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Women and adaptive capacity to climate change in East African seascapes – Zanzibar as an example

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As the climate crisis persists, there is a crucial need to increase knowledge on adaptive capacity and the underlying factors building it. This is particularly important for disadvantaged groups, such as coastal women in East Africa. Women's livelihoods in these seascapes are and will be more severely affected by climate change and the capacity of East African states to deal with these challenges is limited in terms of financial and human capital. In this research, we investigated the underlying factors building the adaptive capacity of coastal women in Zanzibar (Unguja Island), Tanzania. Coastal women (N=117) were interviewed in villages around the island to gather information about potential factors supporting adaptive capacity. This was analysed applying Cinner et al (2018) five domains typology for adaptive capacity, i.e. *assets, flexibility, organizations, learning and agency*. The results show that women had relatively low adaptive capacity, extended poverty and very high dependence on seaweed farming of red algae, a livelihood providing low income and already being seriously affected by climate variability and change. Women's observations of key variables related to environmental changes corresponded to most scientific findings. It was, however, unclear how that knowledge is useful and enhances adaptive capacity. Adaptive capacity was generally low but individual differences were found in which ten women had a high income. The results show that the factors underlying adaptive capacity are complex and interact with each other, being positive, negative and unclear. Many of the identified factors deserve future research. This study adds to the pool of knowledge by addressing women (not only men); coastal ecosystems (as land and freshwater systems are more studied) and the individual level (since most studies focus on national and community levels). The study illustrates that institutional renewal, bridging and cooperation is possible in Zanzibar bringing good news to the region.

KEYWORDS

climate change, climate crisis, seascape, women, adaptive capacity, Zanzibar, Tanzania, adaptation

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Introduction

As the climate crisis continues, there is a growing need to increase knowledge about people's adaptive capacity around the globe. This is particularly important when information is scarce and populations are poor and vulnerable. Economically poor people, particularly women, have been identified as highly vulnerable to climate change (Paavola, 2008; Thomas et al., 2019; Andrijevic et al., 2020). For example, common activities performed by women in rural areas, such as food gathering and water fetching, will be negatively affected in most tropical settings (e.g. Lauria et al., 2018). Women who are already in a disadvantaged position may experience further stress (Dankelman, 2001) and rural women depending on ecosystem services will suffer from production decreases and ecosystem damage (Dankelman, 2001; Nyangoko, et al., 2022). Although generalizations about women being victims or virtuous to deal with climate are unhelpful (Arora-Jonsson, 2011); it is clear that women are vulnerable to natural resource degradation and due to their position providing food security, and their lack of participation in decision-making, the consequences of not addressing the links between women and climate change are potentially devastating. Adaptive capacity, women and gender are central in the "Paris Agreement" (UNFCCC, 2016) which highlights the importance of gender equality and women empowerment (P. 2); the whole Article 7 is devoted to adaptation and adaptive capacity, stating it should be gender-responsive (P. 9-11). In addition, the importance of women and gender is largely acknowledged in the climate change literature (Arora-Jonsson, 2011; Berrang-Ford et al., 2011; Cohen et al., 2016; Djoudi et al., 2016; Pearse, 2017; Rao et al., 2017; Rao et al., 2019; Hans et al., 2021; Vercillo et al., 2022). For coastal zones, this information is particularly important, as the predictions of negative effects in these areas are high (e.g. sea-level rise, increase in water temperature, acidification, species migration, shifts in underwater vegetation, changes in circulation, etc.) (Harley et al., 2006; Hoegh-Guldberg and Bruno, 2010; Hoegh-Guldberg et al. 2017). Moreover, climate change is predicted to have a high influence on coastal livelihoods and food security (Pauly et al., 2005; Ricel and Garcia, 2011; Berman et al., 2020; Hastings et al., 2020), and the degree of adaptive capacity is not uniform for coastal areas around the globe (e.g. Ferro-Azcona et al., 2019; Hidalgo et al., 2022). Therefore, knowledge about the adaptive capacity of coastal women in specified geographic settings is a central opportunity for policy-making, management and program intervention (e.g. FAO ISFS, 2019), and timely since 2021-2030 is the UN decade of the ocean when "adaptation science for the ocean" (Hidalgo et al., 2022) can be further developed.

The urgency of addressing women and the sea to understand management, adaptive capacity and paths for sustainability was also stated in the FAO international symposium on fisheries sustainability (FAO ISFS, 2019) (Figure 1). There is a clear paucity of information on adaptive capacity in the sea compared to land[1]. Geographically, studies in Africa dealing with gender and climate change are scarce, but increasing (Vercillo et al., 2022). However, the themes of adaptation and coastal resources are clearly under-investigated (Vercillo et al., 2022). In this study, we focus on women in a tropical coastal setting in a low-income country (Tanzania has been recently upgraded to lower-middle). The objective is to investigate the factors building and mediating adaptive capacity of women to deal with climate variability and change in the seascapes of Unguja Island (hereafter Zanzibar) and discuss ways to work further with adaptive capacity of women in Zanzibar; Tanzania. Women in coastal Zanzibar are particularly vulnerable since these areas are highly attractive for coastal tourism, which may displace local people. Women work with nature dependent livelihoods that are at stake when temperature and other key variables for ecosystem health are changing. Thus, women in Zanzibar coastal areas experience multiple pressures. Here, we focus on adaptive capacity to climate variability and change but recognize the complexity and multiple links to other stressors. The research contributes to fill some important gaps in knowledge, 1) it adds to the relatively low number of studies on women and climate change as compared to studies with pooled or aggregated data; 2) the low number of studies dealing with marine coastal areas as compared to land and freshwater and 3) the relatively few studies addressing adaptive capacity at the individual level (as most of them are at community or national levels). Concerning this, we analysed the adaptive capacity of coastal women based

FIGURE 1
Word cloud presented during the concluding session in the FAO international symposium on fisheries sustainability – strengthening the science-policy nexus. The words "***women***" and ***"gender"*** rank among the most mentioned during the whole event. Nov. 21st, 2019.

1 Results from the Web of science: climate change AND forest≈77,000 hits; climate change AND agriculture≈75,000; climate change AND coastal zones≈5,500 climate change AND ocean≈65,000 checked 2022-06-30.

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on Cinner's typology for coastal tropical contexts comprising five domains constructed to understand adaptive capacity (Cinner et al., 2018). Briefly, the first domain is *assets*, and refers mainly to financial and physical assets, but also technical and service-related ones. The second one is *flexibility*, and deals with people's ability to switch between different activities, strategies, and/or occupational sectors. *Social organization* constitutes the third domain and relates to social organization for cooperation, collective action, and knowledge sharing. The fourth is *learning* and deals with "people's capacity to generate, absorb, and process information related to climate change". Finally, the fifth domain of *agency* brings up the capacity of people to actively shape their own lives and future. The data for the analysis was collected by applying a mixed interview form (combination of semi-structured sections with closed questions), to coastal women in Zanzibar and analysed the information in relation to the five domains. The article begins with a short depiction of the local context and climate change; followed by methods, results of the interviews and links to the domains in the discussion. Finally, a table summarizing the findings and a brief discussion of the way forward is given; the text ends with a concluding section. The study contributes to the Sustainable Development Goals (linking SDG goals, No. 5. *Gender equality*; No. 14. *Life below water*; and No. 13. *Climate action*). Specifically, the analysis is valuable for policy design, management and program intervention in Zanzibar.

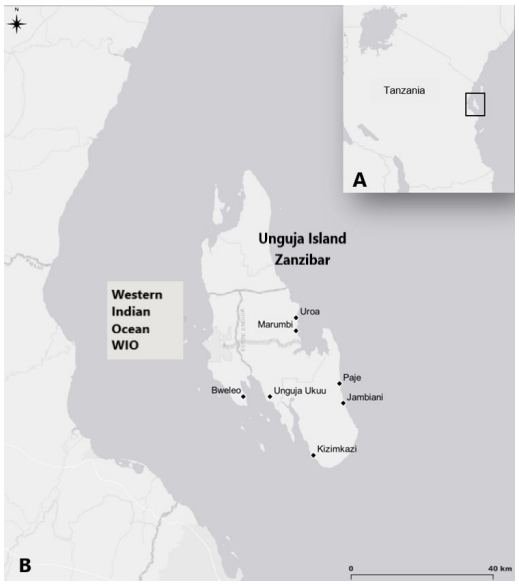

FIGURE 2
Zanzibar (Unguja Island), Tanzania. **(A)** Zanzibar's position in relation to Tanzania. **(B)** Zanzibar map showing the research sites. The black dots represent the villages where the interviews were conducted with coastal women (N=117) to investigate their adaptive capacity to climate change.

Methods

Local context and general features of climate change in Zanzibar

Zanzibar is a tropical island situated off mainland Tanzania's coast (Figure 2), rich in tropical ecosystems and species from all Phyla. Seascapes are comprised of coastal and mangrove forests, seagrass meadows, and coral reefs (Richmond, 1997; Berkström, 2012). It is within this ecological context that people's livelihoods take place. The main livelihoods are small-scale fisheries for men (finfish and shellfish) (Jiddawi and Öhman, 2002). Sea cucumbers are particularly highly valued (Eriksson et al., 2012; Eriksson et al., 2015). For women, collection/gleaning of invertebrates (e.g. shellfish) is a common activity (Nordlund et al., 2010; Fröcklin et al., 2014; Nordlund et al., 2014); but until recently, the majority were dedicated to seaweed farming of red algae for carrageenan extraction, an activity introduced in the 1980s that has spread and become a key livelihood for coastal women around the island (Bryceson, 2002; de la Torre-Castro and Lyimo, 2012). The seaweed farming introduction at the beginning brought large benefits for women and still does for women who have large cultivations (Msuya and Hurtado, 2017). However, there are social-ecological negative effects of the seaweed farming activities. In social terms, low-income generation (de la Torre-Castro et al., 2017); women's health damage (Fröcklin et al., 2012) and women's increased vulnerability (Folkeryd, 2020). Ecologically, the farms change fish species composition (Eklöf et al., 2006; Chacin et al., 2020) and diminishes underwater vegetation important for fisheries and stabilizing ecosystem services (de la Torre-Castro and Ronnback, 2004; Eklöf et al., 2005). A significant problem is that genetic diversity of the Zanzibar algae used for cultivation is very low and it can be compared with a monoculture on land with high risk of suffering from both diseases and physical disturbances. The low genetic variation stems from the fact that all cultivated plots derive from an original variety introduced from the Philippines (Bryceson, 2002; Halling et al., 2013). In addition, the cultivation covers large areas of the coastal zone (Hedberg et al., 2018) and it is well known that spatial configuration is essential for marine planning and adaptive capacity (Weis et al., 2016). There is no consensus in the scientific community about the livelihood value of seaweed farming. Some argue that the low income compared to the environmental damage and the entrenchment of women is not worth the activity, while others think that even if the earnings are small, they are needed and thus welcomed. Aquaculture researchers tend to be positive because the algal growth requires no additional inputs. At the core of the issue, there is a large variation in the benefits from seaweed farming between producing countries (Valderrama et al., 2015).

Zanzibar's coasts experience great pressure due to tourism expansion. During the last decades, increases in hotels, roads and walls, as well as effluents to the ocean have changed traditional coasts with multiple livelihoods and local traditions, to places with links to the global economy. Local people are facing a growing international tourism industry with environmental degradation and restricted access to beaches (Lange, 2015). Tourism has also changed the relationships between people and the environment, jeopardizing sustainability (Gössling, 2002). Competition over space and land is taking place on the island. For instance, in the Fumba peninsula (Zanzibar's West coast), a large urban housing project has affected the people's access rights, with no proper compensation (Johnsson, 2017). The coastal population is generally poor in economic terms (Makame and Mzee, 2014; Moffat et al., 1998; Wallner-Hahn et al., 2016; de la Torre-Castro et al., 2017), while food security and health status are dependent on the intake of high-quality animal protein from fish and shellfish, and the carbohydrates from fruits and vegetables cultivated in family plots (*shambas*).

Summing up, most coastal people are facing poverty, limited livelihood opportunities, and rapid changes due to globalization. Before the introduction of seaweed farming, women were engaged in cooking, baking, handcrafts, embroidery, tailoring, and small-scale trade, parallel to their main activities in the sea like invertebrate collection, and some fishing (de la Torre-Castro and Lyimo, 2012). Tourism, degradation of marine resources and seaweed farming have radically changed coastal villages.

Regarding gender, traditional roles for men and women are, *in general*, present in Zanzibar (exemptions always exist, but this is the usual pattern). It is important to remark that gender relationships have shifted historically with periods in which women had high status, however, gender inequality is found at present (Askew, 1999). Men have higher independence, mobility and agency while women are responsible for the household and children. These traditional values are persistent, particularly in coastal villages (Tobisson, 2013). At the same time the situation is complex and changing, women at present play roles that were exclusively for men, for example being a fish trader. Women are not static actors, they rather have some degree of mobility and individuals can be very successful (Fröcklin et al., 2013; Fröcklin et al., 2018; Msuya and Hurtado, 2017). Despite this, men have the highest societal status and are in a better position in most aspects, for instance, their income is much higher (Wallner-Hahn et al., 2016; de la Torre-Castro et al., 2017); they are also owners of the most important assets such as houses, lands and boats (Fröcklin et al., 2013; Wallner-Hahn et al., 2016; Folkeryd, 2020). Fröcklin et al (2013) compared men and women regarding their roles in the fishery business as traders and concluded that men were more organized, had larger contact networks; had access to higher value fish species and markets, as well as equipment. Men's savings and economic assets were larger, and they had more mobility and freedom. Most of the households were men-headed and had higher representation and participation in public arenas. Overall, society in this context has been considered traditional by a number of scholars (Tobisson, 2013) and traditional systems can survive parallel to modern structures (for example political organizations) (Dean, 2013). In Zanzibar, women's and men's separate beaches are still found; women pray in separate places in the Mosques, and they are separated in ceremonies and rituals (Dean, 2013). Moreover, the use of the coastal space and the activities performed is also highly gender-segregated (Dean, 2013; de la Torre-Castro et al., 2017). A majority of studies on adaptive capacity in the Western Indian Ocean, which includes Zanzibar, address men (e.g. McClanahan et al., 2008; Cinner et al., 2012b; Cinner et al., 2015; Silas et al., 2020), and aspects of gender and social equity in villages are not commonly addressed in the Tanzanian national programs for climate change (Smucker et al., 2015).

The climate change situation in Zanzibar, Tanzania

In Tanzania, there is attention to climate change "in paper" but "real" adaptation in the mainland and in the islands is needed (Watkiss and Hunt, 2012). One of the most evident changes related to climate change is the increase in sea water temperature which has taken place during the last two decades in combination with "El niño/La niña" years causing damage and extended coral bleaching (Watkiss and Hunt, 2012; McClanahan et al., 2019). This has profound consequences due to the people's dependence on fisheries. Marine ecosystems are projected to suffer negatively from climate change, particularly coral reefs (e.g. Hoegh-Guldberg et al., 2007, Hoegh-Guldberg et al. 2017). Acidification damages all shell-forming organisms including molluscs, echinoderms and corals (Doney et al., 2009). Fish catch potential within the tropics has been calculated to drop by 40% (Cheung et al., 2010), and the effects of climate change on fish and fisheries can be traced back as long as four decades, with increasing temperature playing a key role (Cheung et al., 2013). The red algae, (genera *Euchema* and *Kappaphycus*) grown by women, is very sensitive to temperature changes. Algal growth declines as temperature increases and salinity changes (Buriyo et al., 2001). Climate change may produce more storms and rain variability (IPCC, 2014). Although there is a lack of data to make strong statements about rain variability, time series show a reduced rainfall in East Africa during the last 30 years during March and May-June (corresponding to the so-called long rain period in Zanzibar). The horn of Africa has experienced less rainfall during the last 60 years. Warming ocean waters seem to have caused more storms and drought episodes in East Africa during the last 30-60 years. This situation affects coastal areas subject to changing patterns of run-off and erosion. Even more seriously, climate change is projected to undermine food security due to biodiversity loss and redistribution of marine fishes and

organisms, which is expected to take place or is already taking place (IPCC, 2014). A local analysis for Zanzibar indicates that current and future climate change can jeopardize livelihoods and economic growth relatively soon (mid-long term) (Watkiss and Hunt, 2012).

Tanzania works actively with climate change policy and the central government has a National strategy for Adaptation (Tanzania's NAPA), and a National Climate Change Strategy (NCCS). However, these policies have been considered technocratic and insufficient to address complex multi-scalar issues and inequalities such as gender (Smucker et al., 2015). A lot of work remains to address the huge challenges in the country. Empirical evidence of temperature increases and higher rain variability is found in different records and databases at national and local levels (e.g. Tanzania Meteorological Agency; Zanzibar Meteorological Office) and international agencies which have broader data such as SST (superficial sea temperature), sea-level change, etc. (e.g. NASA ECCO). There is a broad consensus that the current increase of about 1°C global mean temperature has and will have serious negative effects in Tanzania including the islands (Adjei and Amaning, 2021). Models at more local scales (e.g. the large Wami-Ruvu river basin connecting with the sea in middle Tanzania) show the same trends as the data, in this case, temperature may increase between 0.2 to 7.5 °C and precipitation variability is very high depending on the scenario used. These models were run up to the year 2080 showing that just a few decades ahead serious changes might happen (Gulacha and Mulungu, 2017). Mkonda et al (2018) showed that temperature was increasing for *all* seven large agroecological zones studied in Tanzania. Sekadende et al (2020) analysed the small pelagic fishery of the Pemba channel concluding that gaps in the knowledge about climate change are large, however current data on SST show an increasing trend. Predictions show that acidification will increase and there will be less available oxygen for marine life. Fortunately, it seems that the SST in Tanzanian coasts is not increasing as fast as in other areas (e.g. Artic waters), but some hotspots are close to the area, i.e. Mozambique channel, South African coasts and parts of the Indian Ocean (Sherman et al., 2009). In addition, it is crucial to consider other factors when considering climate change in the ocean. Popova et al (2016) found that water circulation patterns play a key role and hotspots found today might be different to those projected due to changes in ocean circulation. This means that regions considered hotspots today might not be tomorrow and vice versa.

When it comes to social-ecological perceptions, there is experienced climate variability and change reported by people in the mainland as well as in the islands. For example, pastoralists in rangelands have experienced the effects of climate change through severe droughts (Kimaro et al., 2018); fishers have been strongly affected by climate change amplified by the El Niño/ENSO effects and extended bleaching in coral reefs (McClanahan et al., 2019; Ussi et al., 2019). Seaweed farmers report higher temperatures, winds and irregular rainfall (de Jong Cleyndert et al., 2021) in addition changes in waves and salinity were reported by Hassan and Othman (2019).

Yanda et al (2019) wrote an extensive book with cases from all over Tanzania documenting climate change in both land and water-based ecosystems, including the islands. The overall conclusion is that climate change has happened and is happening. A more difficult question is to make accurate and correct projections and modelling, particularly when it comes to rain pattern changes. Nyangoko et al (2022) stress that even though the reason for rain change patterns (climate change or seasonal/decadal variation) is not conclusive now, the effects of these changes on livelihoods in the coastal zones are taking place and thus they should be addressed. The results of their study of community perceptions of climate change impacts on ecosystem services delivered by mangrove forests in the Rufiji Delta showed that, contrary to what is believed, people could detect very small changes in climate conditions and those, in turn, can decrease well-being and the flow of ecosystem services.

Research approach, data collection and analysis

The understanding of climate change in the study is based on the IPCC's definition stating that climate change is "a change in the state of the climate that can be identified by changes in the mean and/or the variability of its properties and that persists for an extended period, typically decades or longer." (IPCC, 2018). Furthermore, from the marine perspective, key variables were considered essential for climate change in the ocean (e.g. superficial sea temperature SST, pH values (acidification) and oxygen levels in the water. Changes in these variables directly impact biota in marine ecosystems. So, it was assumed that women had an idea of what is "normal" in their coastal environment and thus can identify and report variations. The empirical data for this study was gathered through interviews with 117 coastal women in Zanzibar. An interview form consisting of a mix of questions (for example demographic data, household data, and yes and no answers) and semi-structured sections (to discuss complex issues such as livelihoods, problems, perceptions of natural changes and climate change) (Kvale, 1997; Bryman, 2008) was used (see Appendix 1 in Supplementary Materials). Two pilots (20 interviews on each occasion) were carried out before the final interview schedule was decided. This was done to ensure that the use of key terms such as "climate change"; "temperature rise"; "ecosystem changes" and the like were understood and properly translated. It was stressed that climate change refers to a long-time phenomenon. Decades as well as events in Zanzibar's history were used as references. The pilot interviews were not used for the analysis, only new interviews using the final

schedule form. The whole research was done in collaboration with researchers from the Institute of Marine Sciences, and staff from the Department of Fisheries in Zanzibar. On all occasions, we cooperated with the same translator to perform the interviews. The interviews lasted around 90 minutes each. The translator and a researcher were always present. Interviews were voice and note recorded and took place in public places (house veranda, local fish markets or in the water as seaweed farmers sat and worked). Purposive sampling was used and the work in the villages was done with the permission of the village leaders (*Shehas*), people selection was done with the help of the local beach recorders in each village (*Bwana dikos*), in this way we assured that the most important authority in the place was informed and we were welcomed and that the person working daily with coastal issues selected appropriate candidates for the study. Selection of interviewees was based upon a) being a woman permanently residing in the selected village b) being an adult c) having their main livelihood related to coastal work, and d) willing to participate in the study. Two open information meetings were held to inform all the people in the villages about the project objectives and the possibility of participation. All respondents provided oral consent and anonymity was ensured. A total of 117 interviews with women were performed with the final schedule during September and October 2013. The villages selected for the study were Bweleo, Jambiani, Kizimkazi, Marumbi, Paje, Unguja Ukuu and Uroa. The village selection was based on discussions with local researchers, geographical spread, accessibility and previous knowledge of the area (Figure 2). We are aware that changes have taken place in the system since 2013; particularly in the policy and economic spheres, Zanzibar has continued to receive funds from the Global Environmental Facility (GEF) and the World Bank to perform projects, e.g. SWIOFish which uses a regional approach to fisheries (mainly in deeper waters), tourism, and aquaculture. The coastal/marine policy favouring the establishment of Marine Protected Areas and the Blue Economy has continued and strengthened. The original research idea was to perform a longitudinal study analysing 2013-2023, however, due to the urgency to accelerate knowledge for policy and action, it was decided that the publication of these results even without the ten-year comparison was pertinent.

The interview form was designed to gather information relevant to evaluate adaptive capacity, e.g. livelihoods and alternatives, relationships and knowledge about local ecosystems, and opinions and perceptions about climate variability and change. Table 1 shows how interview data informed Cinner's domains. As a complement to the qualitative information, data was coded and transcribed digitally in an electronic sheet to compute descriptive statistics and graphs (see Appendix 2 in Supplementary Materials). Qualitatively, information was analysed by themes and group categorization. To be able to discuss adaptive capacity levels (high, medium or low) we assume that a woman will have high adaptive capacity when she has relevant local ecological knowledge, allowing a general understanding of climate change, possible threats deriving from it and some idea on how to tackle this (Jones et al., 2010). A woman with high adaptive capacity has the capacity to choose between different options and livelihoods and to secure a decent income over time. To evaluate the economic dimensions of having a "good" life, we use the official data on minimum salaries for Zanzibar, which is 300,000 TZS per month (10,000 TZS per day) (Tanzania Government homepage; wageindicator.org homepage), and living wages (how much is really needed), and the amount was 762,800 TZS/month for an average family (tradingeconomics.com homepage). We discussed these indicators with local researchers and all thought that the official minimum wage amount was not enough to have a decent quality of life; according to them, people need at least the double (20,000 TZS/day). Furthermore, higher formal education levels were considered to correspond to higher adaptive capacity as well as higher levels of organization. For the analysis, no quantitatively aggregated measure of adaptive capacity was used. All the data from the interviews were then categorized, linked, and analysed using Cinner et al. (2018) five domains (*Assets, learning, flexibility, agency, and organization*) (see Table 1). Cinner's domains function as an organizer framework and are gaining popularity and influence both in the climate change scientific community and in policymaking. For the choice of framework, it was also important that Cinner's typology was specifically proposed for tropical coastal communities.

TABLE 1 Themes for discussion during the semi-structured interviews with coastal women (N= 117) in six villages in Zanzibar to gather information about their adaptive capacity.

Themes/Topics that were discussed with each coastal woman during the interviews	Main domain that interview data informs/operationalizes
Basic information of respondent and household situation	All
Knowledge about climate change and observed seascape ecological changes	Learning
Existing livelihoods and possible alternatives	Flexibility, Agency
Economic situation such as income and other material assets	Assets
Social capital in terms of organization (formal or informal)	Social organization
Education levels	Learning, flexibility, agency

The table shows what domains from Cinner et al. (2018) typology the themes operationalize.

Results and discussion

Knowledge, seascape changes, climate variability and change

Research on adaptive capacity emphasizes that knowledge is important (e.g. Pahl-Wostl, 2009; Lemos et al., 2012) and can produce better policy outcomes, for example combining scientific knowledge and local knowledge in an iterative process (Lemos et al., 2012). A general assumption is that local ecological knowledge will enhance adaptive capacity since the more that is known about a problem, the more understanding and capacity is to tackle it. In this case, a majority of women (≈ 65%) had difficulties relating to the question about what climate change is and what it means to them. For clarification purposes, two expressions of "climate change" were presented in Swahili. The results showed that some women had clear opinions about climatic changes, such as wind seasonal changes, changes in rain patterns and temperature increases. However, some respondents did not answer at all and a relatively large group (about 20%) linked it to social issues which were unclear and difficult to understand, e.g. *"I think this is an issue of morals"; "To me it means less development in society"*. Climate change is a complex concept embedded in a Western scientific perspective and other understandings might be in place, thus climate change can mean different things in different contexts and epistemologies. It seems also, that it is difficult to identify, describe, and relate to a natural phenomenon that manifests slowly; some researchers argue that humans cannot perceive climate change due to the large temporal scale (see Reyes-García et al., 2016 for a discussion). The local researchers and our translator expected a higher degree of knowledge aligned with the Western conceptualization of climate change since information in scientific terms has been reported continuously by NGOs, government officials, and *via* media (mainly TV and radio reports) in Zanzibar. This can indicate that critical information may not reach women, because the ownership of TVs and radios varies a lot in different households. There is an important intersection between gender, economic power and climate change knowledge. It is also possible that barriers in language and understandings are present.

Women had, however, clear perceptions about environmental changes for a number of variables. There was consensus about air and sea temperatures increasing, rainfall decreasing and therefore droughts increasing. Changes in salinity had no clear pattern. Perceptions about changes in monsoons were more problematic, with no consistent answers. About half of the women reported windier monsoon seasons, while about a third observed less wind, and the rest mentioned no changes. Highly varied answers were given regarding changes in monsoon duration. The answers to the questions regarding responses and information about climate change were very similar among all women interviewed. Information about climate change (from state, civil society, NGOs or individuals) and its consequences were reported as nearly absent. Confronting this with the fact that climate change information is disseminated on the island, it could be that women either have not been particularly targeted or that they have been missed for other reasons. It could be that information is given in public places when women perform household chores and thus they cannot partake. Lack of participation in environmental issues is of course detrimental and unfortunately widespread and well known in the women and environment literature (e.g. Dasthagir, 2009; Agarwal, 2010; Fröcklin et al., 2013; Gustavsson et al., 2014; Hanson, 2016; de la Torre-Castro, 2019).

Livelihoods and alternatives

Livelihood diversification has been emphasized as a solution to poverty and increase resilience. However, this is not always a positive strategy (Bryceson, 2007; Hanh and Boonstra, 2018; Eriksson et al., 2020), and results are not always successful (Roscher et al., 2022). Previous research in Zanzibar shows that diversification is very difficult and expectations should be moderate (Torell et al., 2010). Despite this, as climate variability and change will affect most coastal livelihoods the question of livelihoods is fundamental. Common livelihoods are of rural character, related to the environment and direct extraction of coastal resources. A vast majority had seaweed farming of red *Euchemoid* algae as their primary livelihood combined with something else. *"Mwani (the algae) alone is not enough"*. In order of importance, the following primary livelihoods were reported (N=117): Seaweed farming in intertidal shallow areas (103 women); fish traders (3); baking of cookies and/or cakes (3); farmers on land (2); invertebrate collection (1); petty commerce with groceries (1); local restaurant owner/employee (2); tailor (1); madrasa teacher (1). The most mentioned complementary livelihoods were: Farming on land (17); stitching/tailoring (17); baking (12); and firewood collection (12). When asking women about other activities that they can perform as a coping strategy to handle environmental variability and climate changes, a large majority (≈ 75%) said that there were no more good options available. The rest of the women provided information on rural activities with little market demand, i.e. petty business, farming, firewood collection, cooking, handicraft production, livestock activities, rope making, agriculture, bivalve collection, goat dairy products manufacture, irrigation, making juice, and knitting.

Economic factors (income and assets)

Financial capital is essential to understand adaptive capacity (Freduah et al., 2019). A sufficient and stable income, and having the possibility to sell assets into cash are critical. Economic security and savings can make migration possible, start a

business, or reduce vulnerability. In agroforest systems, credit provision was also beneficial given the right circumstances and in the short term (Caretta, 2014). Specifically, for women, economic independence is needed for empowerment, emancipation and freedom (Kabeer, 1999; Nussbaum, 2000).

Income was classified into three categories: High ≥ 10,000 TZS/day; mid 3 – 9, 000 TZS/day and low ≤ 3,000 TZS/day. A significant majority of women fall in the low-income category (72%). Further, a total of 84 women fall below the poverty line. The mid group earned slightly more but not as much to reach the salary needed for a "good/decent" life in this context (about 20,000 TZS/day see method). Within the high-income category, only 10 women were found (Table 2). The main difference between these women and the rest of the group was that they were more business-oriented with two of them having a small restaurant, one dealing with fish commerce, and another one owning a baking business. Six also had seaweed farming as the main livelihood but their diversification degree was higher. A multivariate significance test (SIMPER/PRIMER) showed no significant differences between the high earning group and the low earning group. Pairwise comparisons also showed no significance. Thus, the actual reasons require further research.

Other important economic assets such as credit, savings and remittances were absent for the majority, *"It is rare to have more, we focus on the earnings of the day"; "Do you really mean that people will send money from abroad? (Laughing))"*. About 60% of the households reported a traditional structure with men as breadwinners. *"You should know that here in Zanzibar, men and male elders take decisions … they are very important…"*. However, in about 20% of cases, women were the main provider while the other 20% reported an equal provision of money. Thirty percent (30%) of women inherited assets (valuable items, jewellery or money) from deceased relatives or parents. The seaweed farmers were particularly concerned about their economic situation *"Mwani (the algae) was good, but now many have to quit"; "Life is difficult, but I have to endure…"; "Things are bad … the algae is spoiled"; "Do you have pain killers? Working with seaweed is bad for my back"*.

Other material assets showed an uneven distribution. With a few exceptions, women did not own assets such as cell phones, bikes or motorcycles, *"You can ride when you are a girl, but after is stop"*. When it comes to animals, ownership was reported for about 50% of women. About 30% of women reported being the formal owners of the family house. Fishing items were almost absent for women, but eight women reported having fishing gears, and many of them owned some equipment such as buckets, knives, bags or ropes (used for the invertebrate collection activities). No woman owned a fishing boat. About half of the women owned some jewellery. Electricity was still a luxury in the household, and about two-thirds reported having no electricity at all. It follows that no TV and fridges were present. However, most households had a toilet (even though in most cases very basic, a small room with a hole in the ground). A majority reported having running water. Radio was a common asset, but still not present in all households.

Women and organizations

Women's situation related to social capital was investigated by checking the type of organizations found and if they were part of it or not (organized or not organized). There were no restrictions for noting the type of organizations in the interviews. Any organization mentioned was recorded, i.e. formal, informal, governmental, or NGO. A total of 33 organizations were mentioned by women ranging from livelihood-related (e.g. Fisheries committee, Agriculture committee, or Seaweed farming committee), to general aspects concerning village life (e.g. Development committee, School committee, or Madrasa committee). Economic-related organizations were mainly related to micro-credits (e.g. Credit provision, and informal saving groups). Organizational membership was as follows; from the total of 117 women interviewed, 70 (60%) were not organized; 47 (40%) were organized in at least one organization. JECA (Jozani Environmental Conservation Association) was the organization with the highest number of members (16); six women were part of the village's Environmental committees and remarkably only eleven (11) women were members of the Seaweed farming committee. Knowledge about organizations beyond the local village level was very rare. This lack of organization and internal

TABLE 2 Income categorization for the women interviewed during the study along coastal villages in Zanzibar, Tanzania (N=117).

Category	Range income	Number/Percentage of women	Average income
High-income	**Above** 10,000 TZS/day (4.37 USD/day)	10 (8, 4%)	26,860 TZS/day (11.70 USD/day)
Middle-income	**Between** 3,000-9,000 TZS/day (1.25-3 USD/day)	23 (19, 6%)	4,691 TZS/day (2 USD/day)
Low-income Poverty line = 1.25 USD/day	**Below** 3,000 TZS/day (1.25 USD/day)	84 (72%)	1,424 TZS/day (0.6 USD/day)

drive to organize have to be addressed as it can be detrimental to adaptive capacity (more in the next section linking results to the adaptive capacity domains).

Education levels

Formal education for women was relatively high (compared to other African countries with high illiteracy levels). About half had studied to some year of secondary level. However, none of them had reached all the way up to the last year of high school. The school levels were reported as follows: Primary (35 individuals); secondary (67 individuals); almost finished high school (only one woman). Ten women reported having religious education only (e.g. Quran School/Religious lessons); one woman reported having no education, and three were not sure. These data show that education levels are quite different among women in Zanzibar and the problem of reaching all people to partake in governmental planned education is prevalent.

Women's adaptive capacity linked to the five domains

The literature looks at adaptive capacity as a key feature to deal with climate change and/or other stressors. Eakin et al. (2014) and Lemos et al. (2016) identify generic adaptive capacity (aspects that allow development, e.g. state, institutions, and programs in place) and specific capacity (climate change-related risks and aspects). In this study, we focused on adaptive capacity to climate change. However, in the context of Tanzania, both aspects are relatively weak since institutional and economic support is low and women showed limited knowledge about broader climate aspects and higher scales, although observations about environmental changes were accurate. Adger and Vincent (2005) state that adaptive capacity is "the vector of resources that represent the asset base from which adaptation actions can be made". Adaptive capacity concerns also a latent possibility that can be used and disclosed when needed (Engle, 2011). Further, Grothmann and Patt (2005) define adaptive capacity as "the conditions that enable people to anticipate and respond to change, to minimize the consequences, to recover and take advantage of new opportunities". On tropical coasts, more research is needed and important to keep in mind is that in this context development interventions might be structurally unfair and might not reach women (Gustavsson et al., 2014). A gender and pro-poor perspective to understand adaptive capacity is desirable. Based on the results, we discuss women's adaptive capacity within the five domains identified for tropical coastal communities i.e. *assets, flexibility, social organization, learning and agency* (Cinner et al., 2018). Table 3 summarizes the findings for each adaptive capacity domain.

Assets

We focused on assets owned by women to analyse how these sets of resources may or may not contribute to their adaptive capacity. Normally these data are taken at the household level, but we designed the data collection to target information about the individual situation. It can be argued that having more assets will enhance adaptive capacity; however, this is not always the case. Even if women have an asset (different from cash), the value of the asset can only be realized through selling or exchanging it for another asset or cash that can enhance adaptive capacity. In this context, assets are prioritized for emergencies such as sickness or funerals; but not for environmental problems. Other economic assets such as credit, savings and remittances were low among the interviewed women. Income (Table 2) for the high-earning group (10 women) was well above the poverty line; while the mid-group (23 women) was just on the borderline of poverty. However, the vast majority (84 women) were below extreme poverty, not reaching even 1.25 dollars a day (Table 2). So, in income terms, the majority of women are poor and vulnerable. Compared to men, the income gap is apparent. Men's average income was about 2.81 USD/day compared to the 1.30 USD/day earned by seaweed farmers (de la Torre-Castro et al., 2017; this study). Other studies mainly for Indonesia have reported more economic benefits, for example, a study investigated 39 households doing seaweed farming in South Sulawesi, Indonesia in 2017. Seaweed farming brought several benefits and no related negative aspects to the well-being of small-scale producers. However, income as such was not considered in the set of factors measured, what was measured was the perception of having extra money (Larson et al., 2021). Rimmer et al. (2021) concluded that seaweed farming is potentially beneficial but does not always works to escape poverty. Nevertheless, economic performance considering the type of farming systems used was highest for Indonesia followed, in decreasing order, by Mexico, Solomon Islands, Philippines, India and Tanzania (Valderrama et al., 2015). From this information, it is clear that there is a lot of space for economic improvement in Zanzibar.

Another aspect important here is that men have more freedom to move and work within different occupations, while women perform their activities in the shallow shores near the household where temperature increases due to climate change are more pronounced (Fröcklin et al., 2013; de la Torre-Castro, 2019). Simply put, climate change will bring negative changes to the environmental assets on which women's livelihoods depend while the capacity to realize assets' value, migrate or shift livelihoods is low. The high-income group, represented by ten women, had advantages due to their better purchasing power

TABLE 3 Classification and summary of the results of women's adaptive capacity in coastal Zanzibar, showing the five domains of Cinner's typology for Adaptive Capacity (Cinner et al., 2018).

Domain/	Positive for adaptive capacity	Unclear role for adaptive capacity	Negative for adaptive capacity
Assets	High income High level of inheritance	Ownership of animals Ownership of other items that do not have a clear market (e.g. buckets/ropes) Ownership of jewellery Ownership of house Intra-household dynamics	Low income High dependence on seaweed farming Informal labour Difficulties to realize owned assets
Flexibility	Previous experience showing flexibility and adaptation Literacy	External programs introducing diverse new activities Perceptions of new jobs like tourism Intra-household dynamics	Lack of "real" alternative livelihoods that provide a good income Lack of language skills Lack of time Lack of demand for local products Lack of financial capital Tourism targets international markets Tourism hires foreign employees Cultural norms incompatible with tourism work
Organization	Knowledge about organizations at the local level Participation	Social factors that affect leadership formation Intra-household dynamics	Low organizational level Seaweed farmers are not active in their respective committees Lack of formal arenas for discussion and problem solving Traditional norms and structures Lack of time to participate Lack of time to prioritize environmental issues
Learning	Relatively high level of formal education Awareness of environmental changes Good observation capacity	Different conceptualizations of natural phenomena Local ecological knowledge Intra-household dynamics	Complexities in information exchange Differences in local and scientific knowledge Lack of knowledge at higher scales Lack of knowledge about international market and its dynamics Lack of formal arenas for discussion and problem solving Lack of media coverage Lack of assets such as radio and TV Lack of access to newspapers and information materials No women with a university education
Agency	Relatively high level of formal education Previous experience dealing with change Multitasking capacity Used to have important responsibility	External programs and interventions Religious beliefs Intra-household dynamics	Constant care of the household Focus on the local scale Lack of time for reflection Financial constraints Traditional norms and structures

Factors identified in the unclear column are rarely treated in the literature and deserve further research. Other factors worth noting are e.g. multitasking capacities, lack of time for reflection and difficulties to realize other owned assets.

and their entrepreneurship. These women have increased possibilities to invest in health, education and household things if needed; but in the case of a sudden catastrophic event or rapid climate damages, they would still face difficulties to migrate, change or invest. The role of other assets to enhance adaptive capacity was unclear. For example, the case of owning animals, having jewellery or being the owner of the house. Women having these assets surely can have more space for adaptation but the constraints to realize the economic value of the assets remains; as no woman reported the easy realization of these assets in times of need. Cohen et al. (2016) study in The Solomon Islands found that assets are key to mediate adaptive capacity. This study confirms this finding. Balama et al. (2017) concluded that adaptive capacity increases when the individual and the household gain access to resources not normally used. In their case, situated in forests in Tanzania, people who accessed other products than just timber benefitted. In this case, having access to a variety of assets can be beneficial, even if it seems to be difficult. Important to note is that the gendered power relationships at societal and household levels play a key role. The traditional gender views and the confinement of women to household work and childcare may contribute to men's power and authority in economic decision-making. Previous studies show that women use assets for family well-being, and men's

power within the household may hinder women's self-development, economic independence and decision-making (e.g. Garikipati, 2008). This is found in coastal fishing families as well (Fregene Tosan and Bolorunduro, 2009).

Flexibility

The situation above is closely linked to the flexibility domain. The capacity to switch between adaptive strategies, to do something else, plan for change, and to be able to fulfil those plans is constrained by the lack of knowledge, opportunities and financial resources. Cinner et al. (2018) highlight the ability to shift livelihoods and occupational sectors. There are, however, few options and opportunities in this context. There are no alternative livelihoods, at most there are complementary ones (e.g. honey production, chicken farms, handicrafts). The programs introducing alternative livelihoods in Zanzibar have unfortunately not been successful (Gustavsson et al., 2014) and present elements of injustice (Gustavsson et al., 2021). In this context, there are no major industries that employ women like, for instance, those in South-East Asia. The labour market is very limited. Women have without doubt varied skills, which may provide flexibility. The problem is that the current alternative activities that generate money do not secure a worthy daily income covering needs and leaving mental strength for future planning and reflection. Commonly, women are too busy with various social and organizational burdens to be able to manage additional things (Hoschild, 1989).

The complementary livelihoods that women engage in, provide very little extra income (see Appendix 2 and sections above). Common activities like farming, baking and tailoring are done for the local, village market. The potential to transform complementary livelihoods into main ones is low since substantial national demand for such products will be required, which in turn, depends on the existence of a large middle class. It also requires a more labour-intensive type of production. A case in point is when women in the villages are encouraged to start a "bread business" ("*Chapati*" bread production). The market is too small since most women bake their own bread and tourists do not consume this bread. Where is the market to drive the business? Tourism has not brought the trickle-down effect expected and women are seldom employed by the industry. Local women are not demanded due to several factors, for example, they lack skills and fluency in English, they have religious limitations to deal with alcohol, and cultural ones to leave the family sphere. Thus, opportunities are limited, and labour is imported. An opportunity is working with housekeeping (see also Lange, 2015; de la Torre-Castro et al., 2017) which can bring some income but is a low-status activity. In addition to individual limitations, there are structural problems in the tourism industry in Tanzania, which has not succeeded in being pro-poor and faces challenges such as foreign ownership, low salaries, and poor working conditions (Kinyondo and Pelizzo, 2015). Adding to this, tourism's environmental damage is extensive (Lange, 2015). Some external interventions have been more successful for women, i.e. the introduction of shell and pearl handicrafts. The activity has increased women's quality of life by increasing asset ownership (cell phones, fridges, electricity, and house ownership), knowledge (marketing, organizational), and capacity to organize (Fröcklin et al., 2018). However, the activity reaches only a small number of women and how to scale up such interventions is still unresolved. The jewellery business faces similar market problems such as those mentioned above. The designs are modest, having no high demand. Tourists buy some pieces as an action of solidarity contributing to social sustainable tourism. However, wealthy people in Zanzibar or in mainland Tanzania that could afford them are not interested. The case for algal soap production is similar.

There are big expectations in livelihoods introduction but unless market demand is in place they are prone to fail. Interventions must differ depending on their goals, for example, if the goal is to increase resilience or break poverty traps, or increase adaptive capacity or a combination (Torell et al., 2017). Moreover, livelihoods' introduction is normally gendered, and may not account for the local contexts of norms, traditions, and power structures. Therefore, in order to be effective, livelihood interventions must consider gender inequalities in which women are often disadvantaged (Lawless et al., 2019). If new interventions are designed, it should be remembered that about 75% of women said that there were no livelihoods options (Appendix 2, Figure 7). From those who answered the creation of handicrafts, goats for diary production (particularly cheese making) and preparing fresh juice are the most plausible ones *if the tourism industry opens up for cooperation and a legitimate broker is involved in the process* (our emphasis).

Women in Zanzibar are extremely flexible in other ways, they have managed to juggle between household chores and work; they have managed to accept a tourism industry that overlaps with their working places along the seascape (de la Torre-Castro et al., 2017) and clashes with their customs and religion. Furthermore, they have accepted conservation measures that often have little direct benefits. This flexibility can be understood as an adaptive strategy to endure and to go on. Since adaptive capacity is latent, probably this flexibility and multitasking ability can be an asset in the future. However, as expressed in the interviews, this type of flexibility has also brought frustration and a feeling of being "powerless spectators", with limited agency (as in Fabricius et al., 2007 typology), *"We adapt and we follow instructions from governments and village councils (all with men in high positions), but we cannot create something … I don't know how to explain … but something for ourselves"*.

Organization

Organization leading to improved social capital is considered positive both in rural environments and in the context of climate change adaptation (Adger, 2003; Cinner et al., 2012a; Marin et al., 2012). In marine contexts, Gutierrez et al. (2011) found that leadership was most important but social capital was crucial too. Later, Crona et al. (2017) confirmed that leadership seems to be more determinant. In this study, we checked belonging to formal and informal organizations following Putnam et al. (1994) argument (the higher organizational belonging the higher the social capital). Forty percent (40%) of the women were part of some type of local organization. However, and importantly, the type of organizations in which they were members did not match the livelihoods they worked with, a surprising result. A clear majority of the women were seaweed farmers, but from the total interviewed (N=117), only eleven (11) were members of the Seaweed farming committee. This result deserves future research. From previous interviews women gave lack of time as important reason to limit their possibilities to organize. Seaweed farming is a highly demanding activity causing also negative health effects (Fröcklin et al., 2012). Osborne et al. (2008) demonstrated that the key factors for participation in groups and organizations are 1) not working fulltime, 2) being married and 3) having high levels of education. Women in Zanzibar worked full-time and none had higher education. The management and work literature points out that women's own awareness of the benefits of increasing social capital is fundamental (Kumra and Vinnicombe, 2010), but for women in Zanzibar this has to our knowledge not been investigated. In the development literature it was found that provision of microcredits can, due to the necessity to meet, in the long-term lead to higher social capital, since isolated women can get new connections, networks and relationships. The meetings themselves seem to be empowering and women organized to achieve actions that required collective organization (Sanyal, 2009). Women in Zanzibar have been targeted by various micro-credits programs. However, microcredits are not a panacea and can have its own problems of power disputes, embedded interests, etc., so careful attention is needed if they are introduced (Mayoux, 2001). In addition, Mayoux (2001) found that these types of microcredit programs create mainly bonding capital (among group members), however bridging capital (with other external groups) is also needed and, in that case, higher education levels and other social dynamics may play a crucial role.

Other studies analysing seaweed farmers have found that governments and donors cherish the activity and promotes it as highly positive. However, organization and creation of social capital is not easy, and benefits vary depending on the scale of the organization. Andriesse and Lee (2021) found that at the local level associations and cooperatives can even be negative due to corruption and power disputes. Thus, the personal problems of the women together with dynamics of local politics can lead, under certain circumstances, to a decrease in adaptive capacity. Another reason for weak organization has been related to changes in environment, seaweed farmers in particular settings in the Philippines stopped producing and organizing due to poor water quality and lack of financial means (Andriesse, 2022). Women in Zanzibar experience and observe the environmental changes. They also notice the negative effects on seaweed growth; but they do not have arenas for discussion, which are essential for problem identification, solution creation and further organization (Ostrom, 1990). These results are consistent with previous findings. It has been identified that women's organizational level is low in Zanzibar as compared to other parts of Africa, South-East Asia and Latin America (Fröcklin et al., 2018). Moreover, engagement in environmental issues does not always emerge automatically. Social norms and gender may hinder organization and possibilities for collective action (Agarwal, 2010). The issue of leadership role and its emergence was not investigated, but it is highly possible that being a woman leader in this traditional masculine society will involve confrontation with strong norms and traditional values. This confrontation is a very high price to pay for women. Political engagement, fights for aquaculture workers' and fishers' rights in the villages were not identified as such.

Learning

Women's learning takes place all the time, as a continuous process of observation and experimentation by living with nature daily. This is a common feature related to learning about climate change (Berkhout et al., 2006). In this study, the results about observed environmental/seascape changes were remarkable. Broadly speaking, women's observations of key variables from the field fit well with most scientific observations. This has also been observed in other villages in Zanzibar (Makame and Shackleton, 2020). However, a major challenge is how to use the knowledge in the context of climate change and action. Knowledge should be useful for better adaptation, and a combination of knowledge is the way further for historical understanding, forecasting and policy formation (Saldivar-Lucio et al., 2021). Complementarity between traditional ecological knowledge and conventional scientific knowledge is possible and important (e.g. Moshy and Bryceson, 2016).

Theoretically, women's observations of the environment/seascape could be an incentive strong enough to radically change and/or abandon the seaweed farming activity, whether the negative impacts are caused by climate change or not. In fact, many women are leaving the activity at present. However, environmental knowledge was spatially constrained (women

had deep knowledge in the particular coastal space where they work). There was a scarcity of knowledge about higher scales and a holistic understanding of climate change as a physical phenomenon could not be identified similar to Makame and Schakleton's findings (2020) in which little exposure to climate change as a global issue was found. A central issue for further research is thus how to use women's seascape knowledge for management, policy and adaptation. In other words, how the situated knowledge of these women can enhance both adaptive capacity and climate adaptation planning. Lemos et al. (2012) suggest two components for climate change knowledge i.e. usefulness and usability; in this case, knowledge is present but its usability is unclear. Furthermore, there is no consensus about the value and merit of local ecological knowledge for climate change. Some scientists argue that there is little value in this knowledge (Doyle, 2009), while others consider it critical and complementary to scientific knowledge (e.g. McMillen et al., 2014; Hosen et al., 2020). A recent review analysing local knowledge found that there is a lot to consider before this type of knowledge can be integrated. The review shows that unusual events tend to be overrepresented as well as broad categories instead of specific variables (Reyes-García et al., 2016). However, for Tanzania's fishing community integration of local knowledge (despite the difficulties involved) is recommended as scientific knowledge tends to be limited (Mwaipopo and Mahongo, 2020). The environmental observations from the farmers are important since seaweed production seems to face similar environmental impacts elsewhere. Indonesia, the largest current producer of red seaweed is having critical problems too due to diseases, pests, excessive epiphyte growth on the algae and seedling quality (Kambey et al., 2020).

In addition, learning in terms of adaptive capacity can be related to climate change causality but also to other local matters such as learning about markets. Links between markets and the environment have been highlighted as fundamental (e.g. Galaz et al., 2018), and this is also valid for gender and women studies. Williams (2019) argues that research on women, gender and fisheries has to address political economy, e.g. globalization processes, markets, labour and value chains. This is extremely important for women in Zanzibar, as the seaweed market is global, and demand and prices are set by influential producers in South-East Asia, and by the chemical industries in the North buying raw material (the dried algae) for carrageenan production. Thus, knowledge about the links between the local villages to the global economy, knowledge about project management, and knowledge about market constraints would be very useful to increase women's adaptive capacity. Learning can be formal or informal. In this case, women have relatively good formal education compared to other low-income settings and excellent informal learning about the environment. However, they do not have places to share, compare and discuss knowledge since most of the women are not part of the Seaweed farming committees and time for discussion in other arenas is highly limited. It would be interesting to investigate other forms of informal sharing and organization, if any. Formal education is absolutely desirable and there is a need to encourage women to achieve higher levels. Women in this context were not illiterate, but none of them had higher education, which is necessary to get employment in other sectors such as the government, tourism and to deal with globalized markets. Higher education increases marketplace bargaining power and importantly gives access to political processes and legal systems (Nussbaum, 2010). Structural positive changes are well documented in the literature when formal education increases for women; for climate change, this can mean, a better translation of local knowledge for its incorporation into management, policy or science; increased skills to plan and anticipate; and higher agency for participation. Careful attention should be given to advances when formal education is introduced; a pastoralist case in Kenya found that women with or without formal education reacted similar to droughts caused by climate change, however, women with formal education had higher risk perception (Walker et al., 2022). Making the issue of formal and informal knowledge complicated when it comes to behaviour for adaptation. Therefore, nurturing both types of knowledge is required.

Agency

Agency is related to the capacity to make choices and to be able to act (Brown and Westaway, 2011), and is a key factor for transformation (Westley et al., 2011; Westley et al., 2013). Agency implies a sort of initiative, desire for change or thinking, an inner individual capacity to do things. Agency is the power and liberty to mobilize other domains of adaptive capacity (Cinner et al., 2018). In that sense, "generic" agency can be regarded as high since women are always doing things to assure their own, their children's and in general the family's survival. But there is little time for reflection and planning for the future. So, a key question is agency for what? Actively shaping for the future is considered fundamental in this domain, but for women in the Zanzibar context, time invested in heavy work and household chores follows a day-to-day basis. When it comes to climate change, it would be important and desirable that women develop strategies for anticipation and change, which are linked to learning and education and the large temporal scale (see above). For the Western Indian Ocean, a study performed in Mozambique found that temporal scale is critical, in the short-term people could cope with changes, but in the long run, planned adaptation and learning are absolutely needed (Osbahr et al., 2008).

It seems that the triple burden that women face (focus on income, household and social work) are major agency constraints for change and long-term planning. Women are immersed in the local reality and other regional or global

alternatives were hard to envision. The knowledge found was at most at the national level. This was clear from the results when asking about coping strategies; all answers were expressed in local terms. Agency does not exist in a vacuum. Social structures, local norms and expectations as well as "gender blind" interventions can shape and reshape individual agency (Lawless et al., 2019). Social life and its influences have a fundamental role in individual decision-making (Barnes et al., 2020). One important finding was that about 5% of the women had strong religious beliefs contrary to Makame and Schakleton (2020) who found a vast majority expressed religious beliefs. Here, these few women pointed to God's will when discussing initiatives, coping strategies and future perspectives. *"I will just sit down and see what God's plan is", "God will give me the clue", "God will send a miracle"*. This type of thinking may slow down agency and initiative-taking, but at the same time brings some hope and removes problems for the self.

Summing up and the way forward

Table 3 summarizes the key findings of the study. The identified underlying factors shaping adaptive capacity of coastal women in Zanzibar are classified as enabling (positive), unclear and constraining (negative). It is important to note that the findings may be relevant for different domains. The relationships are complex and there is not necessarily one- to-one correspondence.

The unclear factors shown in the table deserve future research, as well as these particular questions:

a. Is there any indigenous local knowledge related to climate change in these settings?
b. What are the power and social structures limiting women's agency (in-depth studies)?
c. How to increase organizational capacities and social capital leading to collective action?
d. What is the role of the "Blue economy" in Zanzibar linked to livelihoods and future planning?
e. How can climate justice and coastal people's rights be considered in coastal governance?

The role of the state cannot be underestimated as well as the role of external donors. Adaptive capacity and adaptation are on-going processes that need to be framed in social, economic and political contexts and not only treated as technical matters (Nightingale et al., 2020); they should be well-anchored in people's lives (Ensor et al., 2019). In the long run, the causes that reduce adaptive capacity should be tackled by societal transformation (e.g. O'Brien, 2012).

For Zanzibar, it is crucial to address the problem of seaweed farming linked to climate variability and change since the ocean temperature is rising, precipitation is highly variable and the algae responds negatively to the impacts of those changes. In the future, it is also important to continue addressing other activities related to coastal women. Much focus has been on seaweed farming since the results showed it was the dominating activity, but invertebrate collection, cooking and frying small pelagic fish as well as the activity as women fish traders will equally face challenges due to changes in ocean variables. A few women who drive small local restaurants in which fish and shellfish are offered will also face the effects of the marine ecosystem changes. Not to speak about the small-scale jewellery production that will suffer from ocean acidification.

A window of opportunity: Zanzibar's institutional set-up to enhance women's situation

There are possibilities to accelerate the adaptive capacity of coastal women using the institutional set-up on the island; through bridging and cooperation and the windows of opportunity found at the moment of writing, where reorganization of ministries is taking place. Zanzibar has, despite many challenges in coastal management, a very good organizational structure (de la Torre- Castro, 2006), and this is constantly evolving to respond to contemporary challenges. At present, the whole ministry dealing with ocean and marine resources is being re-structured into a ministry that seriously tackles the advent of the Blue Economy and highlights marine conservation and protection more clearly than before. The structural proposal for the new Ministry of Blue Economy and Fisheries encompasses five departments namely, Department of Blue Economy, Department of Fisheries Development, Department of Marine Reserves, Department of Operations and Services and Department of Policy Planning and Research. Each department contains units/divisions devoted to specific areas, one key area is the Division of Seaweed/Algae Development. Having the new structure working, internal links to key issues can be established, for example links to research, new policy that benefits women, marine spatial planning and fair commercialization of the product. Placing women's problems and challenges within the ministerial structure is an excellent opportunity to visualize and further implement solutions and also to legitimate the needs through formalization. The lack of a holistic understanding of climate change can be assessed through the division of environmental education. Moreover, beyond internal links within the Blue Economy and Fisheries ministry, links with other relevant ministries and organizations can be done, e.g. Ministry of Tourism, Ministry of the Environment, as well as the Ministry of Health which has a subdivision for women and youth. External donors, NGOs, etc. can focus more on climate change action, education and concrete proposals, for example, investigations about resistant varieties of algae to high temperatures, improvement of growing

methods, biosecurity and multiple species aquaculture. These are good news for Zanzibar, since one of the most challenging aspects to promote sustainability and positive transformation is already in place, i.e. organizational structure capacity.

Conclusions

This study investigated the adaptive capacity of coastal women in Zanzibar (Unguja Island), Tanzania, and discussed the results using Cinner et al. (2018) typology (*assets, flexibility, organizations, learning and agency*). The most important conclusion from the overall analysis is that adaptive capacity is relatively low and adaptation to climate change is more reactive than proactive for women in coastal Zanzibar. Realities of everyday life are constantly faced and environmental changes in the seascapes are observed but not linked to wider climate variability and change. In this sense information about climate phenomena, scenario planning and awareness is highly needed, but also to tackle fundamental needs in parallel such as the creation of worthy livelihoods.

When it comes to assets, women owned different assets that were difficult to capitalize. A few women had a relatively high income due to small-scale business. Women seem to be very flexible in non-climate-related matters, this flexibility can be mobilized for dealing with and adapting to climate change. Organizational levels are very low, so there is a lot of space for interventions to empower women and create higher social capital. Women presented outstanding capacities for learning and observation, their observations about seascape changes should be linked to a holistic understanding of climate change. Climate change takes place in a large temporal scale and this is a huge challenge that needs attention. Agency is high in this context, but women have large limitations in time for reflection. Through highlighting different aspects of adaptive capacity as positive, unclear and negative, the study contributes with approachable targets for intervention into Zanzibar women's adaptive capacity. However, the unclear factors found deserve future research (Table 3).

The study further emphasises a specific vulnerability faced by women in that their major livelihood, seaweed farming of red algae, is particularly prone to climate-driven negative changes. To enhance women's adaptive capacity, empowerment measures are necessary and they are possible through Zanzibar's organizational structure. The multi-level organization and focus in co-management is an excellent start. Zanzibar's evolution of organizational structures for the management of the marine environment has followed contemporary developments and can be considered a window of opportunity bringing good news for positive change.

Another important finding is that the individual level is important but not enough; connecting with regional and global agendas is needed, for instance, strong investors like the World Bank, the Global Environmental Facility (GEF) and the SDGs global agenda. The reliance on seaweed farming is a case in point having links with global scales (global warming and price setting in international markets) and thus strategies are needed to consider these dynamics at the local level. The question of livelihoods is critical and should be a priority for politicians, policy makers and managers. Interventions, such as the introduction of alternative or complementary livelihoods have to go hand in hand with market analysis and clearly defined goals as well as a thorough analysis of possible negative consequences (Jones et al., 2022).

Data availability statement

The original contributions presented in the study are included in the article/Supplementary Material. Further inquiries can be directed to the corresponding author.

Ethics statement

The studies involving human participants were reviewed and approved by Stockholm University ethical guidelines to handle interviews with NO sensitive data. Written informed consent for participation was not required for this study in accordance with the national legislation and the institutional requirements.

Author contributions

MdlT-C: idea, field work, analysis and lion writing; LL: social data planning and analysis, field work and writing; NJ: local field work and logistics, writing; FP: analysis, writing, editing; AM: field work, analysis, writing, editing. All authors contributed to the article and approved the submitted version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fmars.2022.931883/full#supplementary-material

APPENDIX 1
Interview form.

APPENDIX 2
Diagrams based on the results of the interviews (N=117 women in Zanzibar, Tanzania).

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