



Community-centred scenarios development for water–energy–food security on Zanzibar

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Abstract

Small developing islands demonstrate strong social–ecological interactions as well as a high level of exposure to climate-related effects, which can result in intense land use pressures. Scenario methodologies are useful for reflecting on how competing pressures interact when planning for a more sustainable future. In small islands, local knowledge is integral to the development of scenarios because of the close connection between people and local environments. However, local communities are often underrepresented in scenario development processes. This study provides a methodological example of how local knowledge can be used to create scenario themes. Ten community participatory workshops were hosted on Zanzibar ($n = 142$), where a water–energy–food framework was used to examine impacts of environmental change on resource security. Major drivers of land use and land cover change affecting water–energy–food security were identified; these include population growth, development and climate change. Solutions to observed challenges formed three coherent scenario themes, centred on adaptation, ecosystem health and sustainable settlements. Findings support the idea that communities need space to frame their resource challenges for sustainability planning to work at the appropriate scale.

Keywords Sustainability · Livelihoods · Climate change · Ecosystems · Small island developing states · Nexus

Introduction

Communities in small developing islands often depend on ecosystems to meet their livelihood needs, and have become unjustly and disproportionately impacted by rapid environmental change and exposure to climate threats (Nunn

and Kumar 2018). The COP21 statement says that those impacted “must be meaningful participants in and primary beneficiaries of climate action, and they must have access to effective remedies” (p2). The increasing recognition of the importance of self-determination in decision-making, about both climate change adaptation and sustainability, calls for increased scrutiny on existing participatory methods and how these might better represent those affected. This study focuses on how participatory scenarios development processes could better integrate social–ecological insights from communities by applying a water–energy–food nexus framework at the local scale.

Small islands encompass intense pressures under tight spatial scales. Population growth is frequently concentrated in the coastal margins (Neumann et al. 2015); this exerts pressure on coastal ecosystems such as mangrove and coral rag forests, causing a cycle of degradation and increased exposure to climate-related effects such as storm surges, saline intrusion and sea-level rise (Barbier 2015; IPBES 2018). Environmental pressures related to population growth are coupled with competing land use demands from developing tourism infrastructure (Adger 2009; Lange 2015), as well as climate change, characterised by increased temperatures,

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drought, erratic rainfall, severe weather events and warming sea temperatures (Mycoo et al. 2022). Adaptive capacity, or peoples' ability to cope with climate change, in response to such challenges, is limited in small islands due to their small size, degraded natural resources, low lying topography and geographical isolation (Pelling and Uitto 2001; Pomeroy et al. 2006); therefore, effective land planning is needed to ensure the long-term environmental sustainability (Huge et al. 2018).

Participatory scenarios can be used to envisage alternative futures and provide an opportunity to explore the unique opportunities and challenges that communities face (Capitani et al. 2016). In summary, scenarios are alternative future pathways created that identify drivers of change and understand potential land use futures which can inform decision making (Johnson et al. 2012; Oteros-Rozas et al. 2015). Scenario methodologies have become increasingly popular for identifying and addressing potential integrated sustainability challenges for the future (Capitani et al. 2016; Kowalski et al. 2009). For example, they have been used by researchers in the Serengeti to craft pathways for meeting conservation and development goals (Kariuki et al. 2021) and to explore climate-smart options for agriculture in mountains within East Africa (Capitani et al. 2018).

The collaborative process of scenario development fosters multiscale social learning and an appreciation of the complex interactions manifested as land use choices. This helps to sensitise participants to the perspectives and needs of stakeholders at different scales (Kok et al. 2007; Johnson et al. 2012; Oteros-Rozas et al. 2015; Kariuki et al. 2021) and identify issues that might otherwise be missed or disregarded (Kok et al. 2007; Capitani et al. 2018). Consequently, the process of participatory scenario planning helps strengthen understanding between stakeholders, encourage systematic thinking (Johnson et al. 2012) and enhance opportunities for marginalized communities to participate in decision making (Malinga et al. 2013). This increases the durability and legitimacy of scenarios trajectories (Smith and Stirling 2018; Anguelovski et al. 2016; Scoones 2016; Brown and Kyttä 2018).

Whilst community engagement in scenarios processes is highly recommended, it is still limited (IPBES 2018; Kok et al. 2016; Capitani et al. 2018; Kariuki et al. 2021). Though a number of scenarios studies reference multiple stakeholders, this is often restricted to local expert stakeholders based within institutions, so community members (especially in more rural areas) are not represented (i.e., Malinga et al. 2013; Huge et al. 2018). As a result, there continues to be a significant imbalance of how the knowledge and needs of local communities are considered within sustainable land use planning (Fagerholm and Käyhkö 2009). The omission, or ineffective representation, of local knowledge in scenarios outcomes perpetuates the failure of environmental

movements to link environmental issues with wider livelihood challenges (Anguelovski et al. 2016; Scoones 2016).

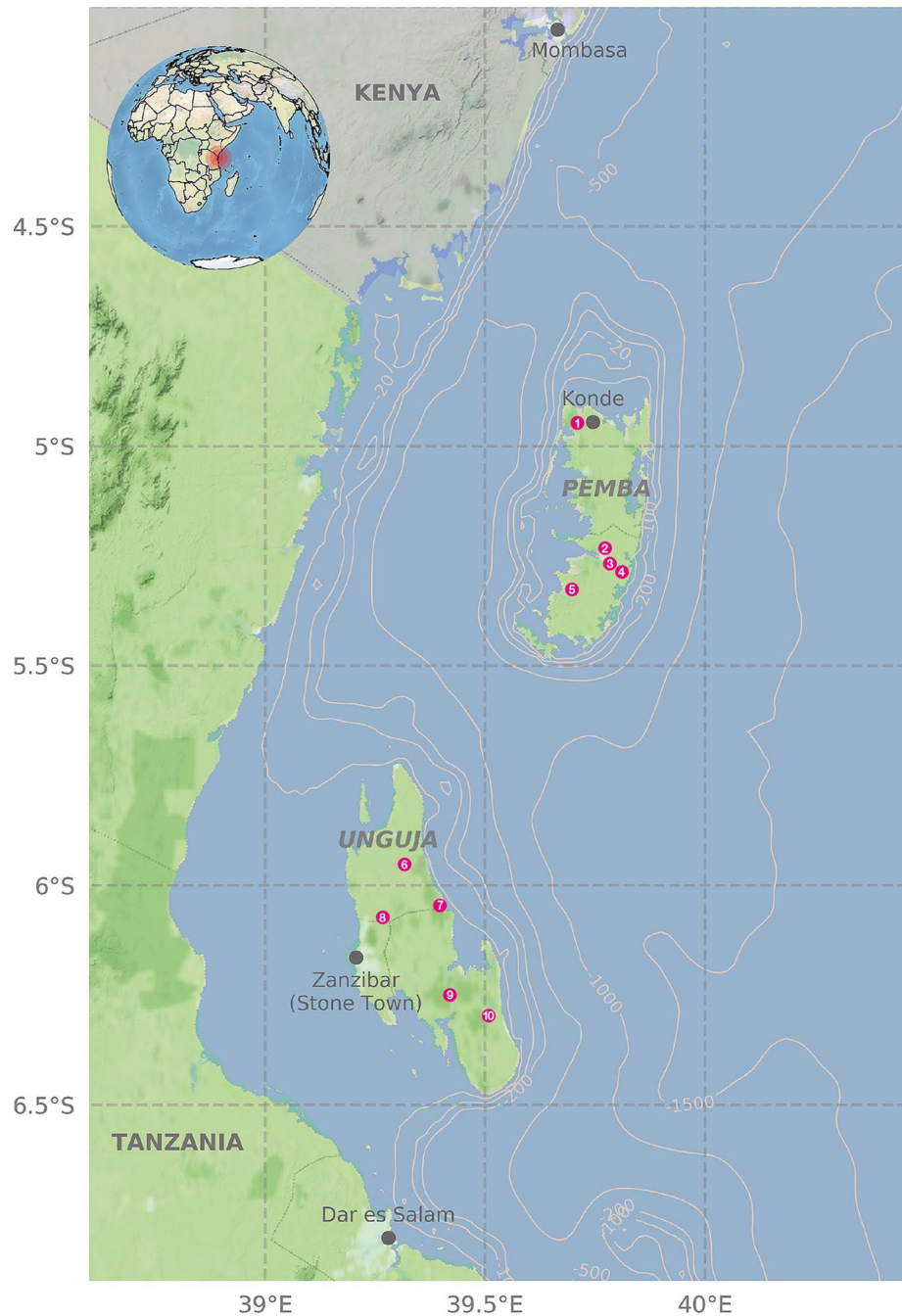
Barriers to inclusion exist even when local communities participate in scenario planning, as power dynamics influence the consensus building processes, whose voice is heard (Cleaver 2005). Barriers to participation previously found in small islands include poverty constraints; self-esteem; asymmetrical power relations; and gendered livelihood roles (Gustavsson et al. 2014; Brown and Kyttä 2018). These barriers need to be addressed to enhance the capacity of local communities in decision making processes and represent complex social–ecological dynamics (Cleaver 1999; Gustavsson et al. 2014). If alternative points of view are not represented and captured in outputs, inequities may be hidden and continued (Oteros-Rozas et al. 2015), thereby overlooking the inequality of adaptive capacity and exacerbating unequal outcomes in sustainability planning (Hodson and Marvin 2010; Anguelovski et al. 2016). Consequently, there is still a need to enhance the capacity of local communities in the scenario process (Capitani et al. 2018). This requires acknowledging the value of local knowledge in political and institutional decision making processes, as well as the importance of inclusive land use planning.

This study creates a locally informed framework for scenarios development which frames challenges and opportunities for sustainability from a community perspective using a water–energy–food nexus lens. The core objectives of the study are to: (1) identify key land use transitions which have or are expected to affect resource security and livelihoods, through the effective solicitation of local knowledge and (2) develop themes for scenario development, based on what communities feel are the appropriate actions for mediating experienced or expected challenges. In doing so, results from this study will be able to inform future multi-stakeholder scenario processes and align planned adaption with locally derived experiences and ideas (Juhola et al. 2016; Duvat et al. 2017; Rahman and Hickey 2019).

Conceptual framework: using a water–energy and food nexus lens for participatory scenarios development

People and environments are intrinsically linked in small developing islands as people interact with natural and biophysical resources to meet livelihood needs (Douglas 2006). Strong social–ecological relationships can be due to the relative isolation and limited livelihood options (Ferrol-Schulte et al. 2013). This is especially true for rural low income groups who are typically more dependent on natural resources (Douglas 2006; Suckall et al. 2014; Moshy et al. 2015; de Jong Cleyndert et al. 2021).

Fig. 1 Location of Zanzibar's two largest islands, Unguja and Pemba, adjacent to the coastline of mainland Tanzania. Map provided by Leclair (2020) with study site locations in Unguja and Pemba islands; (1) Mji Mpya, (2) Macho Mane, (3) Mfikiwa, (4) Pujini, (5) Chumbageni, (6) Kinyasini, (7) Pongwe, (8) Kizimbani, (9) Pete, (10) Jambiani Kikadini



Considering the dependence on the natural resource base and vulnerability context, a sustainable livelihoods approach can be appropriate for exploring social–ecological interactions on small islands (Ferrol-Schulte et al. 2013). However, the nature of livelihoods in small islands are complex, usually operating at a household rather than individual level and encompassing diversification, often as a result of seasonality (i.e., stormy weather rendering fishing unsafe, growing seasons for crops) (Pomeroy et al. 2006). Therefore, exploring livelihood sustainability

through examining the overall resource security perspective could illuminate wider transitions.

This study uses a water–energy–food framework to examine with communities the impacts of environmental change on livelihoods and resource security with the aim of identifying land use transitions and informing land use planning. Chambers and Conway (1992) define a livelihood system as the capabilities, assets (including both material and social resources), and activities required for a means of living. Water–energy–food are seen as essential resources that sustain life and livelihoods (Nhamo

Table 1 Group the study sites with the two islands, Pemba and Unguja

Workshop group location	<i>Shehia</i> (village) areas included	Main land cover type represented
Macho Mane	Macho Mane and Mkoroshoni	Peri urban
Mfikiwa	Mfikiwa	Commercial farming
Pujini	Pujini and Dodo	Commercial farming and mangrove cover
Chumbageni	Chumbageni and Wambaa	Coastal area with mangrove cover and some tourism
Mji Mpya	Mji Mpya	Protected forest
Jambiani Kikadini	Jambiani Kikadini	Coastal with high levels of tourism
Pongwe	Pongwe	Coastal with medium levels of tourism and some mangrove cover
Kinyasini	Kinyasini	Peri urban and commercial farming
Kizimbani	Kizimbani	Commercial farming (in particular spice farming)
Pete	Pete	Protected forest reserve and mangrove cover

et al. 2019). Therefore, knowing how people attain water–energy–food security is crucial for understanding the sustainability of livelihoods (Biggs et al. 2015). In this study, the term ‘resource security’ is used with an understanding that this feeds into the sustainability of livelihoods more broadly.

The water–energy–food nexus is especially useful for exploring sustainability in small islands because of the short time lag between ecological or social disturbance and imbalances in resource security (Winters et al. 2022). By exploring interactions between water–energy–food it is possible to identify synergies and trade-offs for resource security and livelihoods (Miralles-Wilhelm 2014). Consequently, it has been recognised as an important framework for decision makers to evaluate sustainability and implement effective policy, which limit significant trade-offs (Keairns et al. 2016).

Land use and land cover change has multiple implications, both positive and negative, across the water–energy–food nexus (Wolde et al. 2021). How these interactions interconnect in island specific contexts and the effect on resource security and livelihoods is still not well-understood. This study implements participatory scenarios at the community scale to understand how environmental change impacts resource security and livelihoods and identify tangible solutions which could be implemented to respond to actual and emerging challenges. In doing so it begins to tackle the limited involvement of local knowledge in both nexus research and scenario development (Foran 2015; Albrecht et al. 2018).

Study area: the Zanzibar Archipelago

This study focuses on Unguja and Pemba, the two main islands comprising Zanzibar, situated in the west Indian Ocean just 83 km from Dar es Salaam (see Fig. 1).

Zanzibar is a semi-autonomous territory and has a political union with Tanzania but its own administrative government. The islands experience a monsoon climate, with 1600–1900 mm annual rainfall and an average temperature of 27.5 °C (DoE 2009). Rainfall typically falls within two periods, the long rainy season from March to May and the short rainy season between October and December.

Land cover in Zanzibar consists of coral rag vegetation, coastal forests, mangroves, sandy beaches, cultivated forests, tree plantations, woodlands, grasslands, farmlands, parks, settlements and peri-urban and urban spaces (Khamis et al. 2017). Protected forests include Kiwengwa-Pongwe, Jozani-Chakwa Bay and Ngezi forest reserves. Ten mangrove species are found in Zanzibar and are estimated to cover approximately 60 km² in Unguja and over 120 km² in Pemba. Despite extraction being forbidden these are under pressure from exploitation, mostly due to over-harvesting for building poles and firewood or charcoal (Yahya in press). Need for housing, food, income, construction materials, cooking energy and other sources of well-being have resulted in unsustainable pressures on coral rag forests (Käyhkö et al. 2019).

Local livelihood activities, such as deep water fishing, shallow water fishing for octopus, squid, crabs, shrimps and mussels, seaweed farming and more recently sponge and pearl farming, depend upon healthy coastal ecosystems (Suckall et al. 2014). Zanzibar’s coral reefs provide important habitat for reef fish and pelagic species (Yahya in press), as well as coastal protection. However, some of these reefs are endangered due to past destructive fishing practices, tourist activities, pollution and bleaching (Brugere et al. 2020). Seagrass grows in the shallow and intertidal mud and sand flats all around Zanzibar, forming important nursery areas for juvenile fish and foraging areas for herbivorous fish (Khamis et al. 2017).

A substantial proportion of Zanzibar’s community rely on subsistence farming to meet household needs, common

crops include maize, rice, wheat, pumpkins, millet and beans (Käyhkö et al. 2019). Agriculture employs 42% of the population and contributes a quarter of the country's GDP (RGoZ 2009). Important cash crops include cloves, coconut, mangoes, tomatoes, seaweed and copra. Marine ecosystem services also support the socio-economic system in Zanzibar and account for approximately 30% of the local GDP (Hugé et al. 2018). Tourism activity contributes to 20% of the GDP, and now operates across the majority of the north-eastern coastline (Gustavsson et al. 2014). However, local residents have mostly not benefited from employment nor services of economic growth related to tourism (Gustavsson et al. 2014; Käyhkö et al. 2019).

Methods

Participatory scenarios workshops were conducted in ten sites with a cross section of people representing the local community. Workshops supported communities to reflect on resource and livelihoods implications of past change and apply their ideas for managing such issues to the development of alternative scenario visions.

Site selection

The Department of Forestry and Renewable and Non-renewable Resources supported the identification of suitable sites, with an emphasis on sites currently underrepresented in land cover research. The study selected 10 sites in total, with 5 sites on each of the two islands, Pemba and Unguja. These sites are further described in Table 1 and Fig. 1, illustrating their locations.

Participant selection

Village leaders facilitated the engagement of the wider community in the workshops; this was part of the formal protocol for research processes in Zanzibar. Participant selection was purposive to represent both men and women of different age groups (see Appendix 1). A total of ten workshops were undertaken, the number of participants at each ranged from 9 to 17 [Pemba $n=69$ (men 38: women 31); Unguja $n=73$ (men 39: women 34)].

Amongst the participants the average number of children per household in Pemba was seven and in Unguja five. In Pemba 7% of participants were divorced, 72% married, 3% widowed and 17% single. In Unguja 8% were divorced, 75% married, 4% widowed and 12% single.¹ The most prominent

livelihood activities across islands were farming, livestock keeping and fishing (see Appendix 2).

Community workshop design

An initial scoping study was conducted with village leaders and elders to develop a foundation of understanding about changes in how communities interact with their environment to meet their livelihood needs and inform workshop design (see Newman et al. 2021). These included planning meetings were held with village leaders and elders, in which they selected a date for the workshop and made suggestions about the schedule of the day. Shared control of the planning process helps to ensure that communities feel involved in the research process and shifts some of the power from the researcher to the participants (Castleden et al. 2008). In these early meetings the aims and objectives of the workshop were discussed, this was followed by a tour covering the diverse types of land use in the *Shehia*'s. Images of these were later used in the workshops, as visual data is recognized as an effective tool to foster shared understanding in participatory research (Henwood et al. 2018).

Community-based workshops were the primary means of data collection. They were conducted over the course of one full day in each location to limit the time investment needed by participants. Each participant was remunerated appropriately for their time commitment to cover potential work lost. Refreshments were provided throughout the day and scheduled rest breaks were taken. Participants were made aware of their rights to anonymity and withdrawal, consent forms (written in Swahili) were signed. Participants were all given an order of the day schedule which outlined activities. The workshops were held in Swahili and supported by 1–3 facilitators. All facilitators had undergone a day's training to understand the tasks involved and how to support equal participation across genders and age groups and to assist any participant with literacy difficulties (see Appendix 3 for workshop order of the day).

Workshop activities

Participatory land cover mapping

The first activity involved participatory mapping to support knowledge construction around changes in the landscape and to generate discussion around perceived drivers of change. Mapping was used as it can help to identify important places which contribute to water–energy–food security. Consequently, it helps to prioritise future land use management strategies (Fagerholm and Käyhkö 2009; Brown and Kytä 2018). For this activity communities were split into two groups, one group was asked to draw a map of land use

¹ One percent on each island unspecified.

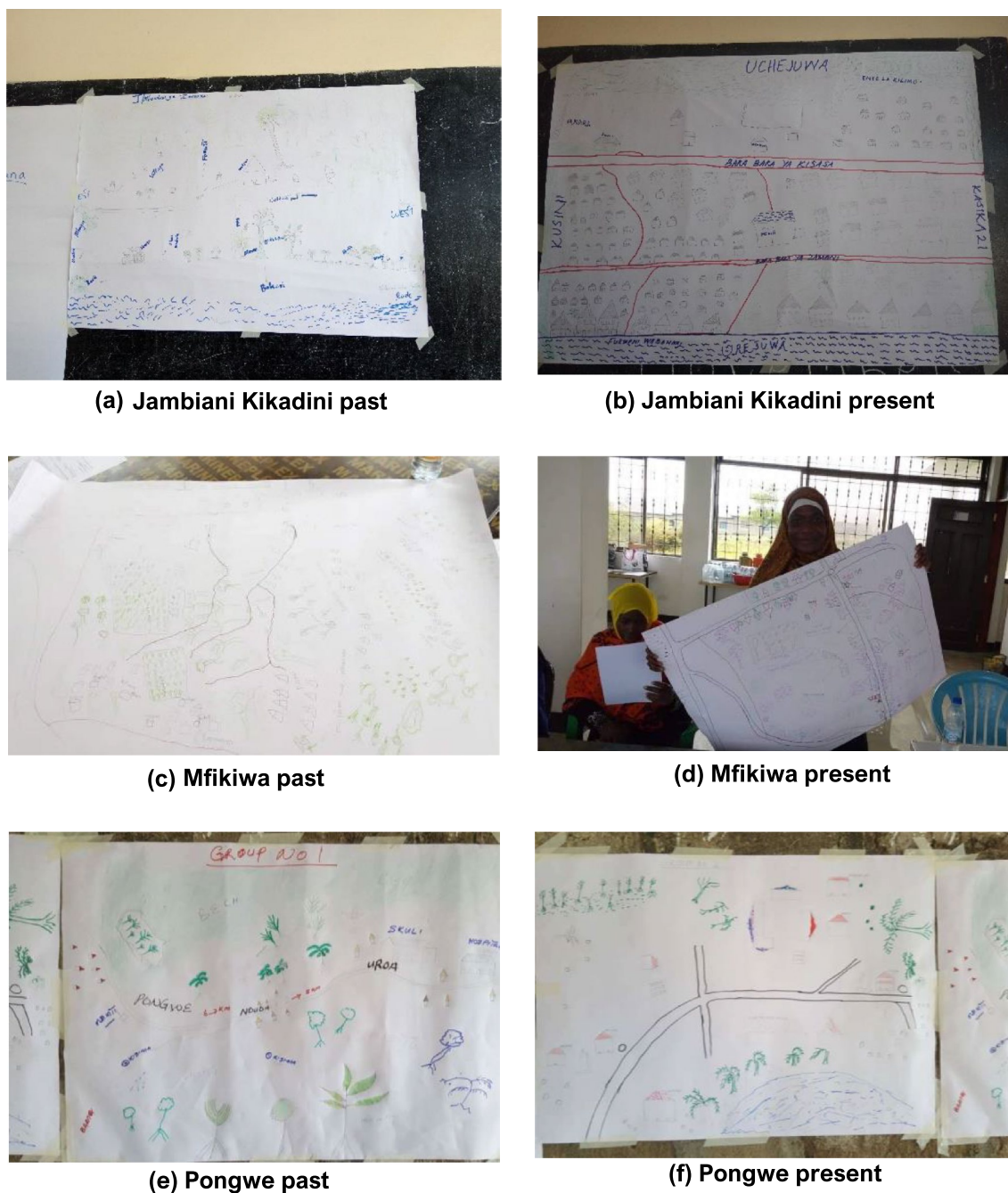


Fig. 2 Examples of community land cover maps for 20 years ago and present day (2019)

and land cover in the village area at present day, the other 20 years ago (see Fig. 2).

The two maps were then presented, and the communities compared them in order to identify land cover changes and discuss what they felt were the drivers of change (see Fig. 3). A list of key drivers was then compiled and displayed on a large piece of paper on a wall. Each individual was given three post-it notes and asked to place them next to what they felt the most significant drivers of change affecting land

would be for the future, in order of significance (1 = highest to 3 = lowest). The ranking activity aimed to equalise power when prioritising the significance of drivers.

Land cover predictions for a BAU scenario

Participants were then split into pairs or groups of three and each given images of a specific type of land cover based on photographs taken from earlier village tours. They were asked

Fig. 3 Top left Pete, top right Mfikiwa, bottom left Jambiani Kikadini, bottom right Wambaa



if they thought there would be any changes to the type of land cover in the next 10 years given the identified drivers previously discussed. This period was used as to align with the sustainable development goals for 2030, and specifically to inform goals 2 (zero hunger), 6 (clean water and sanitation) and 7 (affordable clean energy). They were also asked what the possible impacts could be on the local community and whether there were any solutions which they felt could remedy potential challenges raised. Each group then presented their responses on past and future land use to the wider group.

Water–energy–food security evaluation

During the workshop, each participant was given a form and asked to state their perception of water–energy–food security at present day, 20 years ago, and in 2030 with no changes in land use management (business as usual (BAU) scenario). Security was defined by quality (i.e., nutritious value of food, sanitation of water and calorific value of fuelwood) and availability (actual abundance of resources whether it is enough to meet the needs of a community). Participants evaluated water–energy–food security by assigning a number to each criterion (1 being the lowest quality to 4 being the highest). Opportunities to reflect on changes in resource security through the nexus lens aimed

to stimulate connections between land use and land cover with livelihood outcomes.

Analysis of workshop outputs

During the participatory mapping activity field notes were taken describing of all the drivers of land cover change. These were collated to identify which might be most prevalent in the coming years. Looking at overall prevalence gives a clear indication of areas of focus for national strategies, but results also suggested that drivers differ according to land cover type. To recognise these differences, the number one top voted drivers were also delineated according to land cover type.

Strategies for remediating potential emerging challenges relating to land use and land cover change were coded inductively in NVivo to form clustered themes. This involved reading all of the proposed solutions for addressing land cover challenges and grouping similar concepts together, then deciding on an appropriate thematic name which represents each cluster most accurately.

Pearson's Chi-squared was used in the R statistical package (version R 3.4.4) to explore whether there was a significant difference in the perceived security of water–energy–food in Unguja and Pemba and across time-scales using the participants individual evaluation scores

of quality and availability. The Pearson's Chi-squared test explores whether to accept a hypothesis by analysing whether the data deviates from a normal distribution.

T tests were also performed to determine whether there was a significant difference in these evaluations of water–energy–food security between islands. The Chi-squared and *t* test analysis aimed to determine which aspects of resource security require most focus and whether policy needs to be differentiated between islands.

Results

Identified land use and land cover changes

Settlement expansion was identified across all sites and associated with deforestation and a reduction in available land for farming. In Jambiani Kikadini village, Unguja the settlement shifted landwards due to sea-level rise and the selling of beach plots to hoteliers.

Participants in this study detailed deforestation of coastal mangrove forest areas, commercial plantations for mangos and cloves and coral rag forests as well as around the Ngezi forest reserve (up to the forest boundary). Deforestation was thought to have contributed to reduced water levels in rivers and the drying of oases. It was also linked to a reduction in livestock keeping as people usually keep their animals in the forest.

A number of environmental changes were identified in farming areas, such as reduced soil fertility, limited space, increases in pest and disease outbreaks and lower production resulting from impacts of climate change. Changes in cultivation choices were also identified, including a transition to commercial production, the start of spice farming for ecotourism and a move towards plantation forest for fuelwood in place of food crops.

Other key developments which influenced land use included built infrastructure for schools, healthcare clinics, roads, piped water and electricity. Communities also commented on changes in the quality of housing with the introduction of aluminium roofing and blocks. Whilst these changes were detailed to some extent across all Shehia's on the two islands, the extent of development differed (see Fig. 4).

Perceived drivers of land use and land cover change

When combining data, both islands' participants identified population increase as a major driver of land use and land cover change (see Fig. 5a, b). This was largely because communities rely on natural resources and agriculture to

meet livelihood needs. Impacts associated with population increase included over extraction of natural resources, reduced space for farming and increased land use competition due to settlement expansion.

An increase in development was also considered a key driver for changes in infrastructure. Development had a direct impact on land cover, but also indirectly caused changes in population dynamics which stimulated subsequent change. For instance, in Kinyasini on the north–east side of Unguja, good connectivity and accessibility provided an opportunity for market expansion, which encouraged more people to move to the area, resulting in settlement expansion. Rates of development were comparably slower for more remote sites, such as Mji Mpya in Pemba.

In addition, climate change came through as a key driver across sites as it impacted on crop productivity and the ability of communities to meet their basic needs through subsistence farming alone. This related to extended periods of drought and hotter dry seasons which caused crop failure. In some cases, communities outlined challenges of heavy rain out of season which caused an issue for submergence of root crops. In Wambaa, on the coast of Pemba, wave overwash resulted in salination of agricultural soils causing long term impacts for farming.

Looking at a national level for both islands, population increase, development and climate change can be considered as the primary factors driving change. However, when delineated by Shehia areas with different predominant land cover types, the perceived number one top drivers differed, showing that a consideration of land cover types is needed for scenarios to capture nuances at local levels (see Table 2) (see Appendix 4 for full lists of drivers in individual villages).

Taking into account reflections of past land use and land cover change, several predictions were made to describe a potential BAU scenario. Key changes included deforestation and forest degradation, declining agricultural outputs, a shift away from agroforestry, settlement expansion and an increase in plantation forest (see Fig. 6).

Water–energy–food security evaluations

Coinciding with identified land use and land cover changes there were significant differences in the perception of quality and availability of water, food and energy between the past (2009), present (2019) and future (2030) (see Table 3a, b). The quality and availability of piped water and electricity was thought to have improved from the past (20 years prior to the workshop) to present day (year of 2019). Fuelwood quality and availability was thought to have declined over time. Similarly, food quality and availability was thought to have declined. In the BAU scenario, the quality and

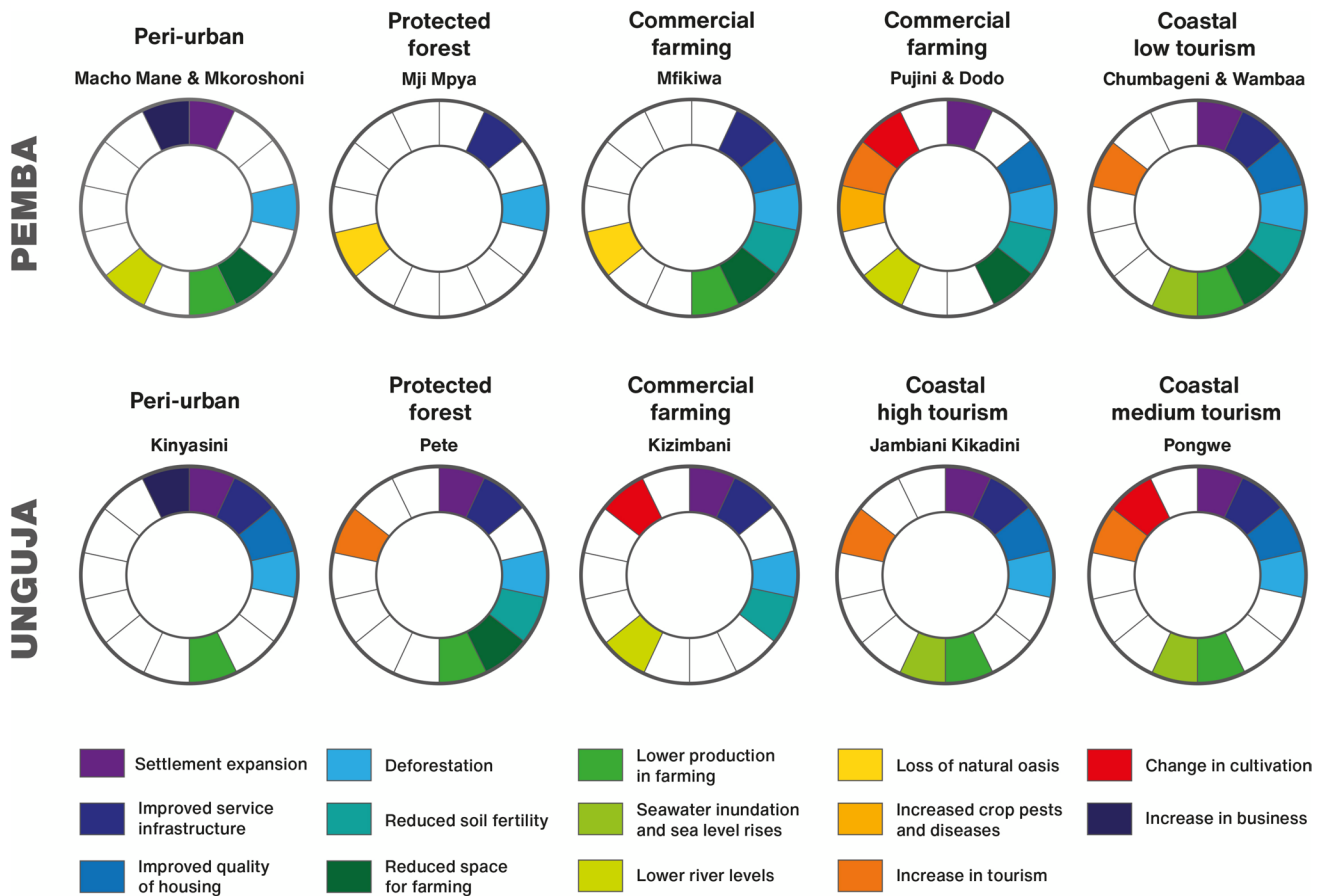


Fig. 4 Land cover changes identified from 20 years ago to present day across all sites in Unguja and Pemba. The presence of a perceived land cover or land use change is presented by the inclusion of the colour code

availability of food, fuelwood and well water are all expected to be negatively impacted.

There were few differences in the evaluations of overall water–energy–food security between Unguja and Pemba, except for fuelwood quality ($t=3.28, d.f.=549.78, p=0.001$) and availability ($t=2.75, d.f.=549.61, p=0.006$). Differences between islands related to their perception of availability and quality for a BAU scenario, with Pemba having slightly more negative evaluations. This was partly because of more optimistic evaluations for future fuelwood security in Pongwe and Kinyasini where communities are already establishing woodlots.

Emergent themes to guide scenario development

Five thematic groups emerge from the coding of 120 proposed solutions. The majority of responses related to improving adaptive capacity, protection and regeneration of ecosystems and sustainable settlement planning, so these are considered to be the three central themes for developing scenarios (see Fig. 7a, c). For improving adaptive capacity, there was a strong focus on upskilling in farming and

transitioning from subsistence to business farming. As outlined in the workshop in Pujuni:

“We must get enough education about best land uses in order to get more food and to do business farming” (Pujini workshop, April 2019)

For settlement planning participants emphasised the need for better spatial planning, for instance in the Pete workshop participants stated:

“We must plan the settlement area in order to keep space for small scale farming and livestock keeping” (Pete workshop, July 2012)

Another key aspect of the settlement theme was the need to protect cemetery spaces, which could be impinged upon in some areas for development projects. Cemetery spaces are typically forested with coral rag and are used to keep livestock cool. Participants in the Pongwe workshop stated that:

“We must hold the environment of the cemetery area, if the cemetery is cleaned, we will lose the animals

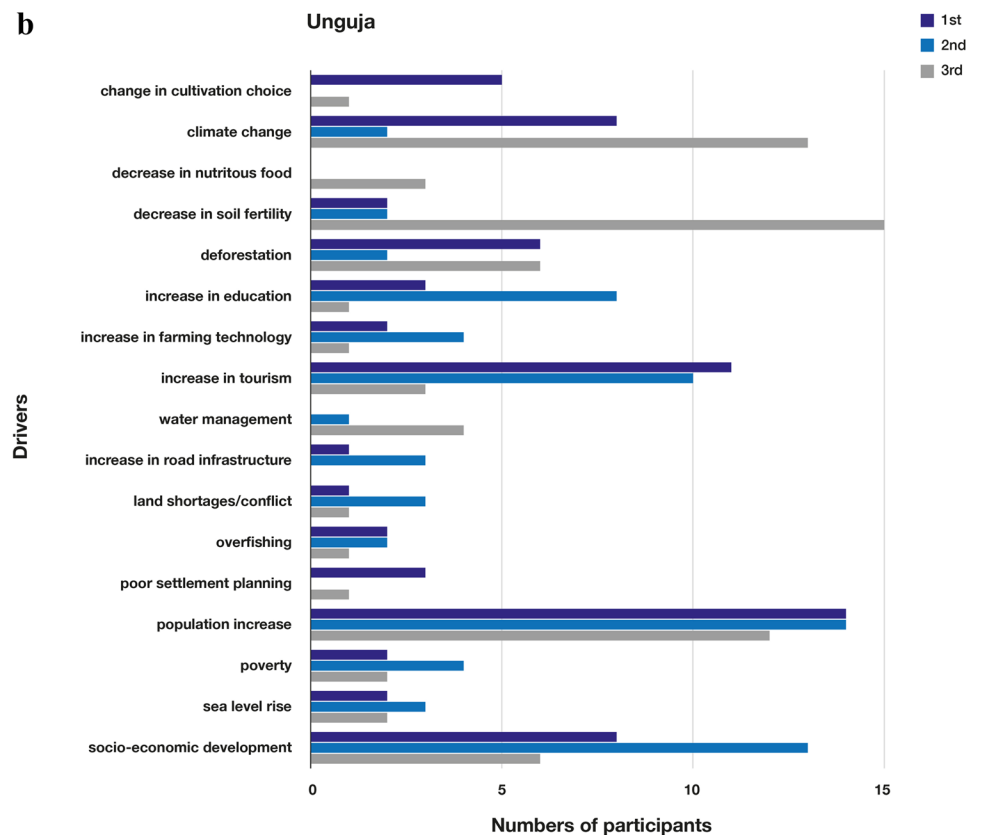
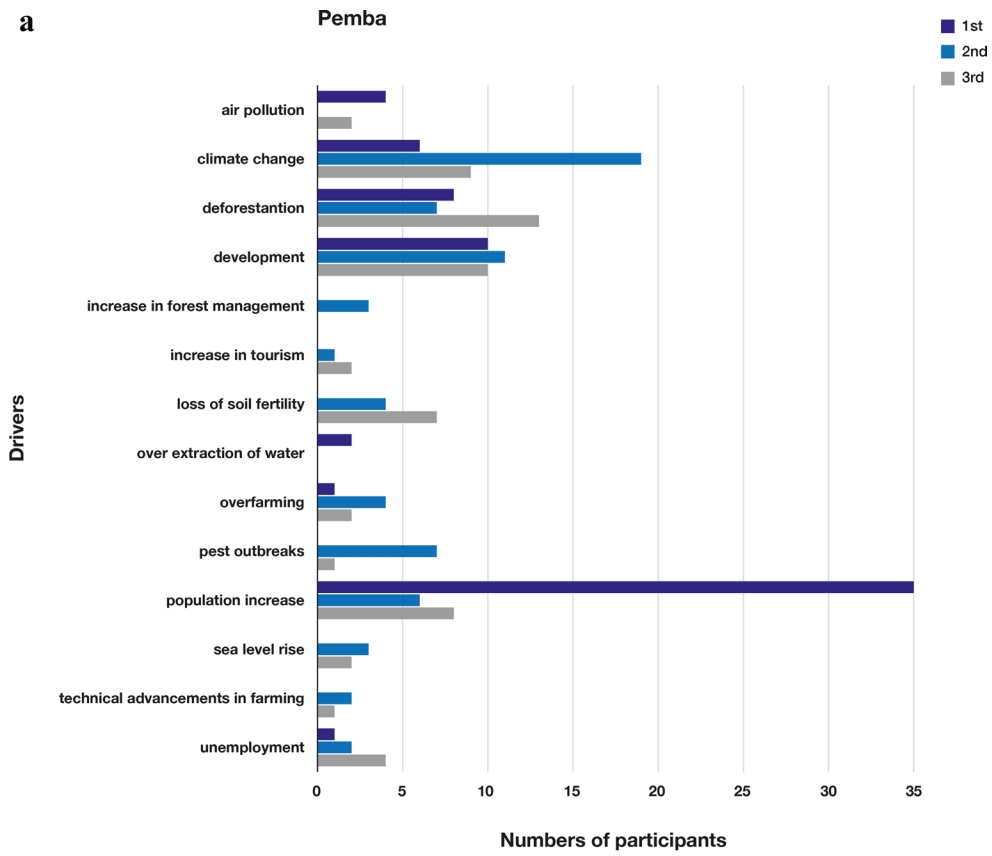


Fig. 5 Number of participants ranking the perceived significance of identified drivers of land use and land cover change for the future in **a** Pemba and **b** Unguja, 1st—most prevalent, 2nd—second most prevalent and 3rd—third most prevalent

[livestock], because they will lack water, good air and food they need for strong health” (Pongwe workshop, July 2019)

Ecosystem protection and regeneration largely centred on forest spaces, with a particular emphasis on mangroves and their wider ecosystem benefits. For instance, in Pongwe, participants said:

“There is a need to avoid deforestation along coastlines, if we lose the natural trees close to the sea, we will lose the habitat for the fish, and they will escape because the place they like to play will be demolished” (Pongwe workshop, July 2019)

Proposed action towards ecosystem protection and regeneration centred on education, including indigenous knowledge sharing.

The other two themes included family planning to reduce population increase and maintaining cultural values. Cultural values related to educating younger generations about places of historical spiritual and cultural importance and includes factors such as good collaboration, unity, and respect within communities and between communities and government sectors. Both of these themes can be considered within all the scenarios options.

Discussion

Land cover pressures

Our findings align with other recent research showing that pressures on the coastline are intensified (Mimura et al. 2007; Suckall et al. 2014; Nunn and Kumar 2018; Mycoo et al. 2022), and degradation of coastal ecosystems increases vulnerability to seawater inundation and intrusion (Mercer et al. 2014; Barbier 2015). However, in addition to this, our findings also demonstrate that areas farther inland on small islands experience a differentiated set of water–energy–food challenges currently not well-represented in wider research in small islands. For instance, results show that factors such as remoteness and land use competition contribute to resource insecurity and, therefore, warrant more attention. More specifically, this study found that in remote locations communities are often excluded from development transitions, such as electrification, piped water provision and road construction. Alternatively inland areas also face increases in commercial agriculture which contributes to land use competition, often leading to high levels of deforestation.

Results from this study indicate how drivers of change emerge slightly differently across spatial scales and uncover some of the reasons for this. Whilst our results align with previous studies by showing that population growth is high at coastal fringes (Neumann et al. 2015), they also indicate that growth is experienced outside of coastal spaces. For instance, areas with good market connectivity, fertile soils for farming

Table 2 Table showing the number 1 top vote for driver of change across the diverse types of predominant land cover in both islands (in Pongwe this was tied between three drivers)

	Peri urban		Coastal		Protected forest		Commercial farming	
	P	U	P	U	P	U	P	U
Population increase	Macho mane and Mkoroshoni	Kinyasini	Wambaa and Chumbageni	Pongwe			Mfikiwa, Pujini and Dodo	Kizimbani
Deforestation					Mji Mpya			
Increase in ecotourism						Pete		
Increase in tourism				Jambiani				
Change in cultivation				Pongwe				
Socio-economic development				Pongwe				
Climate change		Kinyasini						



Legend

- | | | |
|------------------------------------|-----------------------------------|--|
| 1 Reduction in Agroforestry | 4 Degradation of protected forest | 7 Settlement expansion |
| 2 Degradation of plantation forest | 5 Mangrove forest degradation | 8 Deforestation of natural forests |
| 3 Expansion of plantation forest | 6 Decreased agricultural outputs | 9 Enhancement of farming technology and skills |

Fig. 6 Location of expected land use and land cover changes by year 2030 if no new interventions are implemented to address emerging challenges or harness new opportunities for water, energy and food security

or rich natural capital were also found to experience population increase. It is important to understand these dynamics as population growth might contribute to resource pressures inland, where the majority of the population still rely on natural resources to meet their water–energy–food needs. Results further show that coastal challenges are also not homogenous but differentiated according to location specific pressures, such as tourism. Emerging challenges for resource security are discussed below.

Water security

Our findings indicate that water security is a prevalent ongoing issue because of multiple pressures. Water scarcity is expected to increase due to population growth, urbanisation, tourism and increased aridity (Mycoo et al. 2022). Results show that concerns about over extraction of groundwater are especially high in Unguja. Even in 2001, extraction was found to be unsustainable on the east coast of Unguja due to high water demands from tourism (Gössling 2001). Over-exploitation of the aquifer contributes to the lowering of the groundwater table, land subsidence, poor groundwater quality and saltwater intrusion (Gössling 2001; Makame and Kangalawe 2018). Previous research also found that as new users become connected to piped water in tourist hotspots, such as Jambiani and Nungwi, existing users experience a reduction in the supply (Slade et al. 2012). This often forces communities to revert back to well water, which has compromised quality due to over extraction and sewage contamination (Slade et al. 2012).

This study found that though access to cleaner water through piped water infrastructure has been a vital improvement to livelihoods, in terms of both improving sanitation and reducing time spent collecting water, there are growing concerns about the availability and quality of well water. By engaging with communities through our study, it became apparent that well water remains an important back up supply. This back up supply is particularly important because piped water relies on electricity for water pumps and so is affected by power cuts. At times poor maintenance of water infrastructure can also lead to prolonged disruptions in supply. Kondash et al. (2021) found that an interruption in piped water supply, even for one day per month, elevates the likelihood of diarrhoea in children to levels comparable to children without piped water. As the intensity of rainfall and ensuing flooding events are expected to increase in East Africa, there is an additional associated risk of greater exposure to waterborne diseases such as typhoid and cholera due to damage to water systems (Mycoo et al. 2022). Therefore,

our results indicate that there is a need to both monitor and maintain the quality of well water as well as the robustness of piped water systems, especially given predictions about more extreme conditions.

Considering the water demand in Zanzibar, more effort is needed to address issues of overextraction related to tourism. This is not a new or emerging issue; both Gössling (2001) and Slade et al. (2012) advocated for water mandates in hotels, including rainwater harvesting, use of greywater, adequate treatment and disposal of sewage, limited provision of swimming pools (or use of saltwater pools), desalination of seawater, limited laundry of towels and linen, and use of drought resistant plants in landscaping. Zanzibar's 2012 Coastal and Marine Tourism Management Plan objectives also included the encouragement of eco-lodges with rainwater harvesting plans in areas with limited or no water supply. However, since then, the number of tourists visiting has increased and there continues to be inadequate regulation of water use.

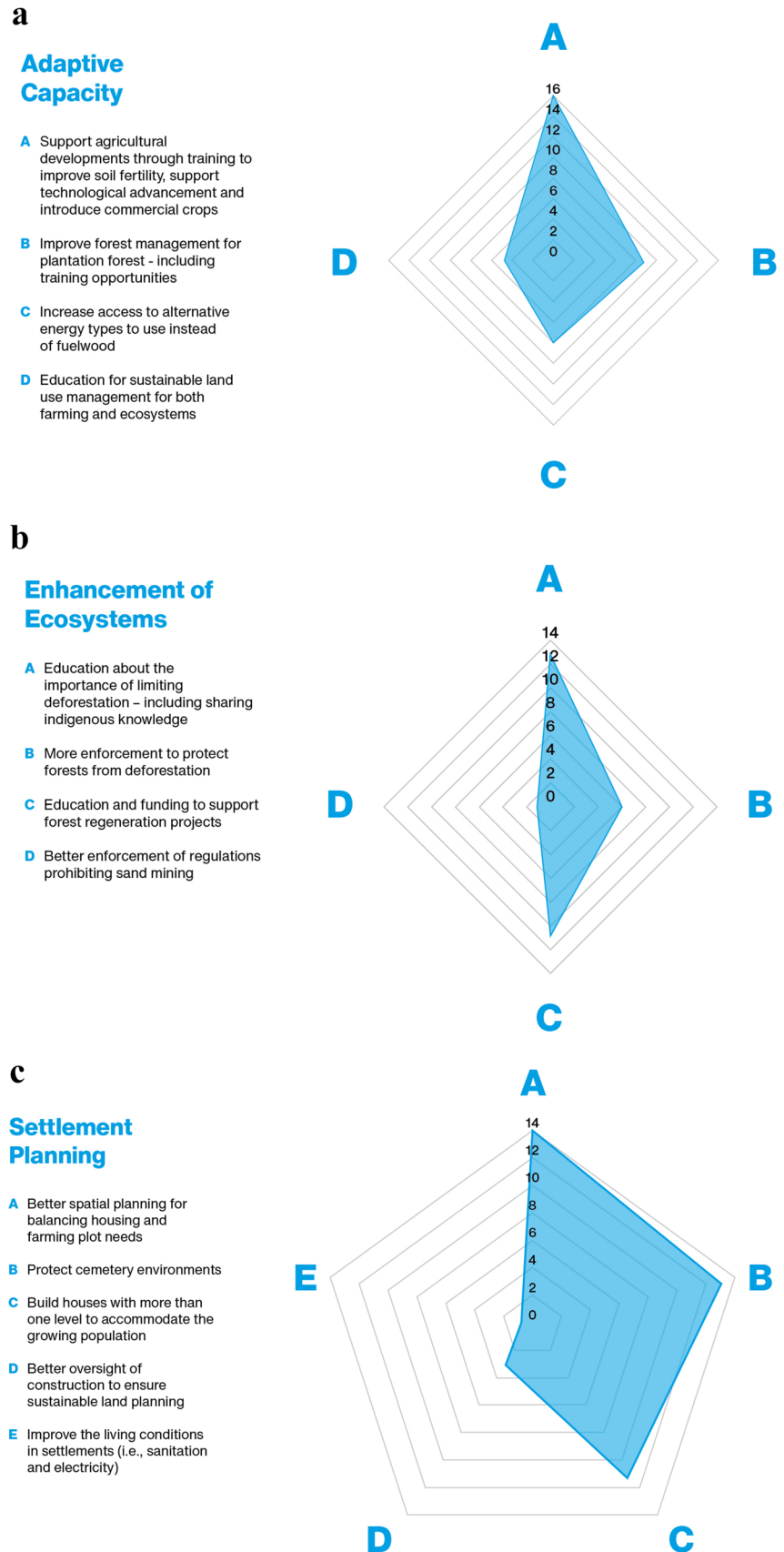
Energy security

Findings show serious concerns about the sustainability of fuelwood extraction. Communities across both islands predict that land use pressures will affect land use and land cover by increasing levels of deforestation across all forest types. As coral rag forests have become increasingly deforested and degraded, deforestation is spreading to other forest types including mangrove and plantation. Implications of the degradation and reforestation of coral rag forests include loss of biodiversity, reduction in the availability of forest products and lowering of the groundwater table (Nowak and Lee 2010; Ahmed and Mishra 2019). In the case of mangroves,

Table 3 (a) Significant differences in the perceptions of resource quality between past (2010) present (2019) and future alternatives (2030); (b) significant differences the perceptions of resource availability between past (2010) present (2019) and future alternatives (2030)

(a) Nexus aspect	Chi-squared result for quality
Well water	$X^2 = 61.97, d.f. = 12, p = < 0.002$
Piped water	$X^2 = 351.84, d.f. = 12, p = < 0.002$
Fuelwood	$X^2 = 246.1, d.f. = 12, p = < 0.002$
Electricity	$X^2 = 321.51, d.f. = 12, p = < 0.002$
Food	$X^2 = 93.12, d.f. = 12, p = 0.004$
(b) Nexus aspect	Chi-squared result for availability
Well water	$X^2 = 61.97, d.f. = 12, p = < 0.002$
Piped water	$X^2 = 333.02, d.f. = 12, p = < 0.002$
Fuelwood	$X^2 = 258.54, d.f. = 12, p = < 0.002$
Electricity	$X^2 = 329.05, d.f. = 12, p = < 0.002$
Food	$X^2 = 107.96, d.f. = 12, p = 0.005$

Fig. 7 Frequency of statements made associated with difference aspects of: **a** improving adaptive capacity, **b** enhancing or regenerating ecosystems and **c** improving settlement planning



communities in this study showed concern about coastal erosion, seawater inundation and salinisation of ground water and agricultural land—this has also been evidenced across other small developing islands (Veitayaki et al. 2017). Continued degradation of both marine and terrestrial ecosystems is anticipated to exacerbate island communities' vulnerability to climate change impacts, such as cyclone and sea-level events, which are predicted to increase in the coming decades (Barbier 2015; Mycoo et al. 2022).

Although communities have seen an increase in electrification, poverty limits the utilisation of this, and fuelwood remains the main energy source. Some communities represented in our workshops are initiating woodlots to establish more secure supplies of fuelwood; yet the extent to which this can meet the needs of the wider population is not currently well-understood. More broadly, small developing islands are considered especially vulnerable to energy insecurity as they rely on imported fossil fuels with high import costs, lack of energy infrastructure, unequal distribution and over reliance on depleting biomass sources (Raghoo et al. 2018; Surroop et al. 2018); which could limit communities potential to transition to electricity. Renewable energy has been recommended for small islands contexts to reduce exposure to price volatility of fossil fuels (Lucas et al. 2017). This is all the more pertinent given the rising prices of fossil fuels seen globally in 2022 and the continued unsustainability of fuelwood extraction to provide energy security to a growing population.

Food security

Communities across all sites in our study explained that food insecurity was a growing issue. At the start of 2023 the President of Zanzibar even introduced a ban on food exports from Zanzibar to curb food shortages and price hikes. Small developing islands are vulnerable to food security as they are net importers of food and, therefore, exposed to global price fluctuations (Pelling and Uitto 2001). The capacity of small island communities to produce their own food is limited by climate change effects including increased temperatures, longer dry seasons, changing rainfall regimes, inadequate freshwater supplies, sea-level rise, saltwater intrusion, increased health risks (e.g., water- and vector-borne diseases), land loss and degradation, coastal erosion, and coral bleaching (Mimura et al. 2007; Mercer et al. 2014; Mycoo et al. 2022).

Existing research has demonstrated that increased heat and drought has increased across most of Africa. In East Africa specifically rainfall is predicted to become less frequent but more intense with increased wind speeds causing increased levels of crop failure (Triso et al. 2022). In addition to this, research in Zanzibar has shown that agricultural declines and erratic fishing yields have pushed households

towards a greater dependence on markets for staple food supplies; this makes households with low purchasing power especially vulnerable (Makame et al. 2015). By engaging with communities, our results revealed that people's relationship with food is also altered as they have less oversight of the growing and processing of foods, and as a result many people felt less confident about its quality and nutritional value.

Integration of results with wider scenarios research

Scenario themes developed by communities to address land use challenges which influenced resource security intersect in some places with wider research on small islands, as well as other environments with strong social–ecological interactions. Communities suggest that there is a need for both regeneration and protection of coastal vegetation, as well as better spatial planning; these scenario objectives align with priorities generated in workshops involving coastal science and management experts in Unguja (Huge et al. 2018). Improving adaptive capacity through developing multifunctional landscapes, which support both biodiversity and humans, is considered to be one of the most desirable scenarios in mountain communities (Lebel 2006; Capitani et al. 2018; Carvalho-Ribeiro et al. 2010; Thorn et al. 2021). Mountain communities face similar pressures to small island communities, such as geographic isolation and resource dependence. Previous research in mountain communities in South and East Africa has also shown the importance of cultural values and opportunities for Indigenous knowledge sharing combined with innovation in scenario development (Malinga et al. 2013; Thorn et al. 2021). Cultural values such as unity and collaboration came through in scenarios for Zanzibar, which emphasises the importance of social connectivity in small islands (Pelling and Uitto 2001). In addition, in line with suggested scenarios in Zanzibar, environmental integrity was identified as a desirable scenario from communities in northern Tanzania (Kariuki et al. 2021). Whilst place-specific insights should guide scenarios at finer scales, these alignments could be used to inform wider policy planning for the Sustainable Development Goals (SDG's) and the longer term African Union 2063 Agenda.

Future application

Inadequate representation of communities in sustainability planning can result in inappropriate action for addressing resource challenges (Juhola et al. 2016). This study attempts to situate communities more centrally in the formation of scenarios by providing an opportunity for them to frame their resource challenges and create themes for developing

scenarios based on solutions which they feel would be effective. These insights need to now be integrated with multiscale strategies to enhance the agency of communities within decision making processes which guide policy formation (Hickey and Mohan 2004). Next steps should involve multi-stakeholder workshops, including representatives from institutional bodies and communities, to discuss how the suggested scenarios could be realised whilst considering potential barriers. This would provide an opportunity to integrate insights on regional, national and global drivers of change and potential bodies and resources to address change. Results could also be used to bring community perspectives into Zanzibar's 2050 Vision, which encompasses aims in line with both the Sustainable Development Goals for 2030 and the African Union Agenda for 2063. This would help to ensure that experiences and insights at the community level feed into tangible land use decisions.

Limitations

This study aimed to enhance the agency of communities in scenario development for sustainable land use by creating an opportunity for communities to frame resource challenges and solutions. Whilst this addressed barriers to inclusion such as self-esteem, financial limitations and power dynamics between experts and community members, there are some limitations which need to be considered. These workshops included those with positions of power at the community level, hierarchical structures are well-respected in Zanzibar, so this could mean people are not likely to propose an alternative viewpoint in open discussions. In addition, because of the nature of research protocols in Zanzibar at the time, village leaders were responsible for engaging participants; this could potentially lead to the selection of people representing just one political party or perspective. Because a small remuneration was paid for participation it could also have resulted in family members or close friends being invited over other members of the community. Consequently, it is possible that more marginalised people were not included and there is still a need to include less represented groups, such as migrants and disabled people.

Conclusion

Islands in Zanzibar are facing land use and land cover pressures, due to climate change, population growth and development, all of which impact resource security. Whilst interaction between local communities and environments in small islands is strong, local insights need to be drawn upon to inform scenario development. Barriers to inclusion involve poverty, self-esteem and unequal power between those representing institutions and community members. To address

these issues, community workshops were held on-site with community members only to frame resource challenges and form themes to build upon in multistakeholder workshops. By including communities from diverse landscapes across Zanzibar, a greater understanding of differentiated land use and cover challenges for water–energy–food security was unveiled. Three clear scenario themes emerged in response to the sustainability context: improving adaptive capacity, sustainable settlement planning and protection and regeneration of ecosystems. These findings could be used to create locally relevant sustainability priorities which address emerging resource challenges in Zanzibar.

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Declarations

Conflict of interest All authors certify that they have no affiliations with or involvement in any organization or entity with any financial interest or non-financial interest in the subject matter or materials discussed in this manuscript.

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