking about products they could collect to either sell or use at home, but they also discussed broader and less tangible ecosystem services. As Table 2 indicates, respondents in Muyuni A and Kitogani attribute a wide range of benefits to forest environments.

A key stakeholder poignantly remarked that forest ecosystems provided so many everyday materials that they were "like an ATM" for community members, forming the basis for livelihoods and fulfilling essential needs, such as for food and shelter. Firewood was the most commonly discussed provisioning resource; it was being used within both communities and also sold to buyers in Zanzibar Town. Though they did not necessarily harvest these products themselves, the majority of participants in both communities reported honey, meat, medicines, fruits, and building material as important forest products. Irrigation and drinking water also came from forest caves, but had to be extracted from there by hand. (Pange Juu Cave, however, has a new pump system providing piped water to the near vicinity.) Respondents also explained that land for farming was key forest resource because it permits shifting cultivation cycles. They therefore consider this forest benefit from a more long-term perspective, seeing land as switching between farmed plots and forest cover over time. Respondents in both communities also mentioned trial carbon payments from CARE though the HIMA project as a direct monetary benefit (of high protection areas, in particular). They were uncertain, however, about if and how the carbon crediting system would compensate them in the future. Overall, there were no significant differences in the provisioning services

that community members in Muyuni A and Kitogani recognized to be important; many respondents listed a range of benefits throughout the course of their interviews.

Respondents also discussed several regulating and supporting services, linking these benefits to successful livelihood strategies and improved quality of life in the communities. Many respondents, for example, pointed out that forests could regulate local climate, bringing moisture through transpiration and slowing the speed of winds coming off the ocean. Particularly in Kitogani, community members reported benefitting from water conservation and purification services for local supplies of drinking and irrigation water. In both communities, respondents also acknowledged the high biodiversity of the forest areas, describing several medicinal and rare species. More diverse forests also regenerated more rapidly following disturbances, and they helped adjacent areas to regenerate via species dispersion. Respondents also briefly mentioned pollination and nutrient cycling as supporting services. However, they did not discuss them in further detail beyond indicating that both processes were important to ensuring good crop yields.

Forests also had several cultural benefits. Men, in particular, explained that they enjoyed hunting – particularly for duiker, bush pig, and various birds – even though the permit process restricted this activity. Respondents of both genders agreed that the forest was a beautiful to look at, although few people said they would go there with leisure as their only purpose. Some forest areas were considered sacred but, perhaps because this information was sensitive, no one explained what made these areas special or what visitors did while there. Both communities identified caves as being a unique opportunities for recreation within their forests. Respondents said they were fun to explore and, in Muyuni A they had attracted tourists, bringing income to local economies through fees to guides and other people who helped support tour activities. Kitogani also hoped to welcome tourists to Pange Juu Cave in the future.

Table 2: Summary of ecosystem services identified by respondents during semi-structured interviews in Kitogani (◆) and Muyuni A (❖). The four categories are based on those described by the Millennium Ecosystem Assessment (2005).

Provisioning	-Wood (fuel, charcoal, building and construction poles, seaweed farming sticks [❖ only]) ◆❖ -Other plant-based building materials (e.g. thatch) ❖ -Water (irrigation, drinking) – especially from caves ❖◆ -Meat (bush pig, duiker, monkey) ❖◆ -Food (fruits, herbs) ❖◆ -Medicines ❖◆

	-Honey ❖◆ -Livestock fodder ❖◆ -Lime (for construction) ❖◆ -Carbon forestry income (HIMA) ❖◆ -Areas for farming (in shifting cultivation cycles) ❖◆
Regulating	-Conserving water supply ◆ -Maintaining biodiversity (including medicinal and rare species) ❖◆ -Local climate regulation: brings rain, increases humidity, cools air temperatures ❖◆ -Trees release oxygen, remove carbon dioxide from air ❖◆ -Carbon sequestration ❖◆ -Wind buffering ❖◆ -Protect against soil erosion ❖◆ -Purifying water ◆ -Maintaining crop pest populations through natural predation ❖◆
Supporting	-Pollination by bees ❖ -Nutrient cycling to create fertile agricultural soils ❖◆
Cultural	-Recreation (hunting, exploring caves) ❖◆ -Sacred forest areas ❖◆ -Leisure time ❖ -Aesthetically pleasing environment ❖◆ -Wildlife viewing ❖◆

4.3 Ecosystem change and disturbance

4.3.1 Perceptions of change in forest SES

Respondents largely agreed that forest environments were changing over time and saw these changes as being predominantly negative. All respondents in Muyuni A stated that the forest was changing; 90% of people said these changes were negative, while the remaining 10% reported both positive and negative changes. In Kitogani, all but one respondent said the forest was changing; 66% said changes were negative, while 17% said changes were either positive or both positive and negative. In both communities, positive changes were only occurring in high protection areas, while negative changes occurred in areas where forest harvesting was allowed. Respondents justified their responses by describing different patterns of change within the two SES (Table 3), linking many of these changes to effects of gradual stress and/or disturbance events.

Table 3: General ecological changes identified by interview respondents in Kitogani and Muyuni A.

Muyuni A	-More animals are moving from adjacent forests to other forest areas -More bare land area has replaced previously forested area

	-More gaps in tree cover allow wind to come through, damaging crops
Kitogani	-Forests have fewer species now compared to before (especially true for trees) -More animals have returned to protected areas but are disappearing elsewhere -Inside forest use areas, forests are declining in size and it is becoming harder to find necessary resources -Inside high protection areas, forests are improving: regenerating quickly, more wild animals, reduced fire incidence, high growth rates
Both communities	-Forests in the community are less connected to other forests in the area -Settlement areas are growing at the expense of forest areas -Tree growth rates are becoming more uneven

4.3.2 Disturbances and associated system responses

Forest surveys and community interviews provide complementary evidence for mixed disturbance regimes and landscape-scale changes in Kitogani and Muyuni A. During survey activity, only a single site in Muyuni A showed no obvious signs of recent disturbance; all 47 other sites each showed evidence of impacts from at least one category of disturbance (Fig. 11). These observations strongly corroborate interview responses, and together they indicate the main factors catalysing change and disturbance within these SES.

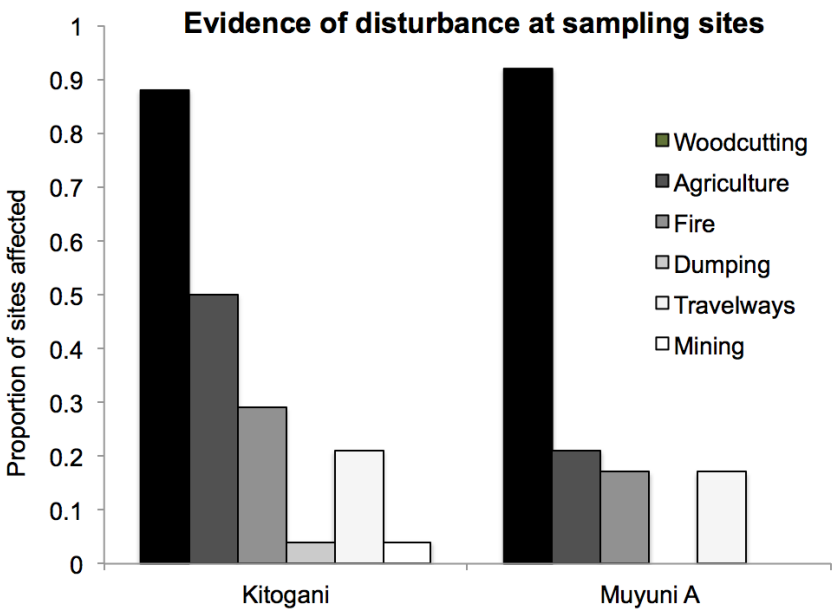

Figure 11. Evidence of different disturbance types encountered at sampling sites in each *shehia*. "Agriculture" refers to evidence of past cultivation; I discuss this disturbance below while addressing the two major activities – land clearing and burning – for clearing farm plots. In this figure, "woodcutting" and "fire" indicate any evidence of these disturbances, regardless of whether they were clearly associated with agricultural activities or not.

Woodcutting and land clearing for agriculture

Respondents in both communities agreed that the primary sources of disturbance in terrestrial forests are land clearing and woodcutting. In their observations, these activities included illegal woodcutting, preparing new land for shifting cultivation, and the cumulative effects of long-term wood harvesting and agriculture (Fig. 12). Collectively, these activities created a combination of one-time and long-term disturbances, reducing forest cover and degrading other forest areas slowly by hampering vegetative regeneration and prompting some animals to relocate to other forest habitats. In Muyuni A, respondents were most concerned about illegal cutting. This activity purportedly accelerated in both *shehia* during election campaigns, when respondents said that politicians helped people to plunder forest resources in exchange for votes. Community members in Kitogani, however, indicated that long-term cutting pressure and land clearing caused greater disturbance to forest ecosystems. Respondents said that harvesting in both communities was mainly taking place within permitted use zones, but illegal harvesters sometimes visited high protection areas to take the wood that was relatively more abundant there. Fishermen from the area also required a steady supply of larger tree trunks to replace worn canoes, an activity taking place every five years.

Figure 12. Bundles of harvested wood along a forest trail in Kitogani (left) and on a cleared patch of agricultural land in Muyuni A (right). Bundles await transport to the nearest road.

As a result of timber removal and forest clearing, people observed that forest environments featured more pioneer species. Recovery and regeneration took place primarily after the two rainy seasons because rainwater helped decompose manure from forest animals, improving forest soil quality. As a result, coppiced plants and seedlings grew and built biomass more quickly. Occasional tree planting in both communities also helped to restore

bare areas by augmenting natural re-vegetation and improving ground cover. SEDCA and the DFNNR have provided (native) plants from local nurseries to replant some of these areas.

Forest survey data corroborates interview responses from both communities: woodcutting was the most common disturbance and affected the wide majority of sampling sites. In Kitogani, 88% of sites featured cut stumps and/or branches, as did 92% of sites in Muyuni A. For old plantation sites and cleared agricultural fields, cutting was more extensive than for firewood collection, which usually involves selective cuts for the largest stems.

Fires

Fires affect the study communities in two ways: as controlled, small-scale fires for land clearing and as uncontrolled wildfires. During forest surveys, we encountered many cases of purposeful burning; charcoal fragments in the soil often accompanied the remnants of charred stumps, indicating that large, valuable stems were cut before burning the woody debris in a single large fire. Participants explained that using fires to clear new cultivation plots added nutrients to the soil, making crops particularly robust in the first growing season. This practice also triggered germination among some (unspecified) plants' seeds. More sites were affected by land-clearing fires in Kitogani (29%) than in Muyuni A (17%).

In both communities, some respondents noted that wildfires were becoming larger and less predictable, especially during dry periods, but these events seemed to be affecting Muyuni A with greater intensity. There, 58% of respondents voiced concerns about these fires (compared to 25% in Kitogani), which they said were caused by hunters, beekeepers, smokers, or farmers burning piles of cleared vegetation. Some respondents said that people were starting fires to increase the amount of dry wood in the forest (because CoFMA regulations allow only dry, dead wood to be removed in some areas). Burning too frequently proved a long-term problem, however, because species that people wanted to harvest for wood often take a long time to re-establish in burned areas.

In Kitogani, respondents spent more time discussing how the community had worked to reduce wildfire incidents, which were no longer common there. A government fire station just east of the settlement area was well positioned to respond to local fires if necessary. It could send fire fighters to oversee controlled burns of woody debris from land clearing (which were often done after rains to reduce the chance of fire spread). Honey collectors had also started using alternatives to open fire to reduce the risk of accidentally igniting forest litter. In both communities, the SCCs could organise community-based fire fighting groups, and the DFNNR could step in to provide them additional support, if necessary.

Travelways: Expanding access to forest areas

Both communities featured an extensive network of trails and motorable dirt tracks branching off from the main roads. During survey activity, we often encountered community members using the same travelways to transport firewood bundles, to access farm fields (by foot, bicycle, or lorry), and – in Muyuni A – to get to the beach for seaweed farming. These observations matched interview respondents' explanations about travelling to harvesting sites, although no one considered trail- or road-building as disturbances during interviews. The connection between travelways and other kinds of disturbance, however, was evident at some sampling sites in particular.

Travelways allowed us almost direct access to many randomly-selected sites, and they coincided with two unique disturbances in Kitogani. There we encountered a coral mine and dumping site, both beside roads maintained for lorry travel. The roads had facilitated removal of heavy coral blocks and also made it easy for a vehicle to dump an assortment of plastic, metal, and cloth waste into a shrubland area. The roads and paths themselves fragmented some of the forested areas we visited, featuring margins of light-demanding pioneer species like *M. dubius* and *P. parvifolia*. Some roads and paths were actively maintained through cutting back vegetation, though we also encountered several travelways that had been abandoned and hosted primary succession.

In general, most of the agricultural and firewood cutting activity we observed was at sites close to roads, where access was likely most convenient for forest users. Satellite imagery for both *shehia* (Fig. 13) illustrates this trend particularly well, showing dendritic networks of travelways reaching many locations where vegetation has been cleared.

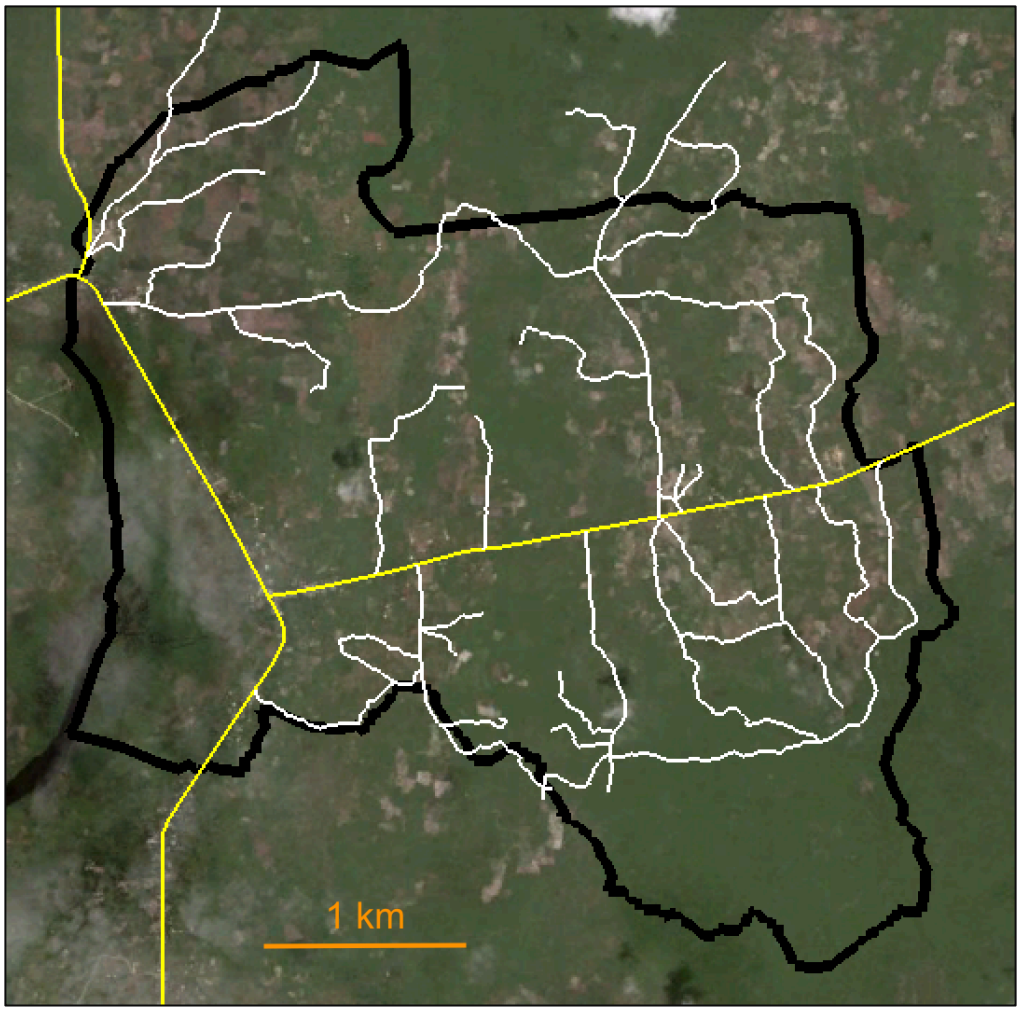

Figure 13a. Sealed roads (yellow) and dirt tracks (white) in Kitogani. Imagery from Google Earth (2016b).

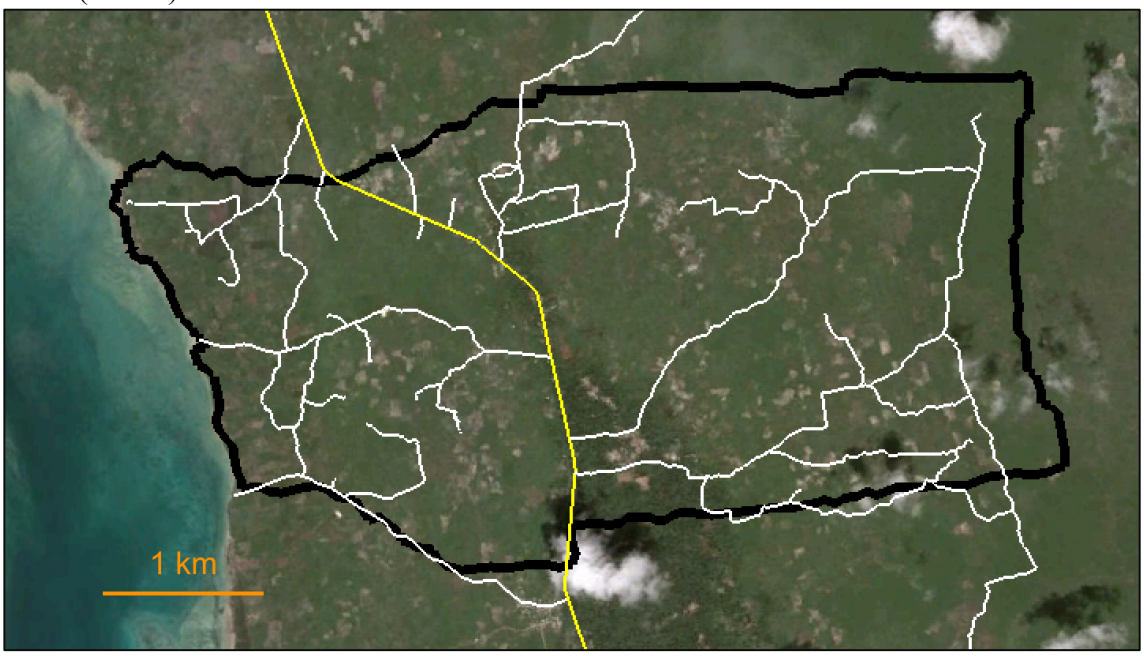

Figure 13b. Sealed roads (yellow) and dirt tracks (white) in Muyuni A. Imagery from Google Earth (2016d).

Other disturbances: Long-term observations of change in forest environments

Community members and leaders also discussed several long-term, gradual disturbances that would have been difficult to detect or measure during the brief forest survey period. These observations included unfamiliar climatic patterns, problems with crop productivity, and conflict-related concerns.

People from both communities explained that temperature and precipitation patterns had varied substantially in recent years. In Muyuni A and Kitogani, people described changes in timing of the rainy seasons, inconsistent and irregular rainfall patterns, and longer dry periods over time. In Kitogani, respondents said that local humidity and precipitation were declining further because of decreased forest cover in the area. In Muyuni A, temperatures had become hotter and *vuli* season often began late. People had observed that, as a result, trees were drying out and losing their leaves, making them more susceptible to wildfires or premature death through disease.

A few respondents in Muyuni A and Kitogani also indicated that crop pests and nutrient depletion were occurring in areas with shifting cultivation. Both communities reported lower soil fertility over time, requiring that more manure be used to supplement soil nutrients. Nutrient depletion reduced the productivity of shifting cultivation, and this problem was compounded by attacks from crop pests. In Kitogani, a respondent explained that forest clearing displaced insects, encouraging them to feed on nearby crops in larger numbers. In Muyuni A, farmers mentioned that fruit trees (especially mangoes) and yams, which were sometimes attacked by snails, were producing lower yields. Some farmers tried to prevent and mitigate these pest outbreaks by applying more insecticides to their crops.

As land uses changed in the community over time, another respondent said that livestock herders and agroforest managers had more disputes, with both groups having competing demands for growing and grazing space. The decline of some forest areas thus proved to be a source of unease and uncertainty.

Unlike with the discrete disturbance events described above, respondents did not explain in detail how the two communities had adapted (or planned to adapt) to more gradual, coarse-scale, and long-term changes. Communities were dealing with many of these issues for the first time or grappling with more rapid paces of change than had been seen in the past.

Remote imagery: Nonlinear forest cover and land use change

Satellite imagery of the two *shehia* indicates that disturbances and other processes (tree planting activities, natural regeneration, etc.) in these SES have catalysed diverse changes in land cover since 2013[26]. While vegetation cover has decreased in some areas, it has increased in others – particularly where old fields have been abandoned and started to re-vegetate (Figs. 14 & 15)[27]. In most cases, land use areas easily reachable by dirt road contain newly cleared farm plots (compare with Fig. 13, above). The settlement area in Muyuni A is a notable exception to this trend; though on the main road, it contains a well-tended, dense, high-canopy agroforest of mature mango and other fruit trees. High protection areas – Kidongoni in (southeast) Kitogani and Jendele in (northeast) Muyuni A – also feature little discernible harvesting or clearing activity in 2013 or 2016. But despite its designation as a high protection zone, the northern half of Kidongoni features many farm plots. Within the land use zones (low-impact, agriculture, settlement, forest/farm), however, these images do not evidence linear changes across the landscape. Instead, they indicate that disturbances and shifting patterns in human activities (mainly related to agriculture) have altered patches within the landscape. Some areas have been fragmented and others reconnected. In both image series, high forests remain relatively isolated from similar forest habitats.

This imagery also illustrates some inter-seasonal variability in forest cover within the CoFMA areas of both Muyuni A and Kitogani. The 2013 images show conditions in September (after the dry season) while in 2016 the images are taken in February, in the period after *vuli*. Vegetation appears particularly desiccated in Kitogani during the dry season. Fields in both communities, however, feature greater plant cover after periods of greater rainfall.

[26] This is the earliest year for which full-coverage, high-resolution images are available for both *shehia*. Google Earth has imagery from as early as 2004, but many images are of poor quality or obscured by clouds.
[27] Note that these images indicate the extent of plant cover but do not reveal the quality or health of vegetation communities. Spectral analyses of remote imagery are required to examine vegetation quality.

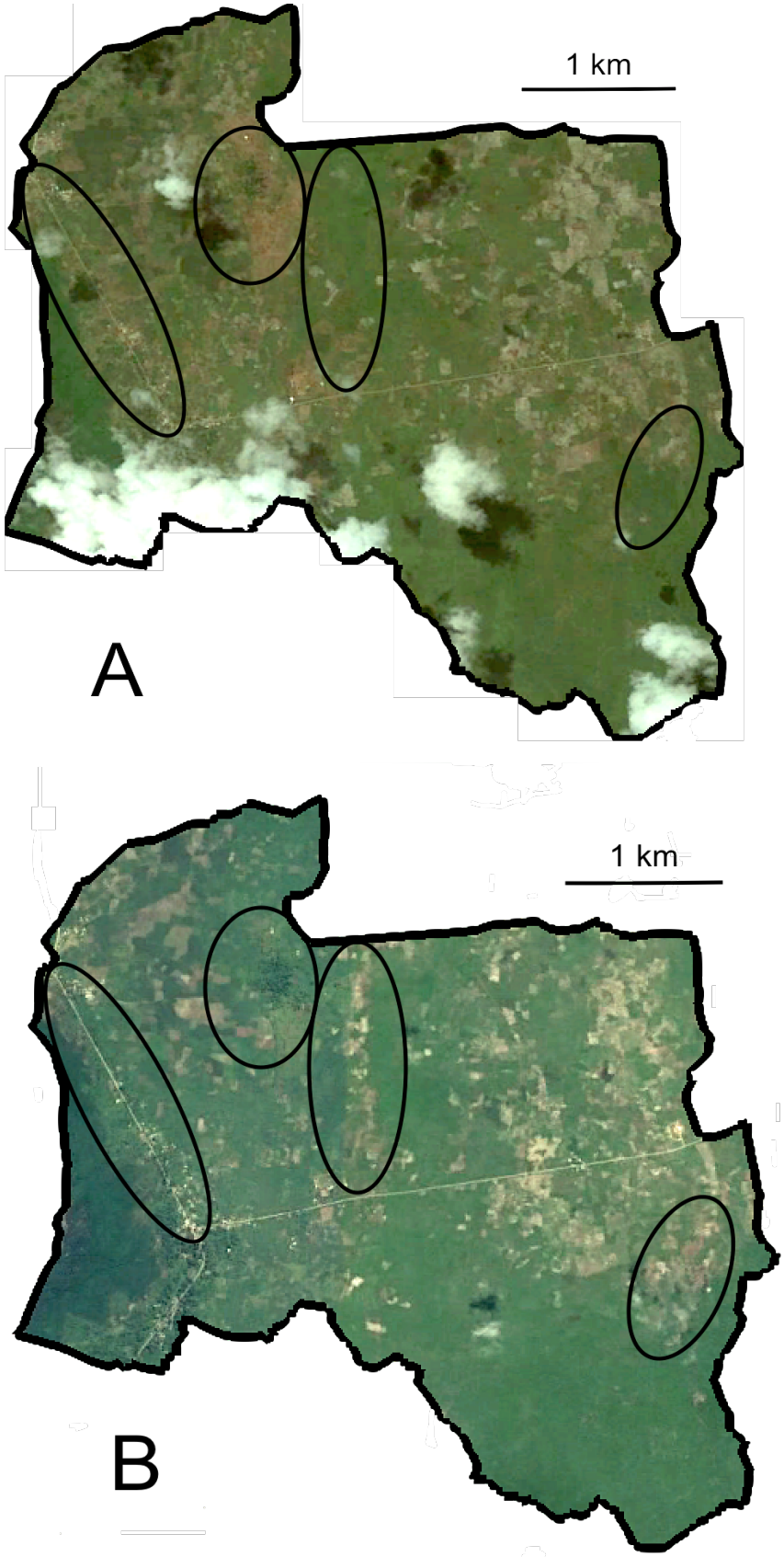

Figure 14. Patches of significant landscape change in Kitogani. Image A dates from 17/9/2013 (GoogleEarth, 2016a) and Image B from 14/2/2016 (GoogleEarth, 2016b).

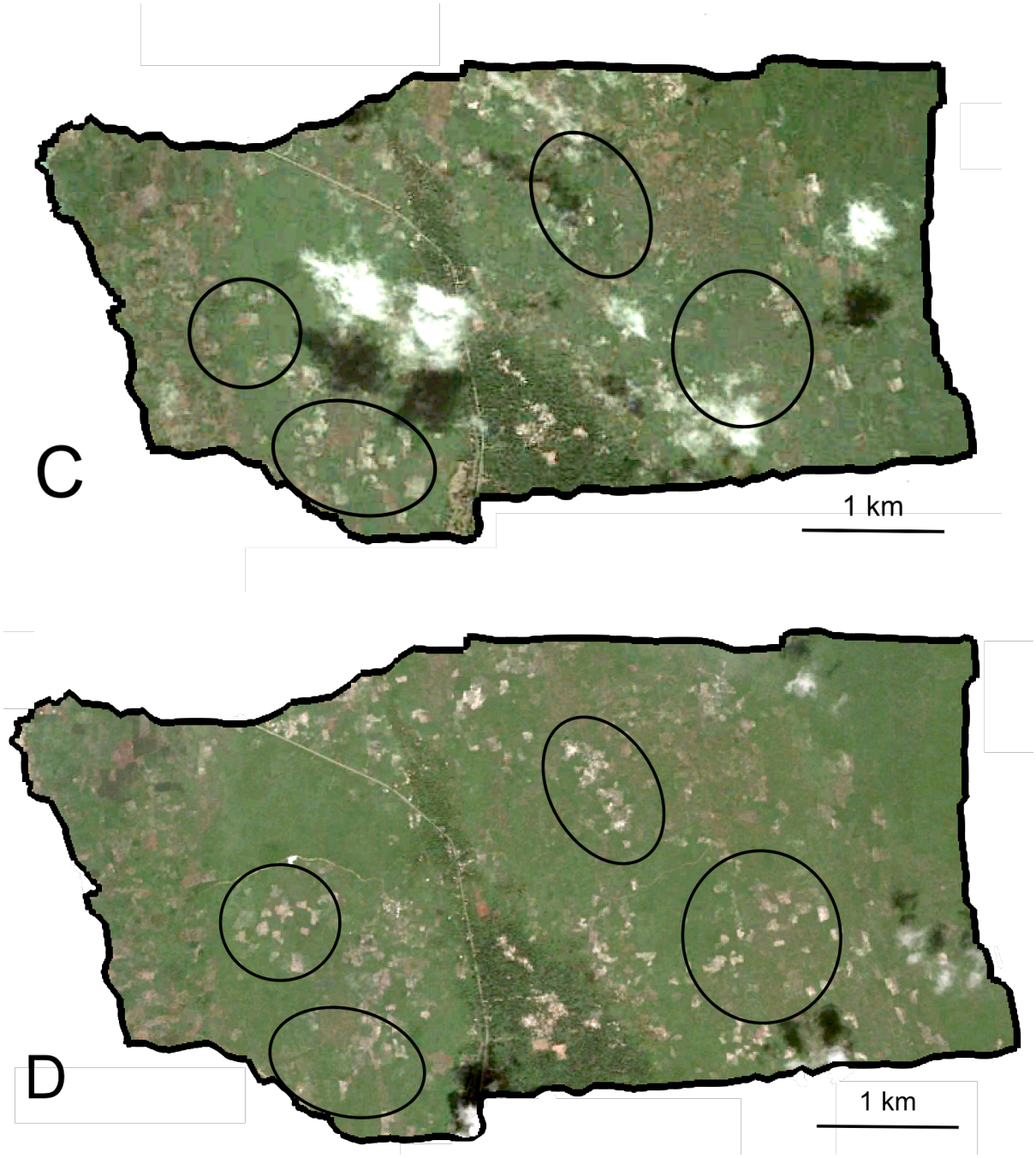

Figure 15. Patches of significant landscape change in Muyuni A. Image C dates from 17/9/2013 (GoogleEarth, 2016c) and Image D from 14/2/2016 (GoogleEarth, 2016d).

4.4 Institutional framework for managing forest SES

4.4.1 CoFMAs and SCCs: The core of local-level governance

The large majority of interview respondents in both *shehia* stressed the importance of the CoFMAs, underscoring how these documents served as a foundation for every aspect of community-based forest management. *Shehia* conservation committees (SCCs) managed related tasks at the local level, including planning, monitoring, reporting, and enforcement. In doing so, they reported to the *sheha* and DFNNR. Just over half of community members were familiar with the contents of each CoFMA, but the majority knew the rules for forest-based activities within the *shehia* (84.6% in Kitogani, 65% in Muyuni A). Despite similar institutional frameworks, the two communities have signed unique CoFMAs that their SCCs have translated into action differently.

The CoFMAs derive from a common template, so they do have several common features. They share their three major objectives: to direct activities that help maintain healthy forest SES, to enhance benefits from ecosystem services, and to transition greater rights and management authority to communities (RGZ, 2013a; RGZ, 2013b). The documents define each LULC zone with both a boundary map and description in addition to detailing historical use of the area, significant changes there over time, and types of permitted and prohibited activities. These zones clearly delineate high protection areas from areas where different land use activities are permitted. The Pange Juu catchment in Kitogani, for example, forms a newly-created high protection area that protects the subterranean water reservoir and encourages wildlife to return to the area (RGZ, 2013a). Forest use rules, therefore, are entirely location-specific, though each document lists a set of fees and fines that universally apply for particular activities (e.g. grazing a herd of livestock, harvesting specific volumes of timber, starting an illegal bushfire) across each *shehia*.

Having been adopted within the context of each community, however, the CoFMAs vary somewhat in the fee structure and scope of SCC duties it presents. Though the aforementioned fees and fines for different forest use activities are mostly identical, some are substantially higher in Kitogani. For example, permission to hunt costs 20,000TZS there versus 2,500TZS in Muyuni A. Kitogani's CoFMA also lists significantly more in-depth responsibilities for its SCC; it extends to managing the CDF, providing education and training about forests, and issuing reports on a regular basis. This document also makes mention of aiming to reduce firewood demand, aligning with community efforts to transition to making and using more efficient cooking stoves. In Muyuni A, the CoFMA's terms may generally be broader but, according to interview respondents, the SCC performs most of the

same duties as in Kitogani anyway. For example, they, too, have provided in-depth training on forest-based activities, even going so far as to provide instruction to individual permit holders in how to harvest forest products using the least destructive methods.

During community and key stakeholder interviews, respondents described a wide scope of activities that SCCs perform, which go beyond the list of day-to-day duties specified by either CoFMA (Table 4). Their main activities in managing forest areas, according to community leaders and members, were awareness-raising, patrolling, and punishing offenders. The comprehensiveness of their roles highlights the importance of SCCs as a primary institution for local forest governance. They retain some flexibility in managing forest resource use, being able to review on-going changes within LULC areas and to adjust the boundaries or regulations if necessary. When I visited Muyuni A during my pre-survey reconnaissance, for example, my guide pointed out an area within the Kipofu low-impact use zone that had recently been closed to harvesting to facilitate re-vegetation. In this way, SCCs can balance conservation and use priorities on an on-going basis, responding to effects of harvesting activities on different forest areas.

Table 4. SCCs' roles toward community forest management in Muyuni A and Kitogani.

Role	**Description of duties**
Planning, monitoring, and reporting	-Update action and management plans for community -Collect and act on reports from SCC committees -Monitor forests through making regular, observation-based inventories -Oversee CDF and use for development work (Kitogani) -Liaise with the DFNNR and send reports accordingly
Access and enforcement	-Issue harvesting permits -Decide on punishments for people doing illegal activities -Determine the fate of confiscated (illegally-obtained) forest products
Mitigating disturbances	-Organise tree planting (often in tandem with DFNNR, SEDCA) -Organise fire fighting efforts -Organise patrols for illegal activities -Put up signs to display rules in different LULC areas
Community engagement and outreach	-Periodically hold community meetings to explain monitoring results and decide on future improvements -Inform communities about conservation efforts, allowable harvesting activities, and rules for different LULC areas

Still, some community leaders pointed out significant challenges they face in carrying out the SCC's mandates. In Muyuni A, these respondents talked about how illegal harvesting continued in spite of efforts to increase patrols. As a result, they worried about not being able to meet forest conservation targets, a central part of the CoFMA's thirty-year management plan. Community leaders in Kitogani had more diverging opinions on management outcomes. Some respondents explained that resource harvesting was degrading low-impact use areas over time faster than the SCC could mitigate the impacts or try to adapt. Other respondents, however, felt that the SCC had protected forest areas effectively using innovative strategies. For example, Kitogani has collaborated with neighbouring *shehia* Muungoni in its patrolling activities in an effort to share resources and cover a wider area. The SCC there had also supported the local football team in exchange for help in apprehending illegal harvesters.

4.4.2 Community members: Participation and perspectives on governance

Community members, through participating in forest harvesting and interacting with the SCC, had unique perspectives on forest governance in each *shehia.* They primarily engaged with the existing management regime through reporting illegal activities, attending meetings hosted by the SCC, making harvests through the permit system, or joining a special-interest committee under the SCC. People also helped to fight fires, participated in tree planting projects, and joined patrols. Respondents in both Kitogani and Muyuni A also said they shared what they knew about the CoFMA rules and encouraged other community members to comply. In doing so, they promoted informal systems for building mutual trust and cooperation around community forest resources.

Based on these experiences, community members had mixed views on forest management in their *shehia*. Most respondents (80% in Muyuni A and 100% in Kitogani) believed that the current CoFMA system was flexible enough to adapt to unanticipated changes or disturbance. Nearly everyone, however, made their statements conditional on the SCC taking certain actions. In Kitogani, over two thirds (69%) of community members said more training on AIGA opportunities – particularly irrigated vegetable farming – was key to reducing demands for forest resources and conserving these ecosystems into the future. They also stressed that the SCC should initiate more tree planting, raise more awareness for conservation, and attract more development funding through NGOs and donors. Some people had stopped attending community meetings to discuss these issues because they were tired of gatherings organised around several similar conservation-oriented initiatives (development projects, research, etc.). In Muyuni A, however, participants saw opportunity for stronger

punitive measures for people harvesting resources illegally; they called for more patrols, harsher fines and punishments, and more fair and transparent enforcement. As in Kitogani, respondents here also thought increasing tree planting, education, and general conservation activities could also make the current management system more effective and adaptive.

4.4.3 NGOs: Builders of local networks and conduits for promoting conservation ideals

Community leaders and members, as well as key stakeholders, said regional NGOs SEDCA and JECA played key roles in forest conservation and community development. Both communities' SCCs were members of SEDCA, which worked to support and share information about forest conservation efforts in member communities. This organisation also helped to resolve conflicts within and between CoFMAs and was working improve familiarity with these documents within Zanzibar's legal system. In Kitogani, JECA gave education on AIGAs and forest conservation, helped with patrolling, and provided paperwork for the permit system. Other small NGOs also helped some community members to explore alternative livelihood opportunities outside of forest areas.

Past work by NGO CARE International also influenced local perspectives on forest use and conservation, especially related to carbon cycling. Several community members in both Kitogani and Muyuni A explained that a major benefit of forest areas was carbon storage. They had learned about this process from the HIMA project and some people believed that conserving forests would make communities eligible for more carbon payments in the future. In Muyuni A, spates of illegal harvesting concerned some community members, who believed they would be ineligible to receive money for the work they had done to protect their forests. The strong focus on AIGAs among Kitogani's community members and leaders seemed to also stem partly from HIMA. The project supported an improved cookstove industry, which continues there today. Most community members, however, said that they currently lack suitable livelihood alternatives, making it difficult to stop harvesting forest areas or clearing new plots for shifting cultivation. One key stakeholder agreed that sustaining momentum from HIMA was a challenge without further support for developing AIGAs. The group of farmers using drip irrigation in Kitogani said they hoped to receive some donor support for purchasing more equipment, enabling them to share their knowledge with the community and transition more farms to permanent irrigated plots.

The HIMA project's focus on carbon storage and accounting is also reflected in the CoFMAs themselves. Signed (during the project) in 2013, both documents plan for monitoring forest carbon stocks and tracking benefits over their thirty-year timeframes.

4.4.4 The DFNNR: Support and advice

The DFNNR had responsibility for managing long-term activities related to HIMA as a part of its role in providing wider management oversight and support to each community. During interviews, community leaders stated that they could turn to the DFNNR for help on matters that are difficult to resolve at the local level, such as fighting large brushfires. The DFNNR provided communities an advising role for cases involving poaching or illegal harvesting, which ultimately came under jurisdiction of Zanzibar's legal system. The representative for the DFNNR in southern Unguja was the district forest officer (DFO) at Unguja Ukuu, though serious matters passed directly to the agency's central office in Maruhubi.

5. Discussion

Forest SES in these two *shehia* represent highly heterogeneous and dynamic mosaics of forest ecosystems and various human activities taking place across the landscape. Coral rag forests have sustained coastal livelihoods and ecosystem services for many generations and continue to provide materials and intangible benefits that people value in everyday life. For forests to demonstrate resilient qualities in this context, SES should be able to reorganise and adapt to human-caused and natural disturbances, retaining their essential characteristics and feedbacks in spite of on-going change (Berkes et al., 2003; Folke, 2006). Indeed, these systems exhibit several processes and feedback loops that help to sustain valued ecosystem services. Under the CoFMA system, a multi-layered institutional framework distributes management responsibilities across different system scales. But the cumulative effects of various stresses and disturbances in Kitogani and Muyuni A have hindered these systems' abilities to sustain certain internal processes and to regenerate effectively over inter-annual time scales. Some regeneration mechanisms have been rendered less effective because periods between different disturbances do not allow them to regenerate completely. This is because, at the community level, impacts from local-scale land use activities reflect and intersect with broader drivers of change, such as poverty. Wood harvesting and land clearing activities, and their effects, serve as a nexus of cross-scale interactions among multiple system elements and scales. Environmental, socio-economic, and political factors drive important trends in coral rag forests in both Kitogani and Muyuni A and influence resilience there.

5.1 Environmental conditions and drivers: Ecosystems' responses to change

5.1.1 Disturbances and diversity

Forest ecosystems in both communities are diverse in their structure, species composition, and function, and some of this complexity relates to the effects of disturbances upon the landscape. Shifting and multi-scalar patterns of land clearing, burning, and resource harvesting influence landscapes on a continuous basis, demonstrating the spatial and temporal heterogeneity that Holling (1973) indicates exists within many natural ecosystems. Disturbances from human activities and natural variation create patches representing different conditions, characteristics, and successional stages. This observation mirrors that of Käyhkö et al. (2011), who indicate that central Unguja's coral rag forests "are not stable in situ but change back and forth from open cultivated to semi-open and closed forest cover" (p. 32). These ecosystems, in other words, do not conform to the traditional notions of *stasis* and *equilibrium* in ecology. Instead, they affirm Turner et al.'s (2003) assertion that "Mixed habitat patches and zones where different successional stages abut one another can be areas of unique ecological diversity and interchange" (p. 456). Indeed, sites with the most evidence of disturbance were the most biodiverse, particularly in Muyuni A. This result is counter to Haji's (2013) findings, which show diversity decreasing toward the disturbed edges of KPFR. But in this study, diversity was high in canopy gaps left by woodcutting or along travelways, where light-seeking plants dominate the understory adjacent to communities of shade-tolerant species, which have adapted to the closed canopies of more mature forest growth. Several light indicator species – e.g. *Mallotus oppositifolia*, *P. trichocladum*, and *Phymatodes* spp. ferns – that Nahonyo et al. (2002) describe in their surveys at Jozani also exist under similar conditions in Muyuni A and Kitogani. In this study, disturbance events appear to have opened various niches, permitting colonisation by different categories of species.

Human activities – including resource harvesting, agriculture, and other purposeful ecosystem modifications – are the dominant source of disturbances to forests in Muyuni A and Kitogani. Woody biomass removal causes the most extensive impacts, affecting forests through clearing plots for farming, coppicing stems and branches of woody species, and maintaining access paths. Illegal cutting outside of permit regulations is particularly destructive because harvesters often aim to remove the most mature, large stems. Fires, used in clearing land for shifting cultivation, are also relatively common in the two communities, usually involving controlled burning within small plots. Both disturbance types have dual impacts: they remove forest biomass but – at low to moderate intensity – stimulate new growth (e.g. through germination from the seed bank after fires or compensatory growth after

coppicing) and regeneration among plant populations. Plant growth form types, characteristics, and functions relate to the ways that vegetation communities and their constituent populations respond to disturbance events in these SES.

5.1.2 Redundancy and connectivity

Diversity and redundancy within these forest communities enables them to regenerate by helping "some system elements to compensate for the loss or failure of others" (Biggs et al., 2012, p. 425). Biodiversity within a system can bolster resilience by providing a basis for adaptation into new niches created by stress and disturbances (Carpenter et al., 2001). These forest SES exhibit moderately high species diversity spread across a number of different botanical families, growth forms, and functional roles. Functional diversity and redundancy also promote resilience because when groups of species have similar ecological roles, disturbances and losses are less likely to entirely remove them from an area (Holling, 2010; Simonsen et al., 2012)[28]. Species in the family Fabaceae[29] (legumes), for example, concentrate nitrogen compounds (from both the soil and atmosphere) in their tissues; some of these species do this through nitrogen-fixing symbioses with bacteria at root nodules (Vanlauwe & Giller, 2006). This function is replicated by two different species in Kitogani and four in Muyuni A, helping to 'back up' their role in the nitrogen cycle in case a given population suffers from a disease outbreak or other disturbance. Not all identified species, however, have populations numerous enough to ensure redundancy persists through larger disturbance events. The lone species of climber identified in Kitogani, for instance, represents a structural role fulfilled by a single population. Other redundancies in these ecosystems relate to various ecological processes: flowering plants adapted to reproducing with the aid of different pollinators and different grass species anchoring herb-dominant communities during early colonisation – to name a few. When redundant species assemblages provide ecosystem services – such as producing edible fruits or wood for building poles, regulating local humidity through transpiration – they may thus also be insured against loss to some degree. Such redundancy implies that "risks and benefits are spread widely to retain overall consistency in performance independent of wide fluctuations in the individual species" (Holling, 2010, p. 62).

[28] Carpenter et al. (2001) assert, however, that if a given population shrinks or disappears and its functional role is largely assumed by other species, they may exhibit different same levels of productivity as did the previous community assemblage.
[29] This family is also known as Papilionaceae or Leguminosae.

Increasing isolation between forest patches in both Muyuni A and Kitogani, however, threaten redundancies of some beneficial processes and services. Too much landscape patchiness hinders redundant species and processes from connecting across scales, detracting from a system's resilience because key system functions can become vulnerable to disruption (Folke, 2006). Respondents in Muyuni A and Kitogani express concern that forest patches are reducing in number and becoming more distant from each other, with patches of dissimilar ecosystems separating them. This trend is particularly problematic where open, exposed environments (e.g. roadways, cleared fields) hinder seed dispersal, split animal and plant populations, and affect animals' travel patterns across the landscape. The absence of wild ungulates, such as duiker, from some forest patches removes the soil fertilisation and seed dispersal services they provide there. Encouraging continued exchange and connectivity between forest patches, the Wildlife Conservation Society's (WCS, 2012) proposes to link forest reserves and community forest areas through a series of wildlife corridors. If their initiative goes forward, such corridors may traverse the western portions of both *shehia*. Simonsen et al. (2012) indicate that managing for a moderate amount of spatial and temporal connectivity between patches is desirable because it can help "safeguard ecosystem services against a disturbance … by facilitating recovery or preventing a disturbance from spreading" (p. 6). The configurations of forest patches on the landscape, and the degree of spatial and temporal connectivity between them, appear to have equally important implications for how individuals, populations, and systems respond to disturbance events.

5.1.3 Regenerative processes, tree population dynamics, and biomass loss

Forest ecosystems in the two *shehia* rapidly regenerate through compensatory growth in coppiced or otherwise damaged individuals and, most commonly, through germination of new plants. Seedlings and shoots populate bare areas left by abandoned farm plots or newly-harvested plantations, showing that local plant populations are reproducing new seeds or gaining recruits that have germinated from the soil seed bank. This new growth is especially rapid after the rainy seasons, when water and soil nutrients are abundant. Many plant populations, therefore, generally exhibit the characteristics of ruderal species, growing and reproducing opportunistically to overcome frequent disturbance within the SES. Such r-strategist species support resilience because they grow rapidly, tolerate high-stress conditions, and persist in spite of frequent disturbances (Holling & Gunderson, 2002). The rapid seedling growth observed in this study reaffirms findings from the ZWBS, which reports high seedling recruitment within Unguja's forest vegetation (RGZ, 2013e). Seedlings and saplings in this

study mostly originate from woody shrub species such as *P. parvifolia*, *E. natalensis, E. racemosa*, and *Rhus natalensis*. These species are common in low forests and shrublands and begin their growth as early pioneers after disturbance. Comparatively few tree species, however, are represented among new saplings and immature woody vegetation – even in areas containing mature, reproductive trees. This trend reveals that, while recruitment may be high in general, it may not represent successful reproduction, recruitment, and early life cycle survival by all species or plant growth form types.

In particular, population demographics for and harvesting rates on tree species indicate that, in spite of rapid growth potential within plant communities, these forest SES may be moving toward a more shrub-dominated state. Community members observe that forests are decreasing in extent and size over time, and large trees are scarce. This study shows that Muyuni A and Kitogani have significantly smaller proportions of mature trees (based on diameter and height distributions) than other surveys in Unguja's coral rag forests (e.g. Nahonyo et al., 2002; Haji, 2013). Large, old trees provide canopy cover and structure in intermediate and high coral rag forests, and Burgess & Clarke (2000) argue that their absence from coastal forests is often a symptom of overharvesting. Of the two communities, Kitogani has a comparatively larger cohort of small-diameter, short (i.e. young) trees relative to Muyuni A. This area therefore evidences greater potential for some trees to reach maturity, even if not all recruits and young trees survive. If tree populations cannot sustain distributions of individuals in different size and age classes – from seedling recruits to mature trees – SES may shift toward a state dominated by more open canopies and greater proportions of opportunistic shrub species. This change would represent a loss of diversity and structural complexity in the terrestrial environment.

Intensive wood harvesting challenges the regenerative potential of trees and some mature woody shrubs because this activity continues to remove substantial amounts of plant tissue and forest biomass – especially during the dry season. Mature trees in both communities have lost large branches to coppicing, and many woody shrubs have had several stems removed. Based on ages of cut marks, thresholds for desirable stem diameters (for firewood harvesters) appear to be decreasing, indicating that larger, more desirable stems are becoming harder to find. Haji (2013) noted similar trends in his surveys of KPFR. There, wood harvesting has removed a large volumes of forest biomass and accelerated forest degradation, especially where trees and woody shrubs have been unable to cope with the rate of tissue loss. This trend is island-wide in its scope: the ZWBS states that all coral rag forest LULC categories are so overexploited that wood collection should be immediately banned

there to allow natural regeneration to take place (RGZ, 2013e). Such a ban has not been implemented but, in Muyuni A and Kitogani, community members are trying to enhance natural regeneration processes in overharvested and bare land areas by planting native tree species (often working in collaboration with DFNNR and SEDCA before the long rains begin). Because sampling activities in this study encountered relatively few mature trees, more research is needed to understand tree population dynamics in these forests. If populations of species that characterise higher-canopy forests decline, however, a broader shift toward shrubland-dominated SES seems probable in the future.

5.1.4. Major ecosystem variables

Based on these observed dynamics in forest ecosystems, some variables play key roles in defining system characteristics and conferring potential to reorganise and adapt. Dense, woody thickets with low-moderate canopy height characterise most coral rag forest areas, which are found over rocky, fossilised coral limestone. The unique composition of vegetation communities, therefore, is a fundamental system characteristic and therefore a state variable (Thompson et al., 2009; Brown, 2016). Though other land cover types – e.g. agricultural fields, shrublands – can persist on the same substrate, they do not provide the same services and functions that most community members associate with forests. Forest ecosystems in these communities feature woody shrub and tree species that provide structure and maintain unique micro-environmental conditions (create shade, retain moisture, etc.). Fast variables, the foci of current community management efforts (Brown, 2016), mainly comprise forest products harvested by people. Community members in both *shehia* cite wood products as the most important forest resource, and regulating wood harvest is indeed a key management activity. In this study, therefore, woody biomass serves as the major fast variable. Land use planning and the CoFMA quota schemes have also, however, sought to manage various additional resources: catchment zones that filter water, wildlife (for bush meat or biodiversity conservation), land for grazing or shifting agriculture, and non-woody vegetation (e.g. for traditional medicines), among others.

Given that this research focuses on information about forest dynamics in the present and recent past (i.e. within living memory of interview respondents), determining slow variables in these systems proves a greater challenge. Resilient management regimes must be familiar with these variables because they are long-term, slow changing variables that can modify and alter their fast counterparts (Carpenter et al., 2001; Biggs et al., 2012; Brown, 2016). Considering the focus on managing for woody biomass, they influence how

communities of woody plant species change over time. Variables may include – but are not limited to – climate conditions (e.g. temperature, precipitation, and carbon dioxide concentration), soil-forming processes, and nutrient cycling. Though these variables have influenced change in other forest ecosystems (see Thompson et al., 2009), the dynamics of coral rag SES must be more thoroughly discussed, researched, and monitored to determine the most important slow variables within these unique terrestrial environments. This knowledge would promote a better understanding of potential thresholds within SES that, if crossed, may trigger sudden changes within systems or shift them into qualitatively different states (Carpenter et al., 2001; Biggs et al., 2012; Brown, 2016).

5.2 Socio-economic and political factors: Stakeholders, institutions, and management

5.2.1 Forest as a socio-political construct

An overarching obstacle in researching, monitoring, and managing these complex forest ecosystems is that "forest" does not have an official definition in Zanzibar or unanimous interpretation within the study communities. Coral rag forest areas have diverse qualities across patches and serve as the basis for different human activities, providing a wide range of services and benefits. Without a unifying set of criteria to distinguish forest from non-forest areas, these terms exist as social constructions of individuals, social groups, and community leadership – and their interpretations do not match. This situation endangers consistency in managing this collective resource because people often define natural environments based on their interests or objectives, which change with time and prevailing socio-political conditions (Robbins, 2012). Today, all governance institutions involved in forest management in Muyuni A and Kitogani lack working definitions for coral rag forest areas, complicating their ability to manage resilient systems.

Government policy and inventory documents have refrained from defining forest – legally or socio-ecologically – in Zanzibar. The Forest Act of 1996, for example, describes a host of closely related terms (e.g. *forest resources*, *forest reserve*, and *forest area management plan*) but does not define their common root word. The ZWBS acknowledges that what constitutes "Zanzibar forest" is unclear, making it difficult to compare the archipelago's forests to other areas and report data through widely accepted international standards (RGZe, 2013). Statewide inventories have also changed their LULC class criteria between surveys. Researchers, meanwhile, have chosen altogether different thresholds for measuring and classifying forest vegetation. For example, Haji (2013) assesses forest structure and composition based on measured stems with *dbh* ≥ 5 cm; Nahonyo et al. (2002)

and RGZ (2013e) use stems wider than 2 cm. Disparate approaches and categorisation schemes make landscape- and region-wide comparisons and trends more complicated still.

Table 5 lists the ZWBS categories and three broader forest definitions, some of which use criteria that would discount some of the "native forest" LULC categories from being classified as forest. These native forest criteria include areas with low, scrubby vegetation (LULC category 1.1) (RGZ, 2013e), where community members identify few ecosystem services typically associated with forest environments. For example, some medicinal plant species are found in coral barrens, but these areas have poor potential for providing wood, fodder, arable soil, or fruits. Mainland Tanzania has designated some of these more open, patchy areas as "bushlands" and "otherlands" to distinguish them from the characteristics and values normally associated with more contiguous, closed-canopy forest (URT, 2016). They adapted the Intergovernmental Panel on Climate Change's (IPCC) land use categories into the Tanzanian context through stakeholder engagement and participation to develop their definition (URT, 2016). This approach facilitates comparisons with forested areas outside of Tanzania and attempts to capture some of the diverse ideas about what forest attributes and benefits are important to rural residents.

Table 5. Forest definitions in Zanzibar and at broader scales.

Context	Definition
Zanzibar*	RGZ's (2013e, Annex I, p. 2) numbered LULC sub-classes for "native forest" areas: ● 1.1 Low coral rag: canopy cover <50% and height <2 m; coral soils. ● 1.2 Intermediate coral rag: canopy cover >50% and height 2-5 m; coral soils. ● 1.3 Bush and tall trees within coral rag: canopy cover >50% and height >5 m; coral soils. ● 1.4 High forest: canopy >70% and height >10 m; deep soils. ● 1.5 Other native bushlands: falls outside of criteria for sub-classes 1.1-1.4; deep (non-coral) soils.
Tanzania (mainland)	"'Forest' means an area of land with at least 0.5 ha, with a minimum tree crown cover of 10% or with existing tree species planted or natural having the potential of attaining more than 10% crown cover, and with trees which have the potential or have reached a minimum height of 3 m at maturity in situ" (URT, 2016, p. 12).
Coastal East Africa	A coastal forest is "evergreen or largely evergreen closed canopy

	vegetation > 8 m tall" that is usually within 50 km from the coastline and below 600 m in altitude (Burgess et al., 1992, p. 206).
Global	"Land spanning more than 0.5 ha with trees higher than 5 meters and a canopy cover of more than 10 per cent, or trees able to reach these thresholds *in situ*. It does not include land that is predominantly under agricultural or urban land use" (FAO, 2015, p. 3).

*These inventory definitions are based on field data and have been slightly modified from the categories established during the 1997 survey. They do not have any legal basis in Zanzibar.

In Imani village, Kitogani, Andersen (2012) also notes that some people see forests as being part of a holistic, comprehensive view of their natural surroundings, which must be cared for and stewarded. She cautions that differing opinions and expectations surrounding forests may be "a source of misunderstandings" (p. 38), both within the community and between it and other stakeholders engaged in projects like HIMA. Markedly different perspectives also exist within each the *shehia* in this study, but they have not been integrated into how these environments are ultimately constructed by managers, government agencies, or development organisations in Zanzibar.[30]

This lack of clarity about what areas qualify as forest poses some significant challenges in pursuing resilient resource management. At the most fundamental level, stakeholders do not share common views on which attributes and processes define and shape forest SES. Are forests only areas with tall, closed canopies, or do they also include patches of mixed thickets and margins of former and current agricultural plots? What ecosystem services and qualitative features must a forest have? Participant responses and the CoFMA documents in both communities provide a starting point, indicating that woody biomass is a key provisioning service and management concern. But wider uncertainty surrounding other forest attributes may detract from attention toward other system dynamics, including their main variables (slow and fast) and possible thresholds or tipping points. Understanding these variables is, however, crucial to forecasting how a system may respond under stress and disturbance, a conceptual activity that is crucial to fostering greater adaptive capacity among

[30] To capture the diverse perceptions and values that community members and key stakeholders associate with forest resources, I report information, observed trends, and themes from interview responses based on the way they individually discussed and defined areas. However, to ensure that my survey data are comparable with that of the most recent island-wide forest inventory, I have classified my sampling sites into the ZWBS LULC categories. This categorization scheme is the only one that specifically refers to coral rag forest, which comprised the majority of the sampling sites I surveyed.

managers (Resilience Alliance, 2010). This activity also precludes determining the desirable system characteristics, processes and services communities want to retain. Prioritising attributes' values requires negotiating different norms, opinions, and political perspectives (Robbins, 2012), but this activity seems to be an essential step toward coordinating resilient forest management practices in the future and at all scales throughout Zanzibar.

5.2.2 Rural income-generating activities: Alternatives and the conservation approach

Community members strategically make use of different income sources, but much of the economic activity centres on forest areas and products, especially in Muyuni A. Provisioning services provide various opportunities generate income in both communities. Similar to other communities in Unguja (Fagerholm et al., 2012: RGZ, 2013d), fuel and food resources are the most important commodities in these *shehia*. In general, when people can pursue different occupations in times of stress or exploit during periods of abundance, these different activities distribute and reduce risk (Adger, 1997; Adger, 2000b; Simonsen et al., 2012). In coastal communities, opportunistic switching between livelihood strategies is a well-documented and common practice used to increase resilience to varying environmental conditions and disturbances (e.g. Adger, 1997; Andersson & Ngazi, 1998; Adger, 2000a). By switching between different combinations of forest and non-forest occupations, many community members demonstrate a degree of flexibility and adaptability. In Muyuni A, however, two simultaneous trends have rendered this approach less successful. Several community members farm seaweed and collect wood, but they have seen productivity decline within both realms owing to warming sea temperatures and increasing wood scarcity, respectively. Gradual changes and stress within these environments affect Muyuni A most adversely because it has the greatest proportion of primary and secondary livelihood strategies based in resource harvesting. With more formal activities (e.g. government and tourism work) undertaken by Kitogani's residents, households there can maintain more stable incomes in the event that environmental conditions or resource stocks fluctuate.

Both *shehia*, however, feature some community-based initiatives that support livelihoods and reinforce processes that sustain ecosystem services. Small-scale ecotourism activities centring on each community's forest caves show promise for using forest areas to generate revenue from foreign visitors. But although Muyuni A hosts tours on (at least) a weekly basis, the scale of the operations remains small, such that few individuals are directly benefitting from tourism at this point. In Kitogani, a group of community members are using their agricultural skills to pursue less land-intensive farming techniques. Having discussed

sustainable income sources at recent development project seminars and community meetings, they recognise that livelihoods rooted in non-forest activities can reduce vulnerability to disturbances and also require less labour. This awareness has driven a campaign toward more lucrative and diverse AIGAs in the community, with individuals largely sustaining these efforts themselves. Three farmers, for example, have successfully transitioned to irrigated farming systems, turning good profits (Fig. 16). This system up-scales practices used when growing vegetables in home gardens, a traditional activity with which several community members are familiar. It represents a bottom-up, learning-oriented approach; the farmers are self-taught and readily share their experiences by networking with others. The start-up costs for irrigation equipment, however, have proven too prohibitive for other community members to make the transition, and no NGO or government funds have yet been secured to help them. Despite the limited scale of irrigated growing to date, these farmer's efforts prompt continuing discussion about opportunities to make income in ways that do not require clearing new land or removing trees. The community has energy, education, and awareness for embracing new, non-forest income alternatives, but the resources and institutional capacity to support them lag behind.

Figure 16. An irrigated vegetable farm in Kitogani.

Though ICDPs have raised awareness about conservation and AIGAs, they have failed to back their outreach with adequate support for grassroots efforts toward sustainable

development. The HIMA project, for example, put little focus on helping community members to generate sustainable businesses and jobs over its four-year duration:

> "A substantial amount of time was spent on activities aimed at building the carbon project while less emphasis and resources were directed towards reducing wood consumption, piloting alternative IGAs [income generating activities] and practices that would create enough income to compensate the fuelwood trade, or shifting cultivation" (RNEDS, 2015, p. 25).

The project focused on providing education to promote forest conservation but not on helping community members to improve skills, explore markets and business networks, or obtain resources. As a result, top-down efforts to convince community members to leave forest-based occupations have proven challenging. Forest resources not only serve as an important local source of basic services and materials for rural residents, but also provide a financial buffer in times of stress, when they can be sold for cash. This observation supports Andersen's (2012) findings; she reports that "only the most fortunate" (p. 40) community members in Kitogani do not collect firewood at least semi-regularly to augment their incomes. In both her study and mine, some people with higher financial security still collect their quota of firewood but purpose it toward buying commodities. In poorer segments of the population, in contrast, some people have gone to harvest wood illegally, believing it to be the best way to provide for their immediate needs. This study identifies young men as being particularly drawn to these activities to earn cash income. In documenting livelihood strategies so similar to those in Andersen's (2012) study, it is clear that forest resource harvests remain commonplace. And though increased conservation awareness has motivated some community members to explore non-forest livelihood opportunities, among poorer households it has fuelled frustration over lack of alternatives.

With its predominant focus on conserving forest areas, HIMA and its legacy activities risk isolating and marginalising the poorer segments of society. Transitioning to different livelihoods presents a substantial risk for people who already endure daily stress in meeting basic survival needs. Simonsen et al. (2012) caution that relying mostly on resource users to make adaptive changes within a system may detract from SER. In effect, such circumstances can place a burden on individuals who have the least resources or power to bring about change (Lebel et al., 2006). The new carbon forestry initiative places responsibility for mitigating a global problem with communities, but it has not yet provided them with the means to effectively adapt to climate change and other disturbances themselves. Lacking tangible incentives and sustained support to switch away from wood harvesting, people

continue to do this activity – even though wood is becoming more scarce and hard to obtain in many areas. Forest products are still viewed as a "safety net" resource that has always been available to community members in need of cash or materials. And owing to the large market for biomass fuels in Unguja, locally harvested wood can be easily sold.

5.2.3 The woodfuel sector: Zanzibar's energy crisis as a driver of rural livelihood stress

With a lack of affordable alternative fuel sources on Unguja, the increasing demand for firewood and charcoal acts as a powerful external driver upon these two SES. A deficit of 0.8 million m^3 of wood per year in Zanzibar means woodfuel is in high demand and sold in local markets, whose supply is further supplemented by charcoal imports from the mainland (RGZ, 2013e). This Zanzibar-wide problem affects Kitogani and Muyuni A because they serve as local sources of firewood and charcoal. Andersen (2012) indicates that, even though wood collection is an arduous and not particularly well-paid activity, many people in Unguja – especially women – continue to do it, perceiving few better alternative sources for income. Harvesters in this study demonstrate the same motivation to continue this practice but indicate that fuelwood has declined significantly in the past 10 years and is no longer as available as it was in the past.

In both *shehia*, the biomass fuel market – compounded by the lack of attractive livelihood alternatives – place stress on harvesters, communities, and forest ecosystems. Stress, in this sense, "encompasses disruption to groups' or individuals' livelihoods and forced adaptation to the changing physical environment" (Adger, 2000, p. 348). In spite of high growth potential, populations of woody forest species are not regenerating biomass at a rate that can match demands for fuelwood. Harvesters must therefore compensate by spending more time and effort within collection areas to locate suitable stems, the threshold sizes for which also appear to be decreasing. Additional effort and time spent harvesting, however, does not necessarily merit greater profitability. Instead, it detracts from energy that harvesters could spend on other occupations (e.g. for community members who run small businesses as a second job), household duties, and other activities. Functioning under stress from the woodfuel shortage, people engaged in wood harvests may have a reduced capacity to respond and adapt to disturbance events.

5.2.4 Participation, local-scale power relationships, and decision-making

By aiming to engage local stakeholders in resource management, the overarching goals behind Zanzibar's CoFMA system reflect core principles of resilient governance.

Resilient systems require participatory approaches that bring stakeholders together to interact, share knowledge, and cooperate to determine locally-relevant management strategies and objectives (Lebel et al., 2006). In moving from centralised government management toward decision-making that involves communities where resource use takes place, this framework – in theory – provides an opportunity for more stakeholders to get involved in managing forest-related issues and activities (Menzies, 2007). By engaging resource users and other key stakeholders, local-scale approaches can also help to foster trust and establish relevant management objectives (Lebel et al., 2006; Holling, 2010). These elements of trust and cooperation are fundamental to building SER (Biggs et al., 2012). Through awareness-raising seminars, community meetings, and collective activities like tree planting and patrolling, these *shehia* feature some opportunities for participation and collaboration.

Events and exchanges that have come about through the CoFMA regime have also spurred some individuals and groups to take action to improve networks for sharing experience and knowledge in Muyuni A and Kitogani. The aforementioned group of farmers growing irrigated vegetables, for example, has voluntarily worked to share information about more productive and less land-intensive farming practices, based on what they have learned themselves. In this way, motivated individuals and groups are building bottom-up momentum to bolster system resilience, particularly by ensuring resource-based livelihoods preserve existing system feedbacks and maintain essential system functions. Beekeeping initiatives also demonstrate this principle, promoting an activity that improves pollination of forest plants, provides honey for domestic consumption and income, and helps to protect high protection areas from would-be illegal harvesters.

But about half of respondents in both communities are unfamiliar with basic tenets of the CoFMA scheme, drawing into question the extent to which community members actively collaborate, share, and help develop processes within this forest management framework. Do community members affect the direction of forest management in their *shehia*, or do they merely participate when SCCs or the DFNNR request input? Nearly all community members in Muyuni A and Kitogani are familiar with the harvesting rules for forest resources; this knowledge, however, does not point to wider engagement of community members in resilient forest management. Rules apply to day-to-day harvesting and other land use activities, and they are shared informally by word of mouth or are sometimes posted on signs. But management activities under the CoFMA system span a greater scope than regulation and enforcement. Communities are meant to determine how to best balance resource use and conservation to the benefit of residents and the wider terrestrial environment (with focus on

the 30-year durations of their agreements). But, as Yakub (2016) observes in Kitogani and other *shehia* in Unguja Kusini, "local communities have little information on their rights under the existing forest policy and a common voice and mechanism to demand their rights" (pp. 11-12). More top-down information sharing, therefore, may improve collaboration between community members and leaders beyond semi-regular SCC meetings, which currently serve as the main forum for open discussions on forest-related issues.

Communities must also carefully consider whether these meetings (and those for ICDPs and other projects) are promoting agency and access to decision-making processes for all societal groups. Like in other communities in Unguja where forest management research has taken place (Menzies, 2007; Andersen, 2012; Benjaminsen, 2014; Suckall et al., 2014; Yakub, 2016), these two *shehia* feature complex socio-political environments. Respondents anchor their perspectives about forests and management according to different interests, political affiliations, income groups, genders (and associated roles), and occupation types. RNEDS (2015) points out a related issue in that, across Zanzibar, women have been less likely to critically discuss forest issues at gatherings where they may be seen as challenging the opinions of men. In Benjaminsen's (2014) study community, differences between community members triggered tension, exacerbated existing inequalities, and marginalised people associated with one political party during successive community meetings about the HIMA project.

Within this study, meetings in Kitogani appear to have limited efficacy in bringing community members together to discuss forest-related issues due to "meeting fatigue". Forest management concerns are discussed at semi-regular meetings, but more gatherings about these topics have been arranged for on-going ICDPs and academic research. Some community members feel that decisions made at these meetings do not always reflect voiced opinions, and attending them comes at an opportunity cost of time that could be spent doing other activities. For this reason, community members indicate that attendance at meetings has suffered. These meetings do not appear to empower community members to participate in collective management efforts, hindering their role as a forum for collaborating, sharing information, and preserving rights for different stakeholder and social groups. SCCs (and the DFNNR) continue to drive decision-making processes and determine the direction for new forest management approaches within these SES.

5.2.5 Learning, information sharing, and the value of local knowledge

Because the CoFMA system is relatively new, community leaders lack prior experience in integrating participatory, community-based approaches to resource management (Yakub, 2016). Resilient SES develop based on learning from past experiences in order to increase flexibility to adapt to unanticipated changes and surprises (Berkes & Folke, 1998; Folke, 2006). This learning generally comes about through on-going efforts to "experiment in safe ways" (Carpenter et al., 2001, p. 778), allowing systems to reflect on responses to past events in order to better adapt to future disturbances and stress (Gadgil et al., 1998; Folke, 2006; Brown, 2016). Having worked under their current CoFMAs for approximately four years, SCCs in both study communities are building familiarity with the ways that SES have responded to and reorganised after disturbances within a relatively short time scale. Though other communities in Unguja signed CoFMAs before these *shehia* did, few opportunities to learn from past experiences within this legal framework exist because there is no established network for sharing best practices between communities (Yakub, 2016). In an effort to learn more about different management strategies, the Kitogani SCC took a trip to another village that had worked to support natural forest regeneration after a destructive fire. This novel approach generated some useful insight toward developing adaptive responses to wildfires.

However, SCCs do not seem to be taking equal advantage of the diverse knowledge existing within their own *shehia* in order to document and learn from disturbance events. Resilient governance depends on integrating different perspectives and resource users' own experiential knowledge to identify management strategies that align with local values (Biggs et al., 2012; Brown, 2016). Interview responses indicate that community members in Kitogani and Muyuni A possess comprehensive and complementary knowledge about forest ecosystems and livelihood activities. An opportunity exists for incorporating more local knowledge into the CoFMA framework in both communities, particularly through monitoring conditions in forest environments. Many people visit forests in the course of day-to-day activities and have been observing changes and trends over several years.

This knowledge base serves as a valuable resource that could provide a record of changing conditions within SES before the CoFMA period began, supplementing more recent qualitative observations from SCCs. Current monitoring systems, however, remain limited. In Muyuni A, SCC members visit harvesting sites periodically to ensure that resource users have heeded the restrictions in their permits. But these surveys have no quantitative dimension – their main aim is to ensure that people are following the rules. As a result, there

exists no way to keep track of key system functions or to gain in-depth feedback on recent management activities. This situation also makes it difficult to track fast and slow variables, the latter of which help to keep SES within current basins of attraction (Simonsen et al., 2012). While monitoring only harvesting areas permits them to be managed at fine scales, it may cause managers to lose sight of the "bigger picture" of system dynamics across *shehia*, such as inside high protection areas. This gap leaves ample room to strengthen current decision-making processes by inviting greater participation and feedback from resource users who interact with forests on a regular basis.

5.2.6 (In)Flexibility in governance

Resilient systems and their governance institutions should also be flexible in order to adapt to changing conditions and respond effectively to a range of unexpected events (Berkes & Folke, 1998; Folke, 2006; Holling, 2010; Biggs et al., 2012). In practice, this means that managers should continuously adapt and tailor their approaches for coping with stress. The CoFMAs' legal framework encourages this type of flexibility by permitting SCCs to judiciously adjust land use area boundaries over time. Community leaders favour this provision because it allows them to rotate different areas through cycles of conservation and use depending on resource stocks there (permanent reserve and settlement areas are, of course, excepted). By modifying land use area boundaries and regulations, SCCs can try to best retain ecosystem services based on current patterns of harvesting and other on-going changes within the system. Flexibility to make minor spatial and regulatory adjustments affords various opportunities: to manage connectivity among landscape patches, to create buffer or transition zones between different land use types, and to reinforce other functions that improve regenerative processes or maximise sustainable ecosystem service benefits.

These SES demonstrate less flexibility and long-term thinking, however, in how they use a heavy-handed, reactive approach to punishing people who break land use rules. Illegal harvesters usually face hefty fines and their forest products are confiscated. Sometimes the DFNNR, police, or High Court also assist in apprehending or deciding punishments for these offenders. In other words, punitive action is the primary means for recourse and deterring community members from illegal activities. In Muyuni A, community members still favour an even stricter action, seeing illegal harvesting as a major local issue. As previously discussed, however, lack of regular access to basic necessities and services motivates at least some people to harvest resources this way, even though they recognise that the chance of getting caught makes it risky. Their actions, therefore, stem from underlying conditions that

may include marginalisation, exclusion, or lack of livelihood alternatives. Heavy fines can push people deeper into poverty, exacerbating social and economic inequalities within communities. SCCs and members of local patrol groups also expend significant amounts of time and effort in an attempt to stop these illegal harvesters, drawing resources that could be used for other activities. Under these circumstances, communities may benefit from careful reflection about the root causes that encourage this behaviour in order to adopt new strategies that help lift people out of poverty traps. Holling (2010) discusses this dimension of flexibility, indicating that resilient SES should have "early signals of error built into incentives for corrective action" (Holling, 2010, p. 63). In these communities, regular instances of illegal harvesting signal critical socio-economic issues at the community level, and corrective strategies should include measures that promote SER through greater equity, access to services, participation, and inclusion in forest resource governance.

5.2.7 Polycentric governance: Addressing gaps in efficacy and connectivity

Governance institutions in Muyuni A and Kitogani feature a multi-layered structure that is generally well-suited to address forest issues at scales ranging from coarse to fine. *Shehia* manage mostly small-scale resource use activities over clusters of landscape patches, while the DFNNR deals with overarching conservation, administration, and support. NGOs have also developed mandates to address the crosscutting issues affecting regions within Zanzibar. In protecting and conserving certain forest areas, for example, SCCs can designate local conservation areas to buffer larger reserves and parks. Community conservation zones surrounding MJFR are one such case. This structure already demonstrates several qualities of polycentric governance, which functions to "improve the fit between knowledge, action, and socio-ecological context in ways that allow societies to respond more adaptively" (Lebel et al., 2006, p. 9). The current governance structure has indeed helped diversify institutional coverage, improving upon past management styles (i.e. top-down and centralised).

Opportunity exists, however, for governance institutions to coordinate their activities more effectively across different scales and over time. While region-scale NGOs like JECA and SEDCA promote greater collaboration on issues facing groups of *shehia*, a substantial gap separates the scale of their management foci from those of their members. Some forest issues are unique to sub-regions, affecting portions of the NGOs' membership. These issues deserve greater attention because, even though the legal nature of CoFMAs gives these areas rigid outer perimeter boundaries, they directly abut each other. Adjacent *shehia* feature interchanges by way of cross-boundary travelways, species migration and dispersal, trades

for different goods, etc. Kitogani and its neighbour, Muungoni, have made an early effort to address common forest management concerns by creating a combined patrol crew. Because they track trans-boundary activities affecting both *shehia*, they can more efficiently allocate resources and volunteer patrollers' time. Other inter-*shehia* agreements may, for example, be able to better harmonise land use strategies (e.g. through buffering conservation areas or creating wildlife corridors) and coordinate responses to disturbance (e.g. promoting early action to mitigate against crop pest outbreaks).

Equally important, however, is to ensure that efforts to build adaptive capacity within these SES include plans for continued, long-term support and knowledge transfer. Williams et al. (1998) argue that, in particular, ICDPs in Zanzibar suffer from a persistent trend: they achieve short-term gains that often erode soon after projects finish. In other words, these projects have trouble making lasting impacts. Though Williams et al. (1998) base their observation on forest wildlife conservation, the half-hearted attempts to introduce AIGAs seem in danger of following a similar trend. The HIMA project introduced greater conservation awareness, but it did not leave communities with realistic approaches for stewarding forests or generating income. People are unsure if the carbon crediting system will translate to adequate compensation for community members engaged in resource-based livelihoods. Communities have been left without continued support to explore and adopt AIGAs, and they appear to lack information about what future direction the project's legacy activities will take. These sentiments closely mirror those of respondents in Yakub's (2016) study. Governance institutions must work to fill such temporal gaps in institutional coverage (e.g. around short-term ICDPs) by better complementing and connecting each other's activities to build adaptive capacity and to contribute to long-term, flexible learning across system scales.

5.3 Current conditions: Relating to the adaptive cycle and panarchy

The wider terrestrial forest environment of Unguja – including coral rag forest SES in Muyuni A and Kitogani – varies spatially and temporally at different scales as a result of political, social, and economic changes; internal feedbacks and external drivers; as well as gradual stress, cyclical disturbances, and surprise events. Rather than existing in isolation, the two *shehia* featured in this study interact with surrounding forests and also to smaller, nested sub-systems (patches), sharing matter, energy, governance institutions, and multi-scalar responses to change. Holling's (1986) adaptive cycle serves as a starting point for examining the behaviour of these systems, while the concept of panarchy (Holling & Gunderson, 2002)

helps to describe cross-scale dynamics. These models, as powerful illustrative tools, underscore the processes and features within the SES that impart – or challenge – resilient qualities there.

5.3.1 High heterogeneity and frequent disturbances: Linking scales between patches and landscapes

Today, much of the coral rag forest area in Muyuni A and Kitogani falls within the rapid growth phase of the adaptive cycle, though individual patches are staggered in their progress through it. Because these secondary-growth forests exist on landscapes regularly affected by land clearing (including controlled burns) and wood harvesting, patches represent different relative positions within r phase. They share some general characteristics: most forests have matured beyond colonization (evidencing moderate structural complexity and biodiversity) and have vigorously growing, healthy vegetation. But frequent, recurring disturbances "release" several landscape patches and prompt new iterations of reorganisation, rapid growth, and conservation beginning in each dry season, when most forest use activity occurs. Nearly all forest areas encountered during surveys were visibly regenerating from different disturbances that happened less than ten years ago. Examining the adaptive cycle at the patch-level, therefore, helps to better identify overall conditions within each *shehia*.

Individual forest patches move through relatively rapid iterations of the adaptive cycle, mainly as a result of shifting cultivation activities. When farmers cut and burn a forest area to begin a new plot, they intentionally release the system from a forested state and cultivate crops there for two or three years. Afterward, when the land is abandoned, wild plant species begin to recolonize it, initiating the reorganisation phase. Patches in this phase feature many shoots and saplings dispersed in areas with full light exposure. As Holling and Gunderson (2002) predict, the species establishing under these conditions are generally well "adapted to dealing with the stresses and opportunities of a variable environment—the risk takers, the pioneers, the opportunists" (Holling & Gunderson, 2002, p. 43). As vegetative communities develop further, they enter rapid growth phase, taking advantage of abundant light and resources to fuel growth and reproduction (Holling, 1986). Habitats in Muyuni A's low-impact use zone feature tracts of shrublands and barrens that provide excellent habitat for light-loving, r-selected pioneers – especially different shrub species. Some patches in Kitogani, meanwhile, indicate that they are progressing toward the conservation phase; more closed canopies and a greater number of tree species show that conditions there promote increasing connectedness, organisation, and storage of matter (Holling, 1986). As biomass

thus accumulates in (late) rapid growth and in conservation phases, patches become increasingly attractive for wood harvesting (i.e. due to larger stems). The same patch may thus be ready to cultivate again within ten to fifteen years, beginning the cycle anew.

Rapid turnover within forest patches has conferred valuable and renewable resource stocks to harvesters in both communities, but forest patches' rapid cycling behaviour poses key challenges to SER at the *shehia* level. Holling and Gunderson (2002) indicate that the r phase often includes "activity energized by a pioneer spirit and opened opportunity" (p. 43), and this trend holds true in both *shehia*. Resource harvesters sell fuel, food, fodder, and building materials – both opportunistically and on a regular basis – to help fulfil basic needs and earn cash income. Even though plant communities grow relatively quickly, matter lost from patches (e.g. through biomass removal) during relatively rapid cycles has instigated substantial "revolt" from the two SES in recent years. Resilience Alliance (2017) indicates that this process, transferring upward in scale, can introduce innovations and opportunities to diversify system functions and components. But repeated cultivation cycles on thin, dry soils and the over-harvesting wood resources have instead reduced the regenerative capacities of local plant communities, imposing stress and more marginal growing conditions.

The impact of this bottom-up trend appears, in some areas, to be overshadowing remembrance, which Resilience Alliance (2017) describes as the process by which "larger, slower levels stabilise and conserve accumulated memory of system dynamics" (17.02). "Memory" in this context refers to surrounding forests' ability to provide colonising species for disturbed habitats and stabilise the local growing environment for newly establishing plant communities. Though Unguja's terrestrial forest ecosystems perform these functions to some degree, current observations indicate that climate change has weakened some of the positive feedbacks that promote persistence of forest environments. Community members in this study explain that forests are drying out, making trees more susceptible to disease and death. These effects coincide with less predictable seasonal rains, which delay or impair regenerative growth and germination. Watkiss et al. (2012) indicate that because forest vegetation in Zanzibar is isolated (i.e. without having regular interchange with mainland plant communities), less genetic material is available for adaptive mutations to spread in time to keep up with changing temperature and precipitation patterns. The uncertain effects of global climate change, therefore, pose an important challenge to the adaptive capacity of governance institutions.

5.3.2 Connections between socio-political systems and forest landscapes

The socio-political dimensions of these two SES also demonstrate adaptive cycle characteristics, although their dynamics are not matched to the same (fast) pace of change within forest ecosystems. Muyuni A and Kitogani are both approaching conservation phase, and they both remain strongly influenced by the wider-scale forest governance trends in the archipelago. Zanzibar's transition to community-based forest management in the mid-1990s triggered the most recent back loop of institutional renewal within the adaptive cycle, a change that reorganised forest governance in Unguja. With the CoFMA system granting local decision-making authority, a new institutional environment established to address specific forest issues and fill service gaps. SCCs and a number of local NGOs (largely spurred by an internationally-rooted push toward greater forest conservation) have adopted and expanded on roles formerly held by centralised government management.

Most recently, the REDD+ debut in Zanzibar has introduced a new layer of forest governance and direction for management efforts through carbon forestry. By moving to align cross-scale efforts toward a common management goal, these institutions demonstrate a characteristic feature of the rapid growth phase (Carpenter, 2016). The HIMA project has built upon the existing governance framework to make institutions more connected and organisationally complex. But the aims of this project have yet to be fulfilled; the carbon crediting system has yet to go into effect to compensate communities for forest conservation gains. These SES may eventually reach conservation phase when institutions become highly connected and efficient, achieving incremental advances toward objectives within each *shehia* (Holling & Gunderson, 2002; Carpenter, 2016). But, for now, governance institutions are adapting to the challenges of managing southern Unguja's forests in line with the new organisational structure and revised management objectives.

Like the forest environments they manage, governance institutions at the community level embed within a panarchy of social, political, and economic dynamics at finer and coarser scales. The diverse opinions, perspectives, and interests of individual community members and social groups provide both a source of learning and knowledge to SES, but they also reveal potential for management approaches to have diverse impacts within communities. Individuals appear to have limited ability (due to lack of resources, capacity, and power) to affect revolt and innovation within these SES – unless they hold positions of decision-making authority. Conversely, processes enforcing system memory permeate the work of community-level institutions in Muyuni A and Kitogani. The aforementioned issues of poverty and energy scarcity represent state-scale issues that limit the distribution of basic

services among citizens (RGZ, 2007) and, therefore, place additional burdens on SCCs, local NGOs, and community members. These coarser-scale problems detract from SER in the study communities: they place additional stress on stakeholders and institutions, complicating efforts to establish inclusive, adaptive management approaches in forest SES. By trying superimpose lofty international conservation ideals on Zanzibar's coral rag forests, initiatives like REDD+ give insufficient attention to fundamental barriers to sustainable forest use, development, and conservation at the local level. With such dominating pressures outside the realm of community control in Muyuni A and Kitogani, these *shehia* face formidable challenges in moving forward with resilient and adaptive management strategies.

6. Conclusion

By analysing forest resource harvesting and management in two communities from a resilience perspective, this study offers insight into the complex dynamics that shape coral rag forest SES in Unguja, Zanzibar. Muyuni A and Kitogani represent highly heterogeneous systems: ecological, social, economic, and political variables catalyse change, shape responses to disturbance, and link communities to on-going processes at both coarser and finer scales. Common trends in how these SES respond and adapt to changing conditions serve to illuminate the key drivers supporting and eroding SER, and they highlight strategies that may be used to build greater adaptive capacity in the future.

Rapid growth and high reproductive capacity characterise these coral rag forests – which have patchy, biodiverse vegetation growing in dense woody thickets – and promote system resilience. Surveys show that ruderals swiftly recolonize disturbed areas and, in doing so, prompt positive feedback by stabilising growing conditions for a variety of other plant populations. Woody shrub species play particularly important roles: colonizing bare areas, anchoring plant communities after their establishment, and later serving as a fuelwood resource. Landscape patches continuously change between cultivated land and regenerating forest in cycles that coincide with shifting agriculture. The relatively low functional redundancy of and regeneration capacity within tree populations (especially in Muyuni A), however, may indicate a gradual shift toward more shrub-dominated ecosystems.

Interview responses indicate that local livelihoods in both communities benefit from forests' ecosystem services – particularly arable land for farming and woody biomass for fuel. The latter constitutes the fast variable for these systems, serving as a regulatory and management focus in CoFMAs. In surveying low-impact use zones in both communities, this study's findings align with those from prior work, indicating that high harvesting rates reduce

forests' capacities to reorganise and regenerate. Land clearing and woodcutting are the greatest sources of disturbance to forest environments; in the past, these activities remained within system thresholds. But intervals between disturbance events are becoming shorter, and each subsequent harvest of forest vegetation removes more organic matter from the system. These activities have weakened internal system feedbacks that help forest SES persist. Social and political drivers, however, continue to reinforce these trends.

Poverty, limited institutional capacity, and an island-wide energy shortage exert stress upon SES and hinder community members' efforts to pursue more resilient livelihoods. Poverty drives some people to overexploit resources as a means of meeting basic needs and earning cash. Poorer members of society are at risk of slipping into poverty traps through a heavy-handed punishment system. Development projects and governance institutions have been unsuccessful in providing the resources, training, and connections to help people transition away from livelihoods centred on forest resources. Community members in Kitogani, in particular, are eager to pursue activities that help support and preserve forest ecosystem services (such as irrigated farming), but lack sustained support. The relatively lucrative market for fuelwood also encourages continued woody biomass harvesting.

Although these drivers impede responses to disturbance and stress, governance institutions have made notable gains toward building greater resilience in community SES. The multi-layered institutional framework established during the first two decades of community-based management addresses forest-related issues at appropriate scales and is starting to nurture system flexibility and promote learning. However, all governance levels in Zanzibar operate without any clear definition of what physical qualities and ecosystem services a forest environment should have, complicating cross-scale management efforts. Establishing a definition that captures the diverse values that community members associate with coral rag forests appears an important step in forging more complementary and consistent management activities across Unguja.

A particularly key opportunity to bolster resilience exists for opening management activities to greater community member participation. Communicating basic rights to all forest users within the CoFMA framework, however, is an important precursor. More input from community members can enrich bottom-up learning and sharing processes among the people working most closely with and having the most experiential knowledge about local forest resources. The existing polycentric governance framework operates at community, region, and statewide levels, but connections between them may be improved to complement cross-scale activities and objectives. This approach would strengthen institutional capacity

and support for sustainable income-generating alternatives, improving resilience by reinforcing systems' abilities to respond to future disturbances.

References

Adger, W. N. (1997). Sustainability and social resilience in coastal resource use. Centre for Social and Economic Research on the Global Environment Working Paper GEC 97-23, University of East Anglia & University College London. 39pp.

Adger, W. N. (2000a). Institutional adaptation to environmental risk under the transition in Vietnam. *Annals of the Association of American Geographers*, *90*(4): 738-758.

Adger, W. N. (2000b). Social and ecological resilience: are they related? *Progress in Human Geography*, *24*(3): 347-364.

Andersson, J. & Ngazi, Z. (1998). Coastal communities' production choices, risk diversification, and subsistence behavior: Responses in periods of transition: A case study from Tanzania. *Ambio*, 27 (8): 686-693.

Andersen, I. (2012). *REDD in Zanzibar: An ethnography of stakeholders*. Oslo, Norway: University of Oslo, Department of Social Anthropology. 126 pp.

Banks, G. & Scheyvens, R. (2003). Ethical issues. In Scheyvens, R. (ed.). *Development fieldwork: A practical guide*, pp. 160-187. London, UK: Sage.

Berg, B. L, & Lune, H. (2012). *Qualitative research methods for the social sciences*: Pearson. 432 pp.

Berkes, F. & Folke, C. (1998). Linking social and ecological systems for resilience and sustainability. In Berkes, F. & Folke, C. (eds) *Linking social and ecological systems: Management practices and social mechanisms for building resilience*, pp. 1-29. Cambridge, UK: Cambridge University Press.

Berkes, F., Colding, J. & Folke, C. (2003). Introduction. In Berkes, F., Colding, J. & Folke, C. (eds) *Navigating social-ecological systems: Building resilience for complexity and change*. Cambridge, UK: Cambridge University Press.

Bhaskar, R. (2011). *Reclaiming reality: A critical introduction to contemporary philosophy*. Oxon, UK: Routledge.

Biggs, R., Schlüter, M., Biggs, D., Bohensky, E. L., Burnsilver, S., Cundill, G., Dakos, V., Daw, T. M., Evans, L. S., Kotschy, K., et al. (2012). Toward principles for enhancing the resilience of ecosystem services. *Annual Review of Environment and Resources*, 37: 421-448.

Brown, K. (2016). *Resilience, development and global change*. London, UK: Routledge. 212 pp.

Burgess, N. D., Matthews, P., Evers, Y. & Woodcock, K. (2000). Non-timber uses, threats and local attitudes. In Burgess, N. D. & Clarke, G. P. (eds) *Coastal forests of Eastern Africa*, pp. 281-302. Cambridge, UK: IUCN.

Burgess, N. D. & Mbwana, S. B. (2000). Forestry. In Burgess, N. D. & Clarke, G. P. (eds) *Coastal forests of Eastern Africa*, pp. 263-280. Cambridge, UK: IUCN.

Burgess, N. D., Mwasumbi, L. B., Hawthorne, W. J., Dickinson, A. & Doggett, R. A. (1992). Preliminary assessment of the distribution, status and biological importance of coastal forests in Tanzania. *Biological Conservation*, 62: 205-218.

Carpenter, S., Walker, B., Anderies, J. & Abel, N. (2001). From metaphor to measurement: Resilience of what to what? *Ecosystems*, 4: 765-781.

Carpenter, S. (2016, April 13). Resilience in social-ecological systems: Models and field studies. Lecture to National Socio-Environmental Synthesis Centre (SESYNC) [PowerPoint]. Retrieved from http://www.sesync.org/events-announcements/thu-2016-03-24-1330/immersion-lecture-resilience-in-social-ecological-systems

Clarke, G. P. & Karoma, N. J. (2000). History of anthropic disturbance. In Burgess, N. D. & Clarke, G. P. (eds) *Coastal forests of Eastern Africa*, pp. 251-262. Cambridge, UK: IUCN.

Creswell, J. W., Plano Clark, V. L. & Garrett, A. L. (2008). Methodological issues in conducting mixed methods research designs. In Bergman, M. M. (ed.) *Advances in mixed methods research: Theories and applications*, pp. 66-81. London, UK: Sage.

DFNNR. (2017). Zanzibar forest resources. Accessed on 26 January 2017 from http://www.forestryznz.or.tz/index.php/plantations

DCCFF. (2008). Zanzibar national forest resources management plan 2008-2020. Zanzibar, Tanzania: DCCFF. 1-57 pp.

Embassy of Finland, Dar es Salaam. (2017). Sustainable management of land and environment programme. Accessed 31 January 2017 at: http://www.finland.or.tz/public/default.aspx?nodeid=47133&contentlan=2&culture=en-US

Fagerholm, N., Käyhkö, N., Ndumbaro, F. & Khamis, M. (2012). Community stakeholders' knowledge in landscape assessments - mapping indicators for landscape services. *Ecological Indicators*, 18: 421-433.

Fagersholm, N., Käyhkö, N. & van Eetvelde, V. (2013). Landscape characterization integrating expert and local spatial knowledge of land and forest resources. *Environmental Management*, 52: 660-682.

Folke, C., Carpenter, S., Elmqvist, T., Gunderson, L. H., Holling, C. S. & Walker, B. (2002). Resilience and sustainable development: Building adaptive capacity in a world of transformations. *Ambio*, 31(5): 437-440.

Folke, C. (2006). Resilience: The emergence of a perspective for social–ecological systems analyses. *Global Environmental Change*, *16*(3): 253-267.

Gadgil, M., Hemam, N. S. & Reddy, B. M. (1998). People, refugia and resilience. In Berkes, F. & Folke, C. (eds) *Linking social and ecological systems: Management practices*

and social mechanisms for building resilience, pp. 30-47. Cambridge, UK: Cambridge University Press.

Google Earth 7.1. (2016a). Kitogani, Zanzibar *37M 549458.78 m E 9305300.42 m S, eye altitude 8.69 km*. Historical imagery from 17 September 2013 [DigitalGlobe]. Viewed 10 April 2017 at: http://www.earth.google.com

Google Earth 7.1. (2016b). Kitogani, Zanzibar *37M 549458.78 m E 9305300.42 m S, eye altitude 8.69 km*. Historical imagery from 14 February 2016 [DigitalGlobe]. Viewed 10 April 2017 at: http://www.earth.google.com

Google Earth 7.1. (2016c). Muyuni A, Zanzibar *37M 550079.25 m E 9299874.13 m S, eye altitude 8.69 km*. Historical imagery from 17 September 2013 [DigitalGlobe]. Viewed 10 April 2017 at: http://www.earth.google.com

Google Earth 7.1. (2016d). Muyuni A, Zanzibar *37M 550079.25 m E 9299874.13 m S, eye altitude 8.69 km*. Historical imagery from 14 February 2016 [DigitalGlobe]. Viewed 10 April 2017 at: http://www.earth.google.com

Haji, N. M. (2013). *The effect of forest degradation on forest structure and carbon stock in Kiwengwa Pongwe Forest Reserve, Zanzibar* Morogoro, Tanzania: Sokoine University of Agriculture. 94 pp.

Holling, C. S. (1973). Resilience and stability of ecological systems. *Annual Review of Ecology and Systematics*, 4: 1-23.

Holling, C. S. (1986). The resilience of terrestrial ecosystems: Local surprise and global change. In W. C. Clark & R. E. Munn (Eds.), Sustainable Development of the Biosphere, pp. 292–317. Cambridge, UK: Cambridge University Press.

Holling, C. S. (2010). Engineering resilience versus ecological resilience. In Gunderson, L.H., Allen, C. R., & Holling, C. S. *Foundations of ecological resilience* (pp. 51-66). London, UK: Island Press.

Holling, C. S., & Gunderson L. H. (2002). Resilience and adaptive cycles. In Gunderson, L. H. & Holling, C. S. (Eds.) *Panarchy: Understanding transformation in human and natural systems*, pp. 25-106. Washington, DC: Island Press.

Johnson, J. (1987). Hydrogeological map of Zanzibar [map]. (1:105 000.) New York, NY: United Nations.

Käyhkö, N., Fagersholm, N., Asseid, B. S. & Mzee, A. J. (2011). Dynamic land use and land cover changes and their effect on forest resources in a coastal village of Matemwe, Zanzibar, Tanzania. *Land Use Policy*, 28 (2011): 26-37.

Käyhkö, N., Fagerholm, N. & Mzee, A. J. (2015). Local farmers' place-based forest benefits and government interventions behind land and forest cover transitions in Zanzibar, Tanzania. *Journal of Land Use Science*, 10 (2): 150-173.

Kotiluoto, R., Ruokolainen, K. & Kettunen, M. (2008). Invasive *Acacia auriculiformis* Benth. in different habitats in Unguja, Zanzibar. *Journal of African Ecology*, 47: 77-86.

Krebs, C. J. (1999). Ecological methodology. 2nd ed. Menlo Park, California: Addison Wesley.

Kukkonen, M. (2013). *Forest cover and its change in Unguja Island, Zanzibar.* Masters thesis. Turku, Finland: University of Turku, Department of Geography and Geology. 166 pp.

Lebel, L., Anderies, J., Campbell, B., Folke, C., Hatfield-Dodds, S., Hughes, T., & Wilson, J. (2006). Governance and the capacity to manage resilience in regional social-ecological systems. *Ecology and Society*, *11*(1).

Millennium Ecosystem Assessment. (2005). Ecosystems and human well-being: Synthesis. Washington, DC: Island Press. 137pp.

Miller, F., Osbahr, H., Boyd, E., Thomalla, F., Bharwani, S., Ziervogel, G., Walker, B., Birkmann, J., Van der Leeuw, S., Rockström, J., Hinkel, J., Downing, T., Folke, C., & Nelson, D. (2010). Resilience and vulnerability: Complementary or conflicting concepts. *Ecology and Society*, 15(3): 11.

Moran, E. F. (2005). Human-environment interactions in forest ecosystems: An introduction. In Moran, E. F. & Ostrom, E. (eds) *Seeing the forest and the trees: Human-environment interactions in forest ecosystems*, pp. 1-21. Cambridge, MA: The MIT Press.

Myers, G. A. (2002). Local communities and the new environmental planning: A case study from Zanzibar. *Area*, 34 (2): 149-159.

Myers, N., Mittermeier, R. A., Mittermeier, C. G., Da Fonseca, G. A., & Kent, J. (2000). Biodiversity hotspots for conservation priorities. *Nature*, *403*(6772): 853-858.

Nahonyo, C. L., Mwasumbi, L. B., Eliapenda, S., Msuya, C., Mwansasu, T., Suya, M., Mponda, B. O. & Kihaule, P. (2002). Jozani-Chwaka Bay proposed national park biodiversity inventory report. Dar es Salaam, Tanzania: CARE Tanzania & DCCFF. 184 pp.

National Bureau of Statistics. (2013). 2012 Population and housing census: Population by administrative areas. Dar es Salaam, Tanzania: Ministry of Finance. 264 pp.

National Bureau of Statistics. (2014). Basic demographic and socio-economic profile: Tanzania: Zanzibar. Zanzibar Town, Zanzibar. 207 pp.

Resilience Alliance. (2010). *Assessing resilience in social-ecological systems: Workbook for practitioners*. Version 2.0. Resilience Alliance. 54 pp.

Resilience Alliance. (2016, 15.07). Resilience. Retrieved from: http://www.resalliance.org/resilience

Resilience Alliance. (2017, 17.02). Panarchy. Retrieved from: http://www.resalliance.org/panarchy

Revolutionary Government of Zanzibar. (1996). The forest resources management and conservation act (No. 10). Zanzibar Town, Zanzibar. 98 pp.

Revolutionary Government of Zanzibar. (1999). *National forest policy for Zanzibar*. Commission for Natural Resources - Forestry Sector. Zanzibar Town, Zanzibar. 20 pp.

Revolutionary Government of Zanzibar. (2007). *Zanzibar strategy for growth and reduction of poverty (ZSGRP)*. Zanzibar Town, Zanzibar. 97 pp.

Revolutionary Government of Zanzibar. (2012). Quick figures: Zanzibar GDP and employment statistics. Zanzibar Labour Commission: Zanzibar Town, Zanzibar. 6 pp.

Revolutionary Government of Zanzibar. (2013a). *Makubaliano ya usimamizi wa misitu ya shehia ya Kitogani* (Kitogani Community Forest Management Agreement). Zanzibar: DFNNR. 22 pp.

Revolutionary Government of Zanzibar. (2013b). *Makubaliano ya usimamizi wa misitu ya shehia ya Kitogani* (Muyuni A Community Forest Management Agreement). Zanzibar: DFNNR. 19 pp.

Revolutionary Government of Zanzibar. (2013c). *Zanzibar environmental policy*. Department of Environment. Zanzibar Town, Zanzibar: The First Vice President's Office. 76 pp.

Revolutionary Government of Zanzibar. (2013d). *Zanzibar woody biomass survey: Socio-economic survey component*. Ministry of Agriculture and Natural Resources: Zanzibar Town, Zanzibar. 61 pp.

Revolutionary Government of Zanzibar. (2013e). *Zanzibar woody biomass survey: Biophysical inventory report*. Ministry of Agriculture and Natural Resources: Zanzibar Town, Zanzibar. 139 pp.

Robbins, P. (2012). *Political ecology: A critical introduction*. 2nd ed. Oxford, UK: John Wiley & Sons.

Robbins, P., Hintz, J., & Moore, S. A. (2010). *Environment and society: A critical introduction*. Oxford, UK: John Wiley & Sons.

Ross, H. & Berkes, F. (2014). Research approaches for understanding, enhancing, and monitoring community resilience. *Society and Natural Resources*, 27 (8): 787-804.

Rowe, N., & Speck, T. (2005). Plant growth forms: An ecological and evolutionary perspective. *New Phytologist*, *166*(1), 61-72.

Royal Norwegian Embassy in Dar es Salaam. (2015). Final review of the project *Hifadhi ya Misitu ya Asili* (HIMA): Piloting REDD+ in Zanzibar through community forest management. Vantaa, Finland: NIRAS. 37pp.

Sharpley, R. & Ussi, M. (2014). Tourism and governance in small island developing states (SIDS): The case of Zanzibar. *International Journal of Tourism Research*, 16: 87-96.

Sheriff, A. (1987). *Slaves, spices and ivory in Zanzibar: Integration of an East African commercial empire into the world economy, 1770–1873*. Suffolk, UK: Ohio University Press.

SNV, VSO & ZATI. (2010). Value chain analysis: Summary report. *Tourism: More value for Zanzibar*. Zanzibar. 12 pp.

Suckall, N., Tompkins, E. & Stringer, L. (2014). Identifying trade-offs between adaptation, mitigation and development in community responses to climate and socio-economic stresses: Evidence from Zanzibar, Tanzania. *Applied Geography*, 46: 111-121.

Turner, N. J., Davidson-Hunt, I. J. & O'Flaherty, M. (2003). Living on the edge: Ecological and cultural edges as a source of diversity for social-ecological resilience. *Human Ecology*, 31 (3): 439-461.

Turner, M. G., Donato, D. C. & Romme, W. H. (2013). Consequences of spatial heterogeneity for ecosystem services in changing forest landscapes: Priorities for future research. *Landscape Ecology*, 38: 1081-1097.

UNEP. (2001). East African atlas of coastal resources. UNEP: Nairobi, Kenya. 111 pp.

UNFCCC. (2009). Calculation of the number of sample plots for measurements within A/R CDM project activities. Annex 15, CDM Executive Board. *A/R Methodological Tools*: UNFCCC. 7 pp.

United Republic of Tanzania. (2007). *National adaptation programme of action (NAPA)*. Division of Environment. Dar es Salaam, Tanzania: Vice President's Office. 52 pp.

United Republic of Tanzania. (2016). Tanzania's forest reference emission level submission to the UNFCCC. Dar es Salaam, Tanzania: Government of Tanzania. 36 pp.

World Bank. (2016). Population density: FAO and WB estimates. Accessed 16 January 2017 at: http://data.worldbank.org/indicator/EN.POP.DNST

Vanlauwe, B., & Giller, K. E. (2006). Popular myths around soil fertility management in sub-Saharan Africa. *Agriculture, Ecosystems & Environment*, *116*(1), 34-46.

Vernon, R. (1983). *Field guide to important arable weeds of Zambia*. Chilanga, Zambia: Department of Agriculture.

Walker, B., Carpenter, S., Anderies, J., Abel, N., Cumming, G., Janssen, M., Lebel, L., Norberg, J., Peterson, G. D. & Pritchard, R. (2002). Resilience management in social-ecological systems: A working hypothesis for a participatory approach. *Conservation Ecology*, 6 (1): 14.

Walker, B., Holling, C. S., Carpenter, S., & Kinzig, A. (2004). Resilience, adaptability and transformability in social–ecological systems. *Ecology and Society*, *9*(2).

Watkiss, P., Bonjean, M. & Shaghude, Y. W. (2012). The economics of climate change in Zanzibar. Zanzibar: Global Climate Adaptation Partnership. 44 pp.

Wildlife Conservation Society. (2012). Protected area spatial planning for Unguja and Pemba islands, Zanzibar: A consultancy to the UNDP-GEF - Extending the coastal forest area protected area subsystem in Tanzania. New York, NY: WCS. 42pp.

Williams, A., Masoud, T. S. & Othman, W. J. (1998). Community-based conservation experiences from Zanzibar. *IIED Gatekeeper Series*, 80: 16 pp.

WWF. (2017). Eastern African coastal forests: A global ecoregion. Accessed 29 January 2017 at: http://wwf.panda.org/about_our_earth/ecoregions/eastafrica_coastal_forests.cfm

Zimmerer, K. S. (2015). Methods and environmental science in political ecology. In Perreault, T., Bridge, G. & McCarthy, J. (eds) *The Routledge handbook of political ecology*, pp. 150-168. New York, NY: Routledge.

Appendices

A-1: Qualitative interview guide (for community members)

Livelihoods

1. Where do you live, and for how long have you lived there?
2. What is your occupation/main activity?
3. Are you involved in any other activities or enterprises to supplement your main income source?
    a. If yes, do these activities generally change in intensity or importance over the course of a year (e.g. are they seasonal)? Please explain.

Forest resources

4. For how long have you been harvesting forest resources in this area?
5. What resources do you harvest there? Please identify and explain the use of each (e.g food, fuel, medicine).
    a. Do you sell any of these forest products? If yes, what are they used for?
    b. Do you use any forest products inside your household?
6. Do you or other community members take any actions to make sure that the resources continue to be available in the future?
7. Are there any seasonal or cyclical processes (e.g. *masika* and *vuli* rains) that are important in the way that forest processes operate or that people harvest forest resources?
8. Does the forest provide any non-material benefits or services (e.g. leisure time, sacred places) that are important to you?
9. What aspects about harvesting resources in the forest do you enjoy, and what do you find challenging?

Perceptions of the forest environment

10. What are some unique or important characteristics of the forest here?
11. What role does the forest play in…
    a. The wellbeing of the community?
    b. The health of the terrestrial environment in this area?
12. Have you noticed any changes (land use, disturbance, ecosystem health) in the forest over time?
    a. If so, what are these changes?
    b. Do they affect the resources you use?
    c. Do you see these changes as being positive or negative?
13. Do you think the forest will be able to provide necessary goods and services to the community in the future? Why or why not?

Perceptions of forest governance

14. Who owns this forest?
15. How are resources and access managed in this forest? What organizations, committees, groups, or people are involved?
16. Are there any rules (e.g. harvest quotas) about what, where, and when you can harvest?
    a. Are these rules well known and clearly communicated?
    b. Are you familiar with the community forest management agreement (CoFMA)?
17. How have forest managers responded to disturbances in or damage to the forest? Do you think they are flexible enough to adapt to unexpected changes in social or ecological conditions?
18. In your opinion, could the management scheme for this forest be improved in any way? If yes, how?

A-2: Forest quadrat data form

Site ID: _____ LULC type: _____Date:_____, 2016

Community: _____Waypoint name:_____

Waypoint coordinates – UTM Zone: _____ S: _____E:_____

Soil texture/depth: _____ Farm plot or agroforest? Yes / No

Photograph numbers/descriptions: _____

_____

Disturbance(s) and land use change(s) (*whole quadrat*)

Type	Age (est.)	Extent (est.)	Response description

TREES (*whole quadrat, based on* dbh *class*)

Plot area	Species name	*dbh* (cm)	Clinometer		Height (m)	Signs of harvest? (Y / N)
			m	tan°		

DBHs (cm)	<5	5-10	10-20	20-30	30-40	>40
Heights (m)	**<5**	**5-10**	**10-15**	**15-20**	**20-25**	**>25**

OTHER VEGETATION (*2 m² plot only*)

Species name	Count	Growth form type

TREE STUMPS & SEEDLINGS (*5 m² plot only*)

Seedlings and Sapling count		Approx. # species	
Stump count		**Avg. diameter**	

Brief description of forest structure (layers, primary/secondary growth):

_____

FAUNA

Whole quadrat	Number	2 m² plot	Number
Mammal		Ants	
Bird		Other insects	
Reptile/amphibian		Other	

A-3. Species identified during forest surveys in Kitogani and Muyuni A.

	Local name	Scientific name	Growth form	Family	Kitogani	Muyuni A
1	Danzilahindi	*Boerhavia diffusa*	Herb	Nyctaginaceae	x	x
2	Kikwayakwaya	*Stachytarpherta indica*	Herb	Verbenaceae	x	x
3	Kipepe	*Clerodendrum sp.*	Herb	Lamiaceae	x	
4	Kishinde		Herb		x	
5	Kitatu		Herb			x
6	Kitoga	*Bidens pilosa*	Herb	Asteraceae	x	
7	Mamboleo	*Tridax procumbens*	Herb	Asteraceae		x
8	Mandachi		Shrub			x
9	Mbebeta	*Psiadia punctulata*	Shrub	Compositae	x	x
10	Mchakati	*Acalypha fruiticosa*	Shrub	Euphorbaceae		x
11	Mchembelele	*Apporrhiza paniculata*	Tree	Sapindaceae	x	x
12	Mchengele	*Rhus longipes*	Tree	Ancardiacieae	x	x
13	Mchofu	*Monodora grandidieri*	Tree	Annonaceae		x
14	Mchopaka	*Mystroxylon aethiopicum*	Tree	Celastraceae	x	
15	Mdaa	*Euclea racemosa*	Shrub	Ebenaceae	x	x
16	Mdikwe	*Anonna squamosa*	Tree	Annonaceae		x
17	Mdimu msitu	*Suregada zanzibariensis*	Shrub	Euphorbaceae	x	x
18	Mfukaduri		Shrub		x	
19	Mfungajama		Shrub		x	x
20	Mgo	*Flacourtia indica*	Tree	Flacourtiaceae	x	
21	Mgwede	*Encephalartos hildebrandtii*	Tree	Zamiaceae	x	
22	Mjojota		Herb			x
23	Mjoma	*Macphersonia gracilis*	Tree / Shrub	Sapindaceae	x	x
24	Mkaaga	*Eugenia capensis*	Tree	Myrtaceae	x	x
25	Mkangara shamba	*Rapanea melanophoeos*	Tree	Myrtaceae	x	
26	Mkaokao	*Salacia stuhlmania*	Climber	Celastraceae		x
27	Mkeneta	*Dodonaea viscosa*	Herb	Sapindaceae	x	x
28	Mkenge	*Albizia sp.*	Tree	Mimosaceae		x
29	Mkeshia	*Acacia auriculiformis*	Tree	Mimosaceae	x	x
30	Mkoko(-mwitu)	*Sophora inhambanensis*	Shrub	Fabaceae		x
31	Mkole	*Grewia bicolor*	Tree / shrub	Malvaceae	x	
32	Mkonge	*Psychotria bibracteatum*	Tree	Rubiaceae	x	x
33	Mkonokono	*Annona senegaliensis*	Tree	Annonaceae		x
34	Mkumba	*Rhus natalensis*	Shrub	Ancardiacieae	x	x
35	Mkururu	*Diospyros consolatae*	Shrub	Ebenaceae	x	
36	Mkuyu	*Ficus sur*	Tree	Moraceae	x	
37	Mkwamba	*Flueggea virosa*	Tree	Euphorbaceae	x	x
38	Mkwivi		Shrub			x
39	Mlachole/Mlashore	*Tarenna pavettoides*	Shrub	Rubiaceae	x	x
40	Mlangamia	*Cassytha filiformis*	Climber	Lauraceae	x	x
41	Mlapaa	*Polysphaeria parvifolia*	Shrub	Rubiaceae	x	x
42	Mnazi	*Cocos nucifera*	Tree	Arecaceae		x
43	Mnimu	*Citrus limon*	Tree	Rutaceae		x

44	Mnusi	*Maytenus mossambicensis*	Shrub	Celastraceae	x	x
45	Mnusi mwekundu		Shrub			x
46	Mpapai	*Carica papaya*	Tree	Caricaceae	x	
47	Mpesu	*Trema orientalis*	Tree	Cannabaceae	x	x
48	Msasa	*Ficus exasperata*	Tree	Moraceae		x
49	Msiliza	Euclea natalensis	Shrub	Ebenaceae	x	x
50	Msisi	*Tiliacora funifera*	Climber	Menispermaceae		x
51	Mtakasa	*Melhania velutina*	Herb	Stericuliaceae	x	x
52	Mtalawanda	*Markhamia zanzibarica*	Tree	Bignoniaceae		x
53	Mtamagoa	*Antidesma sp.*	Tree / shrub	Phyllanthaceae		x
54	Mtambi		Shrub			x
55	Mtatu	*Dalechampia scandens*	Climber	Euphorbaceae		x
56	Mtongo/Goroamvi	*Strychnos spinosa*	Tree	Loganiaceae	x	x
57	Mtowe	*Ancyclobotrys petersiana*	Shrub	Apocynaceae		x
58	Mtukutu	*Vernonia zanzibariensis*	Shrub	Compositae		x
59	Mtumba	*Dovyalis macrocalyx*	Shrub	Salicaceae		x
60	Mtundutundu	*Mallotus oppositifolia*	Shrub	Euphorbaceae		x
61	Mtungujamitu	*Solanum incanum*	Herb	Solanaceae	x	
62	Muwongoti	*Apodytes dimidiata*	Tree	Icacinaceae	x	
63	Mvyongozi	*Dalbegia vaccinifolia*	Shrub	Fabaceae	x	x
64	Mwafu	*Jasminum fluminense*	Shrub	Oleaceae	x	
65	Mwangwakwao	*Bersama abyssinica*	Tree	Melianthaceae	x	
66	Ndago	*Mariscus dubius*	Herb	Cyperaceae	x	x
67	Nyasi		Herb		x	x
68	Shikiolangarue		Shrub		x	
69	Ukoka	*Panicum trichocladum*	Herb	Gramineae	x	x
70		*Asystasia gangetica*	Herb	Acanthaceae	x	x
71		*Convulvulus sagittatus*	Herb	Convolvulaceae		x
72		*Desmodium sp.*	Herb	Fabaceae		x
73		*Gisekia sp.*	Herb	Aizoaceae		x
74		*Indigofera sp.*	Herb	Fabaceae	x	x
75		*Ipomea sp.*	Herb	Convolvulaceae	x	x
76		*Maerua triphylla*	Shrub	Capparaceae		x
77		*Phymatodes biseriata*	Herb	Polypodiaceae	x	x
78		*Scutia myrtina*	Shrub	Rhamnaceae		x
79		*Setaria pumila*	Herb	Poaceae	x	
80		*Torea mombasiana*	Herb		x	x
81		*Triumfetta annua*	Shrub	Malvaceae		x
82		*Waltheria indica*	Herb	Malvaceae		x

Norges miljø- og biovitenskapelig universitet
Noregs miljø- og biovitskapelege universitet
Norwegian University of Life Sciences

Postboks 5003
NO-1432 Ås
Norway