



A people-centred framework for exploring water, energy and food security in a small developing island

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Abstract

Small developing islands face a number of environmental and social pressures which impact resource security. This study uses a people-centred framework to investigate social-ecological interactions for water, energy and food security. Ten semi-structured focus group discussions were conducted in Pemba and Unguja islands with village elders and leaders. Results demonstrate that shocks and stresses affecting resource security are attributed to land use and resource competition, deforestation, climate change and insufficient resource infrastructure. The scale and strength of such pressures are heightened in dry seasons and also correspond with spatial characteristics such as remoteness, intensity of land use and amount of natural resource capital. Whilst a number of adaptive responses are identified, these appear to be incremental and do not address the scale of the challenge. Maladaptive responses are also identified; most concerning is the use of poor quality water when piped water was disrupted, reduced nutritional intake during dry season and using unsustainable supplies or methods of obtaining of fuelwood. Findings illustrate the importance of using people-centred approaches for understanding the complexity of social-ecological interactions for resource security. They also demonstrate that interventions for resource management need to consider spatial heterogeneity and temporality in terms of how specific land cover uses connect to differential pressures and adaptation capacity over time.

Keywords Climate change · Socio-ecological · Land use competition · Deforestation · Resource management · Adaptation · Maladaptation

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Introduction

Communities living in small developing islands face a number of emerging threats to livelihoods due to both environmental and climatic change (Poti et al., 2022). They are exposed to greater tropical and extratropical cyclone frequency and intensities, increasing air and sea surface temperatures, variable rainfall patterns and the associated impacts of sea level rise, such as swell waves, storm surges and sea water inundation (IPBES, 2018; Duvat et al., 2020; Mycoo et al., 2022). The effect of such threats on ecosystems is concerning given the strength of social-ecological interactions in small islands, which result from their relative isolation, and particular cultural identities associated with nature-based livelihoods (Nunn & Kumar, 2018). Alongside high exposure to the associated threats of environmental and climatic change, the adaptive capacity of communities living in small islands is also limited due to low-lying topography, scarce natural resources, isolation from major markets, dependence on external imports, competition for space and associated socio-economic pressures (Douglass & Cooper, 2020; Nunn & Kumar, 2018). These conditions make communities and ecosystems in small islands especially vulnerable to rapid environmental change (Cinner et al., 2018; Glaser et al., 2018; Russell & Kueffer, 2019).

There are a number of studies which explore impacts of environmental and climate change on specific livelihood activities in small islands, such as agriculture, fishing or seaweed farming (i.e. Brugere et al., 2020; Makame et al., 2015; Suckall et al., 2014). However, there is less known about how environmental change influences the ways in which people meet their resource needs more broadly. This is surprising given that communities who live on small islands are especially dependent on ecosystem services to meet their basic needs of water, energy and food provision (Astuti et al., 2019; Belmar et al., 2016; Holding & Allen, 2015). There are a limited number of studies that investigate sustainability of systems in small islands more through a water, energy and food nexus lens (i.e. Chen et al., 2020; Winters et al., 2022); more research is needed to understand how rapid environmental change affects water, energy and food security at the community scale (Biggs et al., 2015).

In order to understand how environmental pressures impact on people's everyday resource security, a research approach which focuses on people and their decision making is needed, recognising people as agents of change (Sen, 1980; Wise et al., 2014). Investigating how people respond to new resource pressures unveils how people can adjust and adapt to environmental change (Poti et al., 2022). By paying attention to the conditions in which responses occur, an understanding about levers and barriers to adaptive responses can be also generated (Duvat et al., 2020). Research exploring responses has previously shown that communities in small islands demonstrate an ability to respond to environmental change through collective action, supported by strong cultural identities and social connectedness (Glaser et al., 2018; Cinner et al., 2018). Though communities have previously demonstrated great resilience under pressure, there is an urgent need to determine whether current responses are adequate in light of the scale of challenge faced, given the rapid nature of environment change and the

pressure this is placing on resources (Cinner et al., 2018; Mycoo et al., 2022). It is also important to learn how and why responses emerge across both temporal and spatial scales (Nunn and Kumar, 2018; Berthet et al., 2022). Such insights would facilitate greater awareness about changing social-ecological relationships and allow for feedback effects to be identified (Kurian, 2020). Harnessing this type of local knowledge requires effective input from local communities (Lechuga Sánchez et al., 2021; Tschakert et al., 2017; Wilson & Forsyth, 2018).

Whilst there is awareness that local knowledge is significant in terms of understanding the nature of adaptation, it is often neglected by policymakers and practitioners in sustainable land use and climate change adaptation planning (Holding & Allen, 2015; Hosen et al., 2020; Parsons & Fisher, 2020; Thorn et al., 2020). Overlooking local knowledge can result in failure to recognise emerging critical, autonomous and incremental adaptations that may be most important to coping with environmental change, especially in the absence of formal planning (Hagedoorn et al., 2019; Thorn et al., 2015). When local-level adaptations are not drawn upon in policy planning, planned institutional adaption can even end up being maladaptive by rebounding vulnerability, shifting vulnerability or compromising sustainable development (Juhola et al., 2016; Rahman & Hickey, 2019). Consequently, there is a need for national-level adaptation planning to be informed by locally derived adaption processes (Fazey et al., 2010; Thorn et al., 2015).

This article attempts to contribute to the understanding of how local communities in small islands respond to rapid environmental to meet their water, energy and food needs using the case study sites of Unguja and Pemba. These sites form the two largest islands of the archipelago Zanzibar in the Western Indian Ocean, often under-represented in environmental research (Poti et al., 2022). The aim of the study is to determine if and how socio-ecological relationships for resource use are evolving under environmental change through exploring adaptive responses. The key objectives are to identify key causes of change impacting on resource security; determine whether adaptive responses enable communities to maintain or enhance resource security; and identify any levers which influence adaptive responses to change. Results could be used to centralise local knowledge within planned adaption processes in Zanzibar. They could also be used to inform how agendas such as the Zanzibar Vision for 2050, Sustainable Development Goals (SDGs) or African Agenda 2063 might address resource challenges in small islands more widely. This said, the study should be viewed as exploratory, thus giving initial insights which potentially require further investigation.

Conceptual framework

This study attempts to evaluate how adaptive responses to environmental and climatic change contribute to water, energy and food security. A people-centred approach is applied to facilitate and understanding of how communities perceive environmental change and its impacts and identify actions in response to such change. In doing so, communities are appropriately recognised as agents of change within social-ecological systems (Sen, 1980; Ayeb-Karlsson et al., 2016). The framework pays attention to spatial differences in how people respond to

environmental change, where their adaptive response is temporary or ongoing, and the type of adaptive response they choose to make.

Much of the research in small islands focuses on vulnerabilities concentrated on coastlines due to intense resource pressures and exposure to seaward climate impacts (i.e. Dumaru, 2010; Ferrol-Schulte et al., 2013; Lange et al., 2015; Hagedoorn et al., 2019). However, there are other spatial indicators that might increase exposure to environmental change or people's capacity to adapt in small islands (Margles-Weis et al., 2016). These include factors such as settlement and demographic patterns; lifestyles and economies; availability of natural resources; and environmental conditions (Duvat et al., 2017). Consequently, there is a need to capture how spatial heterogeneity across small islands might affect people's experiences of environmental change on resource security.

Analysis of the temporal dimensions of exposure and vulnerability to environmental change can also reveal how adaptive responses emerge and differ across different social groups (Duvat et al., 2017). Considering the temporality of responses from a community perspective is especially important, given that adaptation is a dynamic process, mediated by people's subjective experience of change (Frank et al., 2011). In this study, temporality of environmental changes is described in terms of shocks and stresses. Shocks are defined as perturbations which are temporarily bound and potentially recoverable, whereas stresses are considered to be ongoing pressures or perturbations which are experienced frequently (Leach et al., 2010).

To explore how social-ecological relationship evolves under shocks and stresses, there is a special focus on identifying adaptive responses. Here, adaptation is defined as "the decision-making process and the set of actions undertaken to maintain the capacity to deal with future change or perturbations to a social-ecological system" (Nelson et al., 2007 p.397). Types of adaptive response are categorised into proactive or reactive responses. Proactive responses are considered to be pre-emptive to avoid declines in resource security, whereas reactive responses are implemented post shock or stress, often after an initial negative impact on resource security (Rahman & Hicky, 2019; Engler et al., 2021). Maladaptive responses are also recognised within the study. Maladaptation refers to less sustainable actions, which are implemented to cope in the short-term and counteract immediate negative impacts (Antwi-Agyei et al., 2014).

Any adaptive response to environmental change occurs within a context, and for this reason, levers and barriers are also considered in the framework. Here, levers are defined as factors which determine the extent to which adaptive responses can occur (Wamsler et al., 2014). Barriers on the other hand are defined as constraining factors which limit adaptive capacity. An understanding of levers and barriers can offer an opportunity to modify conditions to enable more effective adaption (Haasnoot et al., 2020).

Study area

Zanzibar (Fig. 1) is a semi-autonomous territory, which has a political union with Tanzania but its own administrative government. The population growth rate was c. 3.1% in 2013 and is expected to fall to 2.8% by 2035 (OCGS, 2015). The mean

elevation is less than 20 m above sea level (Khamis et al., 2017). The islands have a humid tropical monsoon climate with 1600–1900 mm annual rainfall and an average annual temperature of 27.5 °C (DoE, 2009). There are four main seasons: “*kaskazi*” (hot season) between December and February; “*masika*” (long rainy season) between March and May; “*kipupwe*” (cold season with high winds) between June and September; and “*vuli*” (short rains) between October and December.

Most (approximately 95%) tourism occurs in Unguja, which contributes to 20% of the GDP. Historic lower rates of tourism in Pemba are due to limited transport, electricity and housing infrastructure and advertising (DCCFF, 2007). Today, coastal spaces are being altered by tourism infrastructure, associated water and waste management demands (Slade et al., 2012) and sand mining (Ladlow, 2015).

The majority of Zanzibar’s residents are still heavily dependent on marine and terrestrial resources and resource-based subsistence activities. Agriculture employs 42% of the population and contributes a quarter of the country’s GDP (RGoZ, 2009). Important cash crops include coconut, mangoes, tomatoes and cloves (Suckall et al., 2014; OCGS, 2015). Agroforestry, where trees and shrubs are grown in and around crops or pastureland, contributes to 2.8% of the GDP (OCGS, 2015). Conversely marine ecosystem services account for approximately 30% of the local GDP (Hugé et al., 2018) including deep and shallow water fishing for octopus, squid, crabs, shrimps and mussels, seaweed farming and more recently sponge and pearl farming (Suckall et al., 2014) (see Fig. 2).

Forest covers 28.9% of the land (Mwalusepo et al., 2017). Indigenous coral rag forests offer multiple benefits; they are an essential habitat for the Red Colobus monkey (endemic to Zanzibar) but are being overharvested for fuelwood needs (Nowak and Lee, 2010). They are also used for pegs and sticks for seaweed (Said & Misana, 2018). Protected forests include Jozani-Chwaka Bay, Kiwengwa-Pongwe forests and Ngezi. Coral rag forests are not fully acknowledged in terms of management and protection (Käyhkö et al., 2011); whilst in some ward areas, they might come under protection through community-based forest management plans (CoFMAS), they are not formally protected nationally.

As Zanzibar islands do not have permanent freshwater bodies, the population relies on rainwater aquifers to meet their needs. Differences in water density ensure that fresh groundwater floats on saline ocean water that permeates the porous geological sub-structure of the island, and this results in the creation of freshwater lenses. The east coast of Unguja experiences the lowest levels of rainfall, elevated levels of transpiration and water demand pressures from the tourism industry, making it particularly susceptible to water scarcity (Gössling, 2001). Zanzibar’s water authority (ZAWA) abstracts water from caves to supply several communities with water via untreated pipelines. Villages on the east coast are largely supplied by pipelines connected to sources further inland. Not all villages are connected to a pipeline, and some rely on locally constructed wells or caves (Gössling, 2001).

Zanzibar’s electricity supply is provided through a submarine cable from mainland Tanzania. Rural villages began being connected to the national grid in the 1980s. However, the uptake is relatively low as it costs the average household 4–6 months’ worth of income to establish the connection.

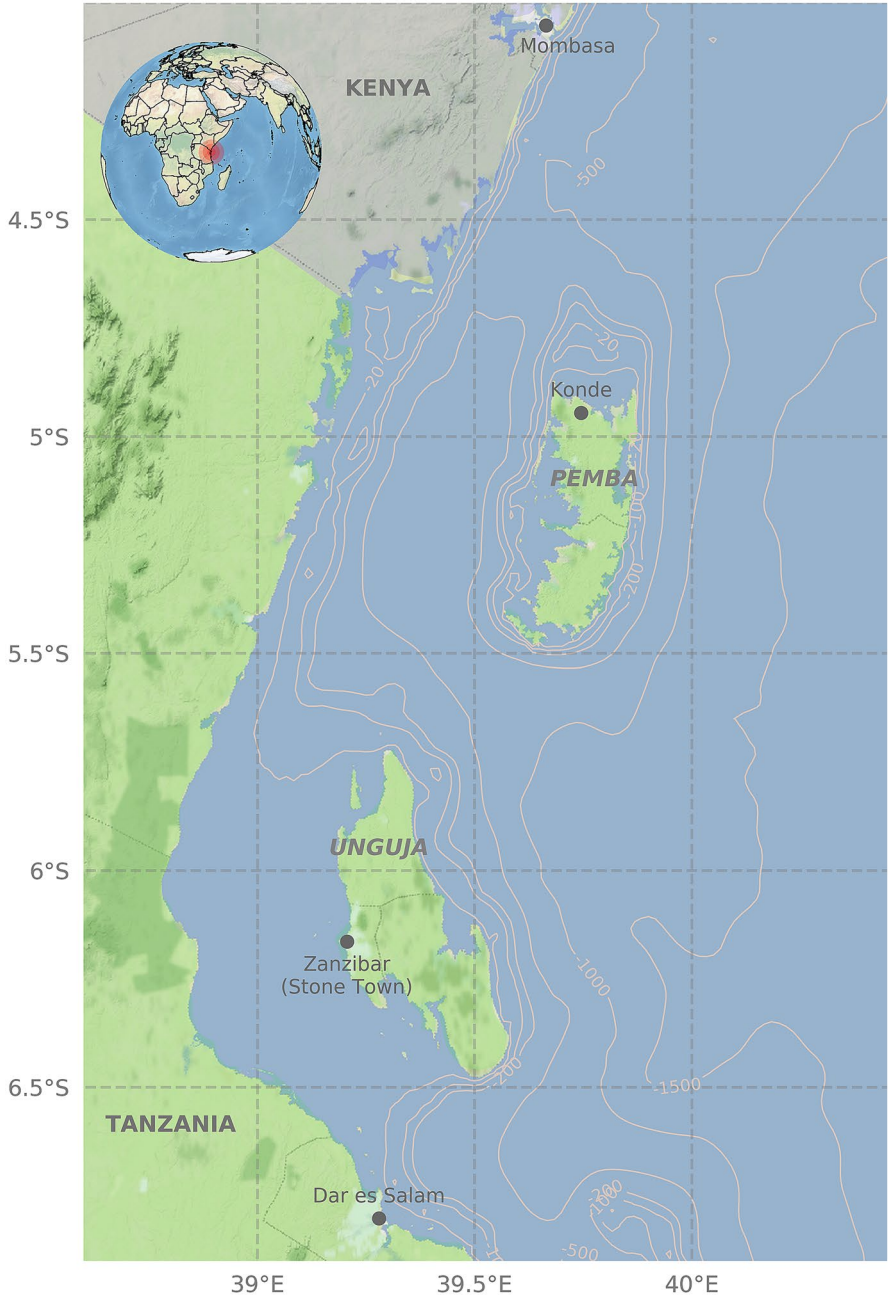


Fig. 1 Location of Uguja and Pemba on the East African coastline, map provided by Leclair (2020)



Fig. 2 Photos of land cover types in Unguja and Pemba, from top left to right including: mangrove forest Kisiwa Panza, Pemba; agroforestry Wambaa, Pemba; Ngezi forest reserve (moist forest), Pemba; Jambiani sandy beach, Unguja including beaches, seagrass meadows, algal beds and coral reefs; clove plantation Kizimbani, Unguja; farming and grassland area Pete, Unguja; small-scale farming Shamiani, Pemba; coral rag forest Pwani Mchangani, Unguja

Methods

Site selection

Ten focus group discussions were conducted covering thirteen “*Shehia*” areas (wards) across Unguja ($n=16$) and Pemba ($n=24$) between April and August 2019 (Fig. 3). Within these sites protected, forest spaces, coral rag forests, peri urban areas, commercial farming and plantation areas, small-scale farming, agroforestry and coastal areas were all represented to ensure inclusivity across land cover types (Table 1).

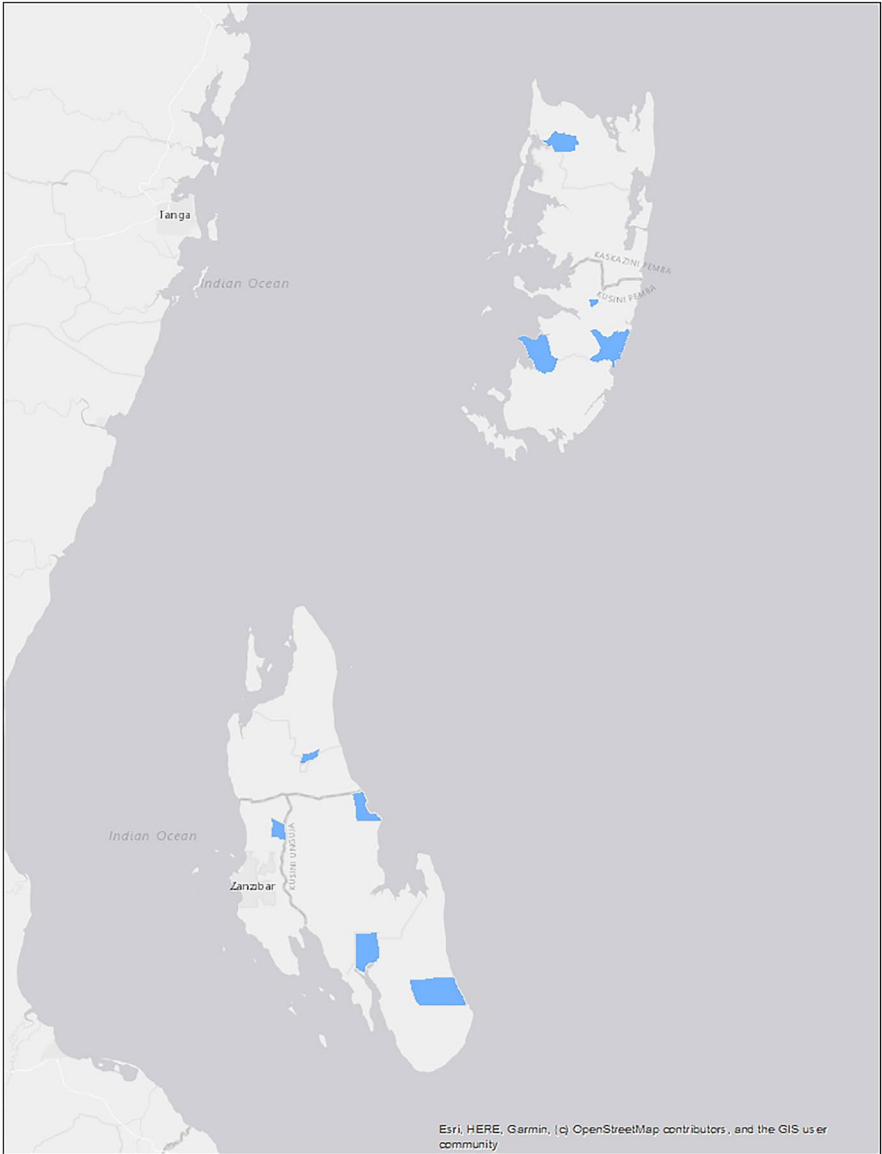


Fig. 3 Sites in Unguja (left) and Pemba (right), coordinates provided by the Department of Renewable and Non-Renewable Resources, Zanzibar

Participant selection for focus groups

Village leaders and elders were selected for the focus group interview because (1) they are respected individuals in the community, maintaining and shaping the social values (Dean, 2013); (2) they have a long-term overview of social, cultural and environmental change with a rooted sense of place (Mustelin et al., 2010); and (3) they have important roles in knowledge construction at the family level and broader social transformation (Holmes, 2002). In Zanzibar, engaging with village leaders and elders in the first instance is also the respected protocol and is important for building longer-term community relationships.

Local regulations were followed in terms of engaging the “*Sheha*” (village leader) to gain permission to conduct the research, select participants and discuss the research agenda. As the project was supervised by the Department of Forestry and Renewable and Non-Renewable Resources in Zanzibar, a representative from this government department made contact with the village leaders, village leaders then engaged village elders. Village leaders were asked to select at least one woman and one man to be part of the discussion.

Focus group framing

The first author spent 9 months living and working in rural, urban and peri-urban sites in Unguja and Pemba: from April to September 2018, based in Stonetown and Pwani Mchangani, and then from February to April 2019, based in Pwani Mchangani and Macho Mane. This period encompassed the “*masika*” rainy season to observe seasonal variability in livelihood activities. During this time, the lead author was embedded in the day-to-day activities of community members. Observations were made around local people’s perceptions about the causes of environmental change and their impacts on water, energy and food security. These observations then informed the objectives of the study and themes of the focus group discussions.

Focus group discussions

Focus group discussions were used because the dynamic of a group discussion stimulates memories of historical changes and gives space for different perspectives regarding events (Kitzinger, 1995), therefore allowing for a robust synthesis of social-ecological changes to be developed. The core themes in the focus group discussions included social context, demographic changes, responses to changes in resource security and visions for the future (see Appendix 1 for full list of guidance questions). Questions of change were temporally bound to the preceding 20 years because this was a period in which respondents could relate to in terms of their personal memory. Interviews were conducted in Swahili, with the support of a translator, at the homes of village leaders or in communal halls. They lasted approximately 2 hours and were recorded with a dictaphone. Participants were informed of their rights, including consent, anonymity and voluntary participation. Participants were remunerated for their time as is common across Tanzania.

Table 1 Focus group locations and attendance of participants

Focus group location	Shehia (village) areas included	Main land cover type represented	Participants included
Macho Mane	Macho Mane and Mkoroshoni	Peri-urban	Two <i>Shehas</i> (men: 2) and four village elders (men: 2, women: 2)
Mfikiwa	Mfikiwa	Commercial farming	One <i>Sheha</i> (women:1) and two village elders (men: 1, women: 1)
Pujini	Pujini and Dodo	Commercial farming and mangrove cover	Two <i>Shehas</i> (men: 2) and four village elders (men: 2, women: 2)
Chumbageni	Chumbageni and Wambaa	Coastal with some tourism	Two <i>Shehas</i> (men: 2) and four village elders (men: 2, women: 2)
Mji Mpya	Mji Mpya	Protected forest	One <i>Sheha</i> (men: 1) and two villages' elders (men: 1, women: 1)
Jambiani Kikadini	Jambiani Kikadini	Coastal with high levels of tourism	One <i>Sheha</i> (men: 1) two village elders (men: 1, women: 1)
Pongwe	Pongwe	Coastal with medium levels of tourism and some mangrove cover	Three elders (men: 1, women: 2)
Kinyasini	Kinyasini	Peri-urban and commercial farming	One <i>Sheha</i> (men: 1) and two village elders (men: 1, women: 1)
Kizimbani	Kizimbani	Commercial farming (in particular spice farming)	One <i>Sheha</i> (women: 1) and three village elders (men: 2, women: 1)
Pete	Pete	Protected forest reserve and mangrove cover	One <i>Sheha</i> (women: 1) and two village elders (men: 1, women: 1)

In Shehia areas where there had been subdivisions in the last 20 years, both areas were included due to the temporal scope of the study. Sites were selected to represent a range of land cover types; the main reason for the selection is highlighted bold. All sites had areas of small-scale farming. Participants included women ($n=17$) and men ($n=23$)

As the village leader's role is often to communicate on behalf of the community, or disseminate information to the community, there was a risk that their status could result in a dominance effect (where one person mainly contributes to the discussion) or a halo effect (where the status of one person influences the discussion) (Nyumba et al., 2018). To facilitate a more balanced discussion, questions were directed at different individuals within the group at various points of the discussion. The facilitator was also encouraged to draw out discussion from quieter participants.

Analysis

Notes were taken during the focus group discussions and were analysed together with the transcripts to connect specific details with contextual elements and thus offer a more integrative and holistic understanding (Hamo, 2004). Data was analysed in NVivo 12 Pro and systematically coded using a cross-sectional coding and retrieval method (Spencer et al., 2003). Shocks and stresses were delineated to demonstrate their perceived causes. Adaptations were organised into four main themes: proactive, reactive, autonomous or maladaptive. Key illustrative quotes were used to demonstrate how environmental and socio-economic changes had altered resource security alongside adaptation strategies.

Results

Identified shocks and stresses

Results from the focus group discussions revealed a number of shocks and stresses which impact resource security. Shocks included crop pests and diseases, disruptions in piped water supply, flooding from rainfall events and infrequent sea water inundation (i.e. seemingly a one-off event). Stresses included frequent harvest losses attributed to climate change, frequent sea water inundation, depletion of fuelwood sources, reduced space for farming and soils and reductions in soil fertility. Whilst we focused on terrestrial landscapes, participants also raised concerns over sea temperature increase and the lowering of fish stocks and seaweed farming yields in coastal areas. Shocks and stresses were thought to be caused by land use competition, deforestation and forest degradation, climate change and inadequate service infrastructure (see Fig. 4).

Land cover types associated with a higher prevalence of shocks and stresses included coastal areas, especially areas with mangrove forest cover. This was thought to be because as well as facing more generalised pressures, coastal areas also faced specific pressures associated with sea level rise, seawater inundation, salination of groundwater supplies and in some cases land use competition associated with tourism. In Unguja specifically, a large number of stresses were also found in the area adjacent to a protected forest. This was partly because it is also next to a large mangrove forest and experiences seawater inundation. Key differences between islands included a higher prevalence of soil infertility mentioned in Pemba

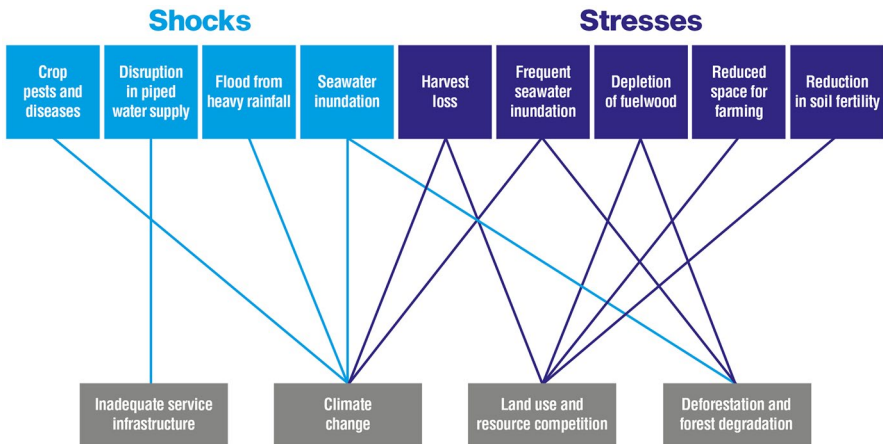


Fig. 4 Shocks and stresses categorised into key factors driving associated shocks and stresses according to connections identified in focus groups. Three of the categories demonstrate multiple linkages and are selected as the main focus for drivers of change in this study

than Unguja and saltwater intrusion of groundwater occurring only in the sites surveyed in Unguja (see Table 2).

Impacts on resource security

Inadequate service infrastructure

Inadequate service infrastructure was described as a challenge for water and energy security, despite improvements in the provision of electricity and piped water across both islands. Whilst some villages had access to a continuous supply of piped water, others were yet to have a connection at all and have to buy water supplies using transport, travel to collect piped water or use lower quality well water. Well-connected villages still faced perturbations when pipes need repair or electric pumps cannot function, though this is described as infrequent.

Despite the frequency of power cuts that occur across Zanzibar, it was only mentioned as a minor issue in one focus group. This was possibly because electricity use was often limited to phone charging and lighting so power cuts may not have been perceived as a significant disturbance. Greater utilisation of electricity was in many cases not achievable due to the lack of financial capacity to invest in appliances such as fridges and ovens, so fuelwood remains the primary source of energy. Few households used solar panels for charging phones and lighting.

Climate change

Climate change presented another major cause of challenges for resource security. Across all study sites, participants agreed that climate has altered over the last 20 years, as detailed by a participant in Pemba's peri-urban area:

Table 2 Shocks and stresses occurring over different land cover types in Pemba (*P*) and Unguja (*U*)

	Peri urban		Coastal		Protected forest		Commercial farming	
	<i>P</i>	<i>U</i>	<i>P</i>	<i>U</i>	<i>P</i>	<i>U</i>	<i>P</i>	<i>U</i>
Crop pests and diseases								
Disruption of piped water supply								
Flood from heavy rainfall								
Seawater inundation								
Harvest loss								
Frequent seawater inundation								
Depletion of fuelwood								
Reduced space for farming								
Reduction in soil fertility								
<i>Total</i>	4	4	6	6	3	5	5	4

The climate has really changed in the last twenty years. Now in the dry season the sun is very hot and in the rainy season the water is not as strong as before. Twenty years ago, the rain would be strong and could continue over several days, but today it lasts a few minutes and stops. (Macho Mane and Mkoro-shoni, April 2019)

Lack of rainfall was thought to have caused reductions in crop yields through drying of the crops as well as increased risk of pests and diseases. It was also thought to have impacted the health of cows due to the resultant lack of fodder. The unpredictability of rainfall was also found to be an issue, as when it falls out of season standing water can increase the risk of disease and cause rotting of ground crops, such as cassava and sweet potato.

Sea level rise and wave over wash, attributed in part to climate change, caused problems for both water and food security. In Wambaa, a coastal area of Pemba, sea water inundation led to salinisation of agricultural land, impacting local food security.

Land use and resource competition

Settlement expansion, arising from population growth, the continued practice of subdivision of plots across generations and coastal squeeze from tourism, reduced the availability of agricultural land for smallholder farming plots, predominately in Unguja (see Table 3). Limited agricultural land resulted in continuous farming with no fallow periods or crop rotation. A participant in Jambiani Kikadini outlined the impact of this on food security:

The majority are now buying [food] whereas before they would normally produce more foods and buy only a few. The changes are because of population increase, the area to farm is reduced. (Jambiani Kikadini, July 2019)

Some participants perceived that land scarcity also contributed to a decrease in soil fertility due to the resultant intensification of farming. In the peri-urban area

Table 3 The distribution of (1) identified changes to climate; (2) types of deforestation and (3) causes of land use competition, and (4) issues with service infrastructure—across key land cover types and islands

	Peri urban		Coastal		Protected forest		Commercial farming	
	<i>P</i>	<i>U</i>	<i>P</i>	<i>U</i>	<i>P</i>	<i>U</i>	<i>P</i>	<i>U</i>
1 Hotter dry season								
Less rain in rainy season								
Longer dry season								
Changes to sea level or temperature								
Unexpected rainfall								
2 Community forest								
Mature forests								
Commercial forest								
Mangrove								
3 Settlement expansion								
Coastal squeeze								
4 Perturbations in piped water supply								
Inadequate piped water supply								
No access to electricity								
Total	6	4	6	10	5	7	6	5

of Pemba and coastal area of Unguja, participants discussed increasing the use of chemicals (e.g. fertiliser, pesticide and insecticide):

Right now, [...] the soil fertility has declined, so if you put the fertiliser or you don't put the insecticide, you will get nothing or low product. (Pongwe, July 2019)

This said, farming inputs could also be connected to the transition from small-holder subsistence (e.g. cassava, sweet potato, bananas) to commercial high value cash crops (e.g. tomatoes, cabbages, watermelon).

In addition to challenges related to crop production, land use competition contributed to conflicts between farmers and pastoralists as livestock encroach into cultivated areas; this was observed in Pete, Unguja.

Alongside challenges related to land scarcity were issues of increased demand for resources. In Pete, the Sheha explained that:

The price [of food] has increased because of the demand from tourism means that the communities are not supplied. (Pete, July 2019)

This was thought to be especially the case in high seasons for tourism, which coincide with dry season, causing an exacerbation in food security.

One village elder in Pemba also commented on how the capacity of people to share resources has declined, compromising reciprocity:

Before you didn't have to ask permission to collect dry clove wood you could just go and get it. But now you must go to the owner and get permission and he might say no because he needs it himself. (Chumbageni and Wambaa, April 2019)

This points to a general decline in resource availability, which may affect the traditional social dynamics within this small island context.

Deforestation and forest degradation

Deforestation and forest degradation were raised as a concern across all sites. Due to extreme overharvesting of coral rag forests, evidence from inland and coastal areas across both islands suggests commercial forests (including clove and mango) were being harvested for fuelwood. In some coastal areas mangrove forests were also being used for fuelwood and timber in the construction of houses.

Agricultural expansion was another cause of deforestation, outlined in a focus group based in a commercial farming area in Pemba:

The forest in Mfikiwa has been gone since 2000 because we needed more space for farming, and we cut it for building and for making charcoal [...] we lost the forest very fast because we had the chainsaw. (Mfikiwa, April 2019)

In Unguja, anxiety around land acquisition for the gazettelement of the protected forest was communicated as a major driver in rapid deforestation:

There was a huge amount of forest loss 12 years ago, where one big area was cleared. This was because in 2004 the national park policy came into effect and they needed a big area to meet the conditions, so they took a large area of Pete village. The community felt that the remaining forest would be taken by the national park, so we cut the trees and planted crops instead, as they would not want the empty land. (Pete, July 2019)

Deforestation has had multiple implications for livelihoods. Mangrove deforestation and degradation were thought to be the main cause for seawater inundation into coastal villages. In Wambaa, Pemba, deforestation of mangrove contributed to coastal inundation and the salinisation of agricultural soil.

Communities in Kinyasini, Kizimbani and Pongwe specifically made the association between deforestation and reductions in groundwater levels, as seen in lower water levels in village wells:

Water is reduced because the forest attracts rain. In the past, there was much [more] water in the rivers. [There was] even [water in the rivers] in summer, because the forest was thick, but now there is a shortage of water. (Kinyasini, July 2019)

In Mji Mpya, adjacent to Ngezi forest reserve in Pemba, the community also described a relationship between forest and rainfall:

We get a good amount of rain because the forest is breathing well to get rain, it's also cooler here because the forest keeps things cool. (Mji Mpya, April 2019)

Insights into the benefits of forests for water security appeared to give communities greater motivation for protecting forest spaces.

Responses to shocks and stresses

Responses to shocks

Adaptation to shocks affecting resource security was limited, but there were two examples, both reactive. After two heavy rainfall events, evidence from the coastal site in Pemba demonstrated community cohesion as the community, with support from the government, worked together to repair damage and recover. Similarly, after a seawater inundation event in the same area, the community lobbied for a seawall to protect agricultural plots, thereby attempting to tackle the cause of the shock and enhance robustness through preventing further inundation events (see Table 4). However, participants commented that they still experienced inundation, as the seawall just redirected the water. So, whilst the agricultural area was protected, there were still some ongoing concerns.

Responses to stresses

There were a greater number of examples identified for reacting to stresses. For example, in response to perceived sea level rise, the community in the coastal area with high levels of tourism in Unguja demonstrated a trend of proactively relocating their household plots landward. This coincided with the selling of beach plots for tourism—allowing people to resettle and have funds to build the “modern house” using blocks and corrugated iron sheet roofing in place of coral rocks and dried coconut leaves or grass. In reaction to sea water inundation, one community planted

Table 4 Responses to shocks and stresses (1) positive adaptations in response to shocks and stresses and (2) maladaptive responses to shocks and stresses

	Peri urban		Coastal		Protected forest		Commercial farming	
	P	U	P	U	P	U	P	U
1 Collaborative recovery after flood								
Construction of sea defences								
Improvement of water infrastructure								
Improvement of electricity infrastructure								
Benefit sharing from ecotourism								
Relocation landwards								
Establishment of woodlots								
Alternative livelihood								
Migration								
2 Reverting to well water use								
Using poor quality fuelwood								
Travelling further for fuelwood								
Using unsustainable fuelwood								
Buying fuelwood								
Decreasing nutritional intake								
Relying on food imports								
Intensification of agriculture								

trees along the coastline. Similarly, another planted mangroves and filled some areas with gravel to try and redirect water away from the village.

In both coastal and peri-urban areas in Unguja, communities were proactively establishing woodlots for personal and or commercial provision in response to fuelwood depletion. Also, in attempting to cope with instances of drought, some farmers were proactively implementing irrigation systems connected to individually dug boreholes—though this was thought to be very limited.

More broadly, in response to ongoing stresses, there was a reactive transition away from subsistence based livelihoods to income-generating roles was communicated. This was described as partly due to the unsustainability of traditional roles, as described by an elder in Pemba:

A lot of people who used to do farming have had to find alternative work. This is because there is a lack of fertility in the soil, before you could have a small plot and grow a lot but now even if you have a big plot, you can only harvest a little. (Macho Mane and Mkoroshoni, April 2019)

Alongside a lack of interest to continue with subsistence-based livelihoods:

There is more education of people but there is a loss of culture to do cultivation and traditional livelihoods because people feel too proud. (Chumbageni and Wambaa, April 2019)

As a result, there was an increase in the movement of people to urban areas, coastal areas or areas with greater natural capital. Coastal areas offered more informal and formal employment opportunities relating to tourism and also attracted seasonal fisher's, urban centres attracted vendors, and areas with natural capital appealed to farmers and pastoralists.

Maladaptive responses

A number of maladaptive responses to resource insecurity were also identified. For example, evidence from Pemba and Unguja demonstrated that when piped water supply is insufficient or disrupted, people reverted to well water (especially during the rainy season), which is of lower quality, therefore increasing their risk to waterborne diseases. Communities from all sites also stated that some members of the community still use well water; it is unclear why, but the 4000 Tsh per month cost to Zanzibar's Water Authority (ZAWA) for piped water could be a potential factor. Whilst it is advised by the health authority that well water should be treated by boiling, it is acknowledged by participants in Pemba that in most cases people do not do this. As the piped water supply is deemed reliable, communities are sometimes not maintaining the quality of well water through treatment (communities refer to treating with calcium or "water guard"), so when faced with a disruption in supply, the quality of the water they revert back to is poor.

Maladaptive responses were also identified with regard to maintaining fuelwood supplies. The reduction in availability and access of fuelwood resulted in communities across coastal regions, areas with high levels of commercial farming and even

adjacent to protected forests, travelling further to collect fuelwood, sometimes into other villages boundaries where there are remaining forest stands. Distance travelled to collect fuelwood could go up to 5 km from their households. This increased the time budget for collection of fuelwood, a task found to be mostly undertaken by women and girls. Some people in peri-urban communities transitioned to buying fuelwood. However, in peri-urban areas and commercial farming areas, some households reverted to using lower quality fuelwood, such as dried coconut palm, sawdust or thinner sticks. Moreover, as outlined above, in areas where community utilisation forest (coral rag) is depleted, communities sometimes used plantation forest or protected mangrove forests to meet energy needs; this is counterproductive as plantation yields could be reduced and coastal defences weakened.

Communities further described maladaptive strategies for coping with food insecurity when food production in household farms is low, which is particularly pertinent in the dry season. Communities often reacted by rationing their food supply or changing their diet. This meant that households limited their food intake by eating less meals a day, having a smaller portion size or eating a higher proportion of carbohydrate to compensate for lack of protein and vegetables. In one village in Pemba, elders explained that this had implications for the health of children, resulting in a swollen stomach from severe malnutrition. As a result of gradually declining harvests due to reduced soil fertility and space for farming, communities also indicated a growing reliance of bought food items:

Before there was enough food and people were farming for themselves, but now people are depending on the shops because the crops in the farm are few. (Pongwe, July 2019)

Challenges around food price inflation for imported foodstuffs (especially rice) were raised in nine of the ten sites interviewed. Also, because income-generating opportunities were often insecure, the instability of income causes fluctuations in food security, as stated by an elder in Pemba:

It's also hard sometimes because the price of food is high and the process of getting money difficult. (Chumbageni and Wambaa, April 2019)

The combination of pressures influencing food security point towards more precarious mechanisms for obtaining adequate nutrition, relying on a mixed approach of subsistence farming and buying food, consequently communities experienced greater exposure to multiple pressures as a result.

Levers and barriers

Levers and barriers to adaptation were linked to the landscape. Spatial aspects such as remoteness, resource demand and natural capital resulted in variations in exposure to shocks and stresses and influence adaptive capacity (Table 5). Some social characteristics also shaped levers and barriers. Financial capacity determined whether households could implement irrigation, electricity, solar panels or extension of water pipelines to homes. Education influenced people's adaptive potential

with regard to accessing alternative livelihoods. Enhanced literacy meant that some people were able to move away from subsistence-based livelihoods and into paid employment. This said there were barriers which also impeded this transition, a lack of language and education relating to tourism prevented many from accessing well paid positions in the tourism sector, which is a major employer in Zanzibar. Individuals from local communities were often limited to lower paid positions in roles such as gardening, housekeeping and security.

Discussion

Although social dynamics have been identified as critical to understanding resource security, there has been insufficient understanding about social and cultural contexts within research exploring water, energy and food systems (Albrecht et al., 2018). This is in part due to the lack of qualitative methods (Albrecht et al., 2018; Foran, 2015). The findings of this study contribute to wider research which recognises the importance of local knowledge for understanding responses to water, energy and food challenges, and how these operate according to spatial characteristics over varying temporal scales (Biggs et al., 2015; Schultz et al., 2015; Albrecht et al., 2018). In doing so, this study provides an example of how qualitative methods can be used to gain insights into social-ecological relationships affecting water, energy and food resources.

Findings demonstrate that shocks and stresses affecting resource security are spatially heterogeneous across land cover types in small islands. Four main factors influence the intensity of shocks and stresses; these include exposure to climate threats; land use intensity; quality of natural capital; and remoteness. Key areas for vulnerability to resource pressures included places with intense land use pressures and those with close proximity to the sea. However, findings also suggest that consideration needs to be given to how vulnerabilities in one area might contribute to pressures in less vulnerable areas with high levels of natural capital.

For instance, results here indicate that as forests are depleted in one village, pressure mounts in spaces with comparatively more forest through increased extraction of fuelwood. Evidence from wider literature has also showed that as new sites get connected with piped water, existing connections experience reduced supply (Gössling, 2001; Makame & Kangalawe, 2018). If these effects not pre-empted and sustainably managed, then vulnerability is likely to shift or spread into new areas (Duvat et al., 2017). Considering how feedback effects of social-ecological issues might operate over extended spatial areas, land use management needs to be viewed at the landscape scale, whilst also taking into account place-specific complexities (Schultz et al., 2015).

Shocks and stresses also vary temporally. Water insecurities are exacerbated in the dry season due to inadequate rainfall and high temperatures, which impacts crop growth and freshwater recharge of aquifers (Gössling, 2001). Dry season coincides with increased resource demand from tourism. For instance, Makame et al. (2015) found that competition for seafood means that communities can often only obtain smaller fish such as anchovies, as larger catch is sold to hotels. Water challenges

Table 5 Spatial considerations relating causes of shocks and stresses alongside the villages where they were identified

Spatial feature	Consequence of spatial feature	Villages identified
Remoteness	Inaccessibility of electricity	Mji Mpya
High levels of commercial farming	Increased land use competition and resultant deforestation	Mfikiwa, Pujini, Dodo, Kinyasini
Urbanisation	Increased land use competition and resultant deforestation as well as pollution concerns	Macho Mane, Mkorothoni
Coastal areas populated with mangroves	Risk of sea water inundation and salinisation of groundwater	Pujini, Dodo, Wambaa, Pete
Areas with standing forest reserves	Producing charcoal for supplying other villages, resulting in increased pressures on forests	Jambiani Kikadini, Mji Mpya
High levels of natural capital	Shared benefits from ecotourism which supported the digging of a borehole and installation of a water pump to generate tap water	Pete
Coastal areas popular with tourism	High value of coastal plots to sell or rent	Jambiani Kikadini

on the east coast of Unguja island are also intensified during high tourism season. Communities in villages on the east coast already receive comparatively less rainfall and higher rates of evapotranspiration; this is then layered with extreme rates of over extraction (Slade et al., 2012). Overextraction, alongside increased temperature and decreased rainfall, has contributed to salination of water wells. Makame and Kangalawe (2018) found that in some areas of Zanzibar, communities have no other option than to cook with and drink salinized water due to the lack of alternatives.

Temporality also influenced adaptive response types, with responses to shocks being reactive and responses to stresses often more proactive. Robert et al. (2016) explain that proactive responses are associated with adaptive capacity over time, whereas reactive responses occur instantaneously, meaning that communities adapt without any anticipation. This suggests that reactive behaviour stems from low access to information, which potentially means higher exposure to vulnerability because of a subsequent inability to plan adaption (Andersson et al., 2019; Engler et al., 2021). This said, knowledge about stresses in the study appeared to derive from subjective experience and personal histories, which indicates that before the onset of a “stress”, information may not have been available either. Consequently, there may be differences in responses across the temporal scale of a stress also. Reactive responses in this study were linked to flooding, one because of heavy rainfall and the other sea water inundation. Communities might therefore benefit from early warning weather warnings (Nhamo et al., 2019; Andersson et al., 2019). However, this needs to be coupled with appropriate planned adaption strategies to implement upon hearing such warnings.

As is the case in many small islands, effective community-based adaptation appears to be limited, and does not address the scale of the challenges they face entirely (Mycoo et al., 2022). Attention should therefore be paid to some of the levers which appeared to facilitate adaptive responses (Dumaru, 2010; Mersha & Laerhoven, 2018). In line with existing research, social connectedness is found to enhance the adaptive capacity of communities (Nunn & Kumar, 2018; Petzold & Ratter, 2015). This was especially the case when responding reactively to shocks experienced at the community level. However, findings also suggest that a reduction in resource availability reduces reciprocity, and that there is an increase in the movement of people, in part because of the unsustainability of livelihoods. The effects of resource scarcity and increased movement of people on social connectedness alongside implications for adaptive capacity are still not well understood and need further investigation.

A number of other levers are found to enhance people’s capacity to respond more proactively. Land ownership, especially in tourism hotspots, appears to serve as a currency for responding to change. However, Humura (2014) found that in selling land people in Zanzibar jeopardised their livelihoods through decreased access to beaches, reduced family assets for the future and increased resource competition. They suggest that the government needs to guide local people on how to manage their land assets through joint ventures, which are mutually favourable. Rather than selling land, Scheyvens and Hughes (2019) recommend leasing of land under robust policy frameworks to ensure more long-term benefit sharing from tourism. More research is needed to explore the conditions in which people decide to sell or lease land, alongside the short-term and long-term implications of doing so.

Education is found to enhance people's mobility, meaning when "traditional" livelihoods become unsustainable, they have some capacity to transition into income-generating roles. Poti et al. (2022) found that climate-induced migration occurs within communities across the Western Indian Ocean. Wider research has shown that the likelihood of migrating due to the instability of livelihoods caused by climate change increases with educational status (Bohra-Mishra et al., 2016). Within Zanzibar participants in rural villages explained that men migrate in search of work, internally (often from Pemba to Unguja), but also externally to countries such as Dubai and Europe. Further research is needed to better understand the conditions that support migration and whether it actually leads to more sustainable livelihoods. Research into the experience of women in the community when men travel in search of work is also needed, especially given that they often remain in the village setting. Questions might explore livelihood security temporally; for instance, is an initial increased level of vulnerability in the household when one person leaves in search for employment?

Financial capital further determines whether people can invest in more sustainable practices, such as irrigation, the establishment of woodlots or installation of solar panels. Participants often explained that whilst these activities were deemed effective, they were limited to the few who had financial capital. Considering the strength of social capital in small islands (Petzold & Ratter, 2015), it might be useful to think about how these activities could be implemented as a group rather than individually. This might lend itself with the engagement of supportive institutions and routes to access microfinance. Robinson (2020) proposed that climate finance needs to focus on locally appropriate adaptation, given that planned structural adaptation, such as seawalls, has often been ineffective. This might involve exploring the suitability criteria and barriers to uptake for these identified adaptations, alongside possible funding streams to support implementation and management.

Worryingly, findings suggest that maladaptive responses are common in Zanzibar. Whether an action is adaptive or maladaptive depends in the social-ecological context, which can change over space and time (Wise et al., 2014). Even actions which address a shock or stress in the short-term can often fail to address the underlying causes of vulnerability, leading to maladaptation over time (Kelman, 2013). Poti et al. (2022) state that planned adaptation in small islands appears to be most effective when co-managed with stakeholders, due to the complex network of actors involved. Co-designing planned adaptation could help to address barriers, associated with resources, regulations, governance and learning, which have impacted adaptive capacity in the past (Suckall et al., 2014; Mycoo et al., 2022). It could also help to integrate incremental adaptation on proximate causes with more transformative action (Poti et al., 2022; Wise et al., 2014).

Interconnections between water, energy and food outcomes for adaptive responses were also revealed. In many small islands, there is a general lack of long-term planning for adaptive management strategies which respond to nexus challenges (Ding et al., 2019; Mycoo et al., 2022; Winters et al., 2022). Existing data also often fails to incorporate seasonal differences in shocks and stresses and their impacts across the nexus (Stylianopoulou et al., 2020; Winters et al., 2022). These findings show connections such as the need for electricity to operate water pumps; the link between deforestation for energy and ground water

supply; and the association between ground water supply and food production. In doing so, results reveal water security as a cross-cutting issue across the nexus and possibly an effective entry point for exploring sustainability issues more broadly. They also help to point out interactions between identified causes of shocks and stresses and the implications these have across the water, food and energy nexus. These include land use competition contributing to challenges in fuelwood supply and space for agriculture and climate change impacting water availability and food production. Monitoring of emerging imbalances in the water, energy and food nexus should be central to informing adaptive management, especially in small islands where social-ecological interconnections are so tight (Winters et al., 2022).

Limitations

Future research would benefit from greater input from other social groups, such as youth, as elders often have a role in maintaining traditional cultural identities, and therefore may not portray alternative perceptions. There is also a possibility that more contentious issues might not have been raised considering that (1) the position of the participants made meant they could not be anonymous and (2) the discussions had to be supervised by a member from a government department according to local protocol at the time. To unveil potential political issues affecting resource security, methods which allow for complete anonymity are needed; this might involve one-to-one interviews. Finally, by sampling through gatekeepers, who have a position of power in the community, there is a chance that people who share a similar viewpoint are selected. Future researchers might try to adopt a more random approach to sampling to overcome this.

Conclusion

This study contributes to the understanding of how social-ecological relationships for resource use are changing according to people's experience of rapid environmental change. Findings reveal that inadequate service infrastructure, land use intensity, climate change, and deforestation result in shocks and stresses affecting resources. The most frequently mentioned impacts relate to harvest loss, disruptions in piped water supply and depletion of fuelwood. Several spatial aspects influence the intensity at which shocks, and stresses are experienced; these include exposure to climate threats, land use intensity, quality of natural capital and remoteness. Adaptive responses appear to be limited and mediated by financial capacity, land assets, educational status and social connectivity. Adaptive capacity within communities does not appear to be sufficient considering the number of maladaptive responses found, all pointing to resource insecurity. Insights could be used to target future interventions to support sustainable research management in a way that is both spatially and temporally appropriate for Zanzibar. They could also be used to suggest potential

emerging challenges for resources in other small island contexts, especially within the Western Indian Ocean.

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Data Availability Detailed fieldnotes are available through Rebecca Newman at rebecca.newman@york.ac.uk. Interview transcripts themselves remain confidential due to the traceability of participants.

Declarations

Competing interests The authors declare no competing interests.

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