# Understanding of Sustainable Development Goals among communities living adjacent to mangroves in Kenya

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## Abstract

Mangroves are among the most productive ecosystems, known for their diverse provisioning, regulating, supporting and aesthetic services. The ecosystem directly supports livelihoods and ensures food security and nutrition of people through its ecosystem services (ES) such as wood, fish and medicines while protecting them by stabilizing shorelines, reducing flooding, and mitigating climate change and natural disasters such as tsunamis. In so doing, the ecosystem promotes several sustainable development goals (SDGs) and co-benefits several others. This relationship however remains under explored with limited studies on the co-benefit scenarios and the cognitive views of mangrove resource users. This paper highlights gaps in knowledge of the role of mangroves in development and the implications on ecosystem governance. The study analysed the 'ideal' scenario presented in secondary data in comparison to community perspectives on mangrove-related development. Bearing in mind the complexity of the concept of sustainability, development was categorised at local, national and international levels, and community members were asked to mention any known links to mangrove ES at any of the three levels. Results indicate that 45.4 % (n=166) of the community understood the roles of mangroves in development. The majority (79.5 %) were able to link the ecosystem to local (village level) development, 43.1 % to both local and national development while only 13.5 % could link the ecosystem to local, national, and international development. Forty-three per cent (n=157) of the community did not know of the relationship between mangroves and development while 11.6 % (n=43) felt that mangroves do not contribute to development. The study further disaggregated this knowledge socio-demographically, highlighting opportunities for enhancing governance, conservation and the use of mangrove ecosystems in Kenya.

**Keywords:** mangroves, community knowledge, synergies, sustainable development goals, governance

## Introduction

In 2015, the United Nations formalised 169 targets with 230 indicators to gauge development under 17 Sustainable Development Goals (SDGs) (United Nations, 2015; Singh *et al.*, 2017). The SDGs incorporated themes from poverty and hunger alleviation (SDG 1 and SDG 2), to environmental sustainability (SDG 7, SDG 13, SDG14 and SDG15), good health and sanitation (SDG 3 and SDG 6), promotion of equality, justice and education (SDG 10, SDG 5, SDG 16 and SDG 4) and sustainable infrastructure and economic growth (SDG 8, SDG 9, SDG 11, SDG 12) all supported under SDG 17 which seeks partnerships for the goals. The SDGs represent an ambitious effort to improve the lives of the world's poor and marginalized communities through a multi-sector approach (Wood *et al.*, 2018). Embedded in the goals is an aim to rebuild and strengthen the integrity and function of ecosystems to secure the

benefits they provide to both current and future generations (United Nations, 2015; Obura, 2020).

Mangroves are critical in this discourse for their social, ecological, and economic functions (FAO, 2007). The ecosystem provides habitat and nursery grounds for fish and other biodiversity (Field *et al.*, 1998; Kathiresan and Qasim, 2005), wood products and medicinal resources for coastal communities (Huxham *et al.*, 2017). Mangroves also capture and store carbon in their above and below ground components while buffering hinterlands against strong waves and storms (Alongi, 2012; Kuffman *et al.*, 2014). Additionally, mangrove areas are important cultural and aesthetic sites (Shilabukha, 2018).

Considering their broader contribution to the SDGs, exploitation of mangrove goods and services like timber, honey and aesthetics contributes to SDG 1 and SDG 8, eradicating poverty and creation of employment (Huxham *et al.*, 2017). Habitat and biodiversity supporting services provide food for SDG 2 (eradicating hunger) while supporting life for SDG 14 (life for marine biome), and SDG15 (life on land), (Wood *et al.*, 2018). Medicinal mangrove species and other therapeutic qualities of mangroves contribute to SDG 3 (improving health) (UN-DESA, 2017; Wood *et al.*, 2018). Carbon capture and storage link them to SDG 13 (climate action) (Chow, 2018), while their water regulating, and hazard barrier attributes makes them relevant for SDG 6 (clean water) and SDG 11 (sustainable coastal cities) respectively (UN-DESA, 2017).

Despite this critical value, mangroves have experienced a net loss in cover in recent decades, and what remains is highly threatened (Walters, 2003; Thomas *et al.*, 2017). About one fifth of the global mangroves have been lost since 1980, due to anthropogenic stressors, including over-extraction and deforestation from infilling, drainage and conversion of forest areas to aquaculture and agriculture (Walters, 2003; Thomas *et al.*, 2017). This decline has negatively impacted coastal communities and threatens to increase the vulnerability of small-scale fisheries which depend heavily on coastal habitats. As a result, at least 45 countries have mentioned mangroves in their national plans to tackle climate change (Deng *et al.*, 2022), 28 in their restoration pledges, and approximately 62 countries in their national biodiversity plans (IISD, 2019). Kenya has lost approximately 20 % of its mangrove cover since 1980 (Abuodha and Kairo, 2001; Government of Kenya, 2017) and now prioritises mangrove

habitats in its commitments to climate change mitigation and biodiversity conservation (Government of Kenya, 2018). The country is committed to reducing its greenhouse gas emissions by 30 % by 2030, and to increase forest cover to at least 10 % of the land area (Government of Kenya, 2018). The latter has seen the introduction of protection efforts including a ban on mangrove logging (Government of Kenya, 2017; Government of Kenya, 2018). Coupled with efforts to enhance community based natural resource management (CBNRM), the country appears to be making steps towards Agenda 2030, but how do such efforts resonate with the primary resource users?

Studies show a close relationship between environmental sustainability and the quality of governance (Friess *et al.*, 2016) which, according to Lockwood *et al.* (2010) are reflected in eight principles - legitimacy, transparency, accountability, inclusiveness, fairness, integration, capability, and adaptability. Although these principles provide a suitable framework for analyzing governance effectiveness, the complexity of assessing the eight principles within a smaller scale and fitting them with the SDG framework remains a challenge. As a result, different schools of thought have developed simplified assessment frameworks, such as procedural justice, that emphasize the understanding of stakeholder engagement throughout the decision-making process (O'Beirne *et al.*, 2020). Procedural justice advocates for openness and inclusivity in decision making from inception to implementation as reflected in socio- demographic characteristics.

Here we apply the tenets of procedural justice in understanding effectiveness in mangrove governance as reflected in community knowledge. We present the community perspective on the role o of mangrove in development in comparison to an 'ideal' scenario presented in the literature as a step towards assessing the effectiveness of mangrove governance frameworks in Kenya. Community perspectives can provide useful insights into governance frameworks by providing a comparison between community identified needs and current regulations (Shirkhorshidi, 2013; Bennett and Dearden, 2014)

## Material and methods
### Study area
The study was conducted in Vanga, a fishing location on the south coast of Kenya. Vanga is located at 4°39´00"S and 39°13´00"E along the trans-boundary area between Kenya and Tanzania. The site was chosen

because of its geographical proximity to mangrove forests and the dependence of the adjacent communities on fisheries as their main source of livelihood (Kenya National Bureau of Statistics, 2013). Four villages within Vanga Location (Vanga, Jimbo, Kiwegu, and Majoreni) were sampled in the study (Fig. 1). Fishing, subsistence farming, small-scale businesses, and mangrove harvesting are the main economic activities in the area (Kenya National Bureau of Statistics, 2013).

## Assessment of the relationship between mangroves and SDGs

The relationship evaluation framework of Singh *et al.* (2017) was operationalized (Fig. 5) in mapping the relationship between mangrove ecosystem services (ES) and the SDGs. Mapping of the relationships was done through a series of secondary data reviews.

Secondary data sources included reports, journal essays, internet sources, and book chapters related to ES and the SDGs. The focus of these reviews was to compile a matrix representing the ES and SDG targets. During the review, SDG targets were translated *verbatim* as presented in the texts of the SDG blueprint while the relationship assessment was in-depth, leading to an array of co-benefits. For instance, although specific targets like halting biodiversity loss refer directly to biodiversity support, the service was not only limited to biodiversity-related targets but assessed from the broader perspectives of poverty and hunger alleviation, good health and sanitation, environmental sustainability and promotion of equality, justice, education and infrastructure development. This information was then compiled into a comprehensive matrix of the "ideal" relationship between mangroves and SDGs for expert review (Appendix 1). The "ideal" relationship was contextually defined as the desirable link between mangroves and SDGs as envisioned in the SDG blueprint. In the ideal situation, social dynamics play harmoniously
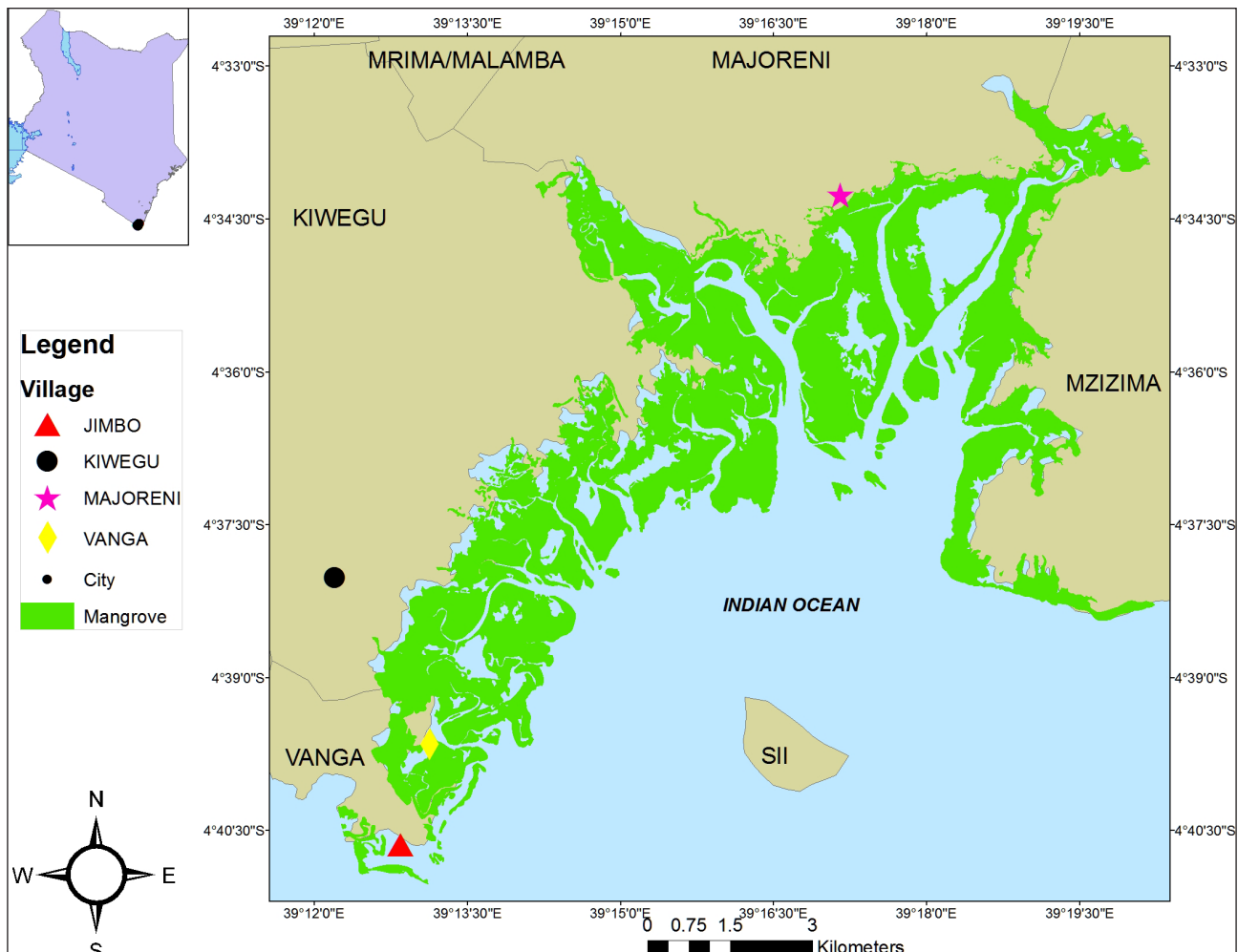


**Figure 1.** A map representing the study area showing the study sites, Jimbo (red triangle), Kiwegu (black circle), Majoreni (pink star) and Vanga (yellow diamond). The extent of mangroves is highlighted in green.

with the ecological needs to present sustainable development outcomes.

## Assessment of community perceptions of the relationship between mangroves and SDGs

Community perceptions were disaggregated by age, gender, level of education, and period of residence in the study area while development was categorized into local, national and international levels. Local development was limited to village boundaries, national development to the country boundaries while international development was development beyond national boundaries. Considering the complexity of sustainability, community members were asked to generally mention the link between mangroves and development at local, national and international level. Sustainability principles were then applied to the responses to assess their perceptions of the link between mangroves and the SDGs.

The study adopted a cross-sectional design employing simple random sampling. Daniel's (1999) sampling formula, reviewed in Daniel and Cross (2018), was used to determine the sample size of the study:

$$= \frac{N \times X}{X + N - 1}$$

Where, X = Zα/2 *p*(1-p) / MOE2 (Zα/2 is the critical value of the normal distribution at α/2, e.g., when the confidence level for this study is 95 %, α is 0.05 and the critical value is 1.96), MOE is the margin of error, p is the sample proportion (50 % for this study), and N is the population size) (Daniel and Cross, 2018). This study used a questionnaire survey, focused group discussions (FGD), and secondary data review.

A total of 366 respondents were sampled for the survey. FGDs involved men and women categorized by age groups (youths and elderly). Each FGD consisted of 8-12 individuals of the same gender and age group.

## Hypothesis and statistical tests

The null hypothesis for the study was that socio-demographic factors influence knowledge of the synergies and trade-offs. Spearman's correlation was used to test the null hypothesis with knowledge of the relationship between mangroves and the SDGs as the dependent variable and sociodemographic factors as the independent variables. The r-value (relationship) was determined using the formula:

$$Rs = 1 - \frac{6 \sum d2}{n3 - n}$$

*p*=Spearman's rank correlation coefficient
*d*2=difference between the two ranks of each observation
n=number of observations

Spearman's *rho* is a statistical framework for non-parametric test of the association between two variables, where the value r = 1 means a perfect positive correlation and the value r = -1 means a perfect negative correlation (Prion and Haerling, 2014). This has been used in a wide range of socioeconomic studies to determine the relationship between trends and phenomena. We based our analysis on the practical guide in Akoglu (2018) in assessing the correlation coefficient between independent and dependent variables of this study.

## Data processing

Qualitative data was transcribed and coded according to themes of the study using Atlas.ti7 then analyzed and presented in rich narratives. Quantitative data was analyzed using descriptive and inferential statistics and presented in graphs and tables.

## Results
### Sociodemographic characteristics of the study area

The sample size of the study included 56.4 % (n=206) female and 43.6 % (n=160), male participants. Forty-eight percent of the sample population were the heads of households, while 52 % were close relatives to the head of households living within the households and contributing to household income. The highest proportion of the respondents (49.3 %) were aged 18-35 years, 42 % aged 35-60 years while 8.7 % were aged over 60 years. Education standards in Vanga were low with the majority of the respondents (62.3 %) having attained only primary school education and 19.4 % no formal education. Only 18.3 % had a post-primary school education, amongst whom 1.7 % had attained tertiary education. This indicated a low transition rate to higher education levels with a 44 % disparity between community members with only a primary school education and those with at least a secondary school education. Most respondents aged over 60 had no formal education while the majority of those aged 18-35 and 35-60 had only a primary school education. Most women had a primary school education while the majority of men had at least a secondary school education (Table 1). Forty eight point six percent (48.6%) of the study population had lived in the study area for more than 30 years, 25.1 % between

**Table 1.** Frequency distribution of the socio-demographic characteristics of the study area.

| Education | | | Village | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Jimbo | | Kiwegu | | Majoreni | | Vanga | | %Aggregate (n) |
| | | | Gender | | Gender | | Gender | | Gender | | |
| | | | Female | Male | Female | Male | Female | Male | Female | Male | |
| | | | % Freq | % Freq | % Freq | % Freq | % Freq | % Freq | % Freq | %Freq | |
| Others/Non-Formal | Age | >60 | 4.3 | 0 | 2 | 13.6 | 0 | 10.2 | 1.5 | 7.3 | 4.9 (18) |
| | | 18-35 | 8.7 | 8 | 6.1 | 2.3 | 0 | 4.1 | 6.2 | 0.0 | 4.4 (16) |
| | | 35-60 | 15.2 | 4 | 20.4 | 2.3 | 6.4 | 6.1 | 13.8 | 7.3 | 10.1(37) |
| Primary | Age | >60 | 0 | 16 | 0 | 9.1 | 2.1 | 2.0 | 1.5 | 2.4 | 3.3 (12) |
| | | 18-35 | 34.8 | 40 | 30.7 | 20.5 | 53.2 | 16.3 | 30.8 | 29.3 | 31.4(115) |
| | | 35-60 | 26.1 | 4 | 38.8 | 34.1 | 19.1 | 18.4 | 40.0 | 24.4 | 27.6(101) |
| Secondary | Age | >60 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2.4 | 0.3 (1) |
| | | 18-35 | 10.9 | 24 | 2 | 4.5 | 17 | 28.6 | 0 | 17.1 | 11.7(4) |
| | | 35-60 | 0 | 4 | 0 | 9.1 | 2.1 | 10.2 | 3.1 | 9.8 | 4.6 (17) |
| Tertiary | Age | 18-35 | 0 | 0 | 0 | 4.5 | 0 | 4.1 | 3.1 | 0 | 1.7 (6) |
| % Aggregate (n) | | | 64.8(46) | 35.2(25) | 52.7(49) | 47.3(44) | 49(47) | 51(49) | 61(65) | 38.7(41) | 100 (366) |

20 to 30 years, 20.8 % between 10 to 20 years while only 5.5 % had lived in the area for less than 10 years.

### Mangrove co-benefits
Sustainable management of mangroves results in several co-benefits with economic, social and ecological importance. 'Co-benefits' were categorised under the MEA (2005) categories of regulating, provisioning, supporting, cultural and aesthetic services. The term 'co-benefits' is contextually used to refer to the ecosystem services whose exploitation results in no trade-offs among the social, economic, and ecological benefits of an ecosystem (Fig. 2). Results indicated that

16 ES provided by mangroves have co-benefits, most of which occurred under the regulating and the cultural and aesthetic services categories (Fig. 2; Appendix 1). Under the regulating services, it was found that the ecosystem is critical in the purification of air and water, shoreline protection, as a carbon sink, for rain catchment and as a hazard barrier, protecting hinterlands from environmental hazards. Under the provisioning services, mangroves were found to be an important store of historic artifact, a source of indigenous medicine and animal feeds. The ecosystem supports small invertebrate life, bees, fish diversity, as well as an important nursery grounds for fish. Under
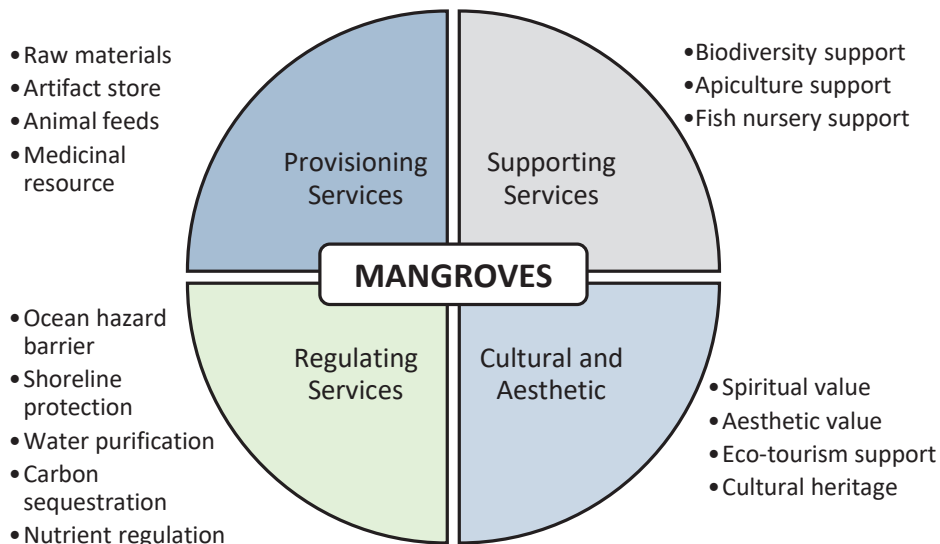


**Figure 2.** The mangrove ecosystem services identified by the community members of Vanga, categorized under the provisioning, supporting, cultural and aesthetics, and regulating services.
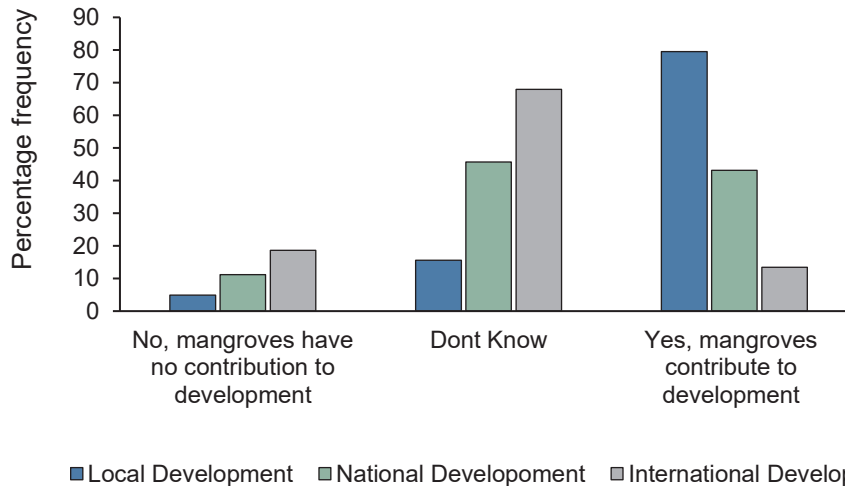
**Figure 3.** Community knowledge of the roles of mangroves in development. Development was assessed at local, national, and international levels represented by blue, green and grey bars respectively.

the cultural and aesthetic services, mangroves were found to be of important spiritual value with some trees acting as religious totems. They provide important sites for traditional practices and with aesthetic value, ideal for recreation and social functions (Fig. 2).

### The 'ideal' link between mangrove and SDGs
*The synergies*
Analysis of the synergies indicated that mangroves contribute directly to the achievement of at least 14 targets of sustainable development goals, co-benefiting at least 18 targets (Fig. 5). Regulating services directly contribute to the achievement of at least 7 SDG targets, co-benefiting 9 SDGs targets. Supporting ecosystem services directly contribute to 2 SDG targets, co-benefiting at least 9 SDG targets. Cultural ecosystem services directly contribute to at least 4 SDG targets, co-benefiting at least 7 SDG targets while provisioning services directly contribute to 3 SDG targets while co-benefiting at least 2 targets (See discussion section) (Fig. 5).

### The trade-offs
Unregulated exploitation of provisioning services results in a tradeoff with all the mangrove benefits (Fig. 5). This was, however, not the view among the majority of the community members who posited that '*our fore-fathers exploited this forest and so did our fathers, yet, the forest has never been depleted. The ecosystem has its natural regeneration mechanisms, hence, impossible to exhaust and should be cut in order to nourish*'. In as much as silviculture activities as pointed out by the community are important to the forest, unregulated extraction limits the ecosystem's capacity to continue providing wood

products, habitat, socio-cultural services, and protective services, among other benefits.

### Community knowledge of the link between mangroves and the SDGs
Community members of Vanga identified 16 ecosystem services accrued from the mangrove ecosystem (Fig. 2). A mutually inclusive analysis of community knowledge however indicated that only 45.4 % of the population knew the role of the ecosystem in development, 79.5 % of whom were able to link the ecosystem to local development, 43.1 % to both local and national development while only 13.5 % were able to link the ecosystem to local, national, and international development (Fig. 3). A large proportion of the respondents (43 %) had no idea whether mangroves contribute to development or not while 11.6 % felt that mangroves do not contribute to development in any way (Fig. 3). The largest proportion (49.2 %) of the respondents who knew the roles of mangroves in local development mentioned income generation from the sale of wood products, ecotourism, and proceeds from conservation as the main contributors, while 21 % mentioned provisioning of affordable building materials (Fig. 4)

Of the respondents who knew the roles of mangrove in national development, 40.9 % mentioned revenue generation from licensing of mangrove cutters, export of wood products, and ecotourism, while 22.6 % mentioned income generation from mangrove-related businesses. Despite having an idea of the contributions of mangroves to national development, 9.4 % of the respondents could not explain how it does but were sure it did contribute in some way.
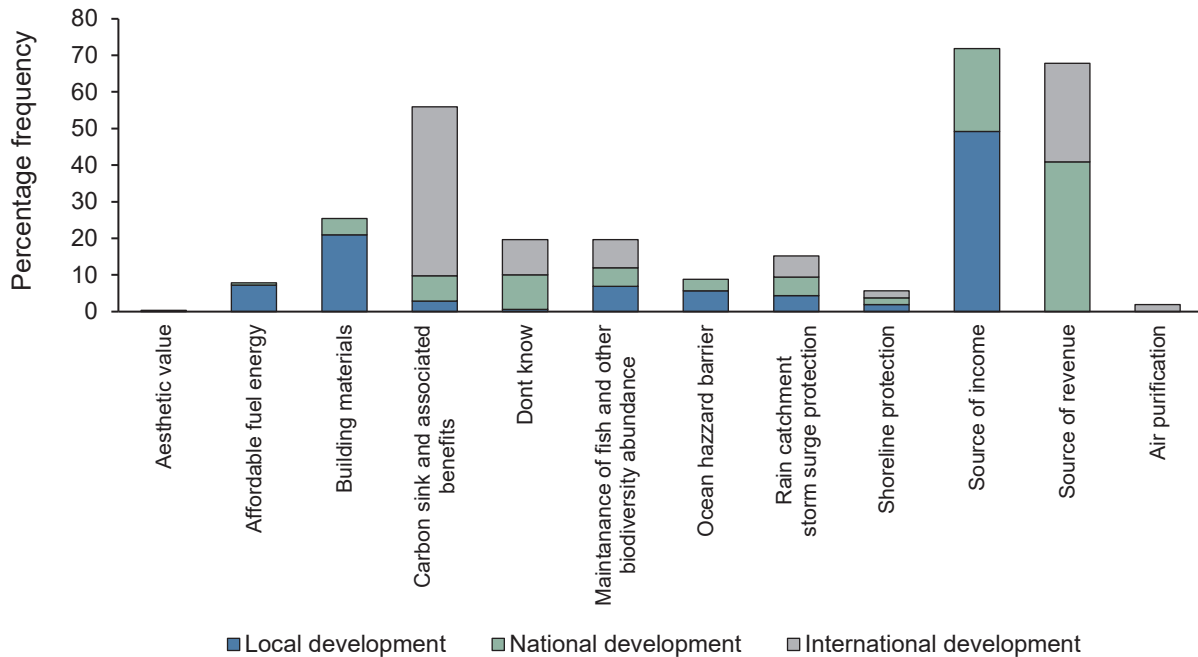
**Figure 4.** Community perceptions of the contributions of mangrove ecosystem services to development. The bars represent the roles of respective ecosystem services in development at local, national and international scales.

At the international level, carbon sequestration was perceived as the greatest contributor to development (46.2 %) followed by revenue from international trade in timber products and ecotourism (26.9 %). Nine percent of the respondents thought mangroves contribute to international development but were not sure how (Fig. 4). When asked how carbon sequestration contributes to international development, the most coherent response from FGDs was, '*it must be important and that's why there is a lot of international investments in the ES*'. The
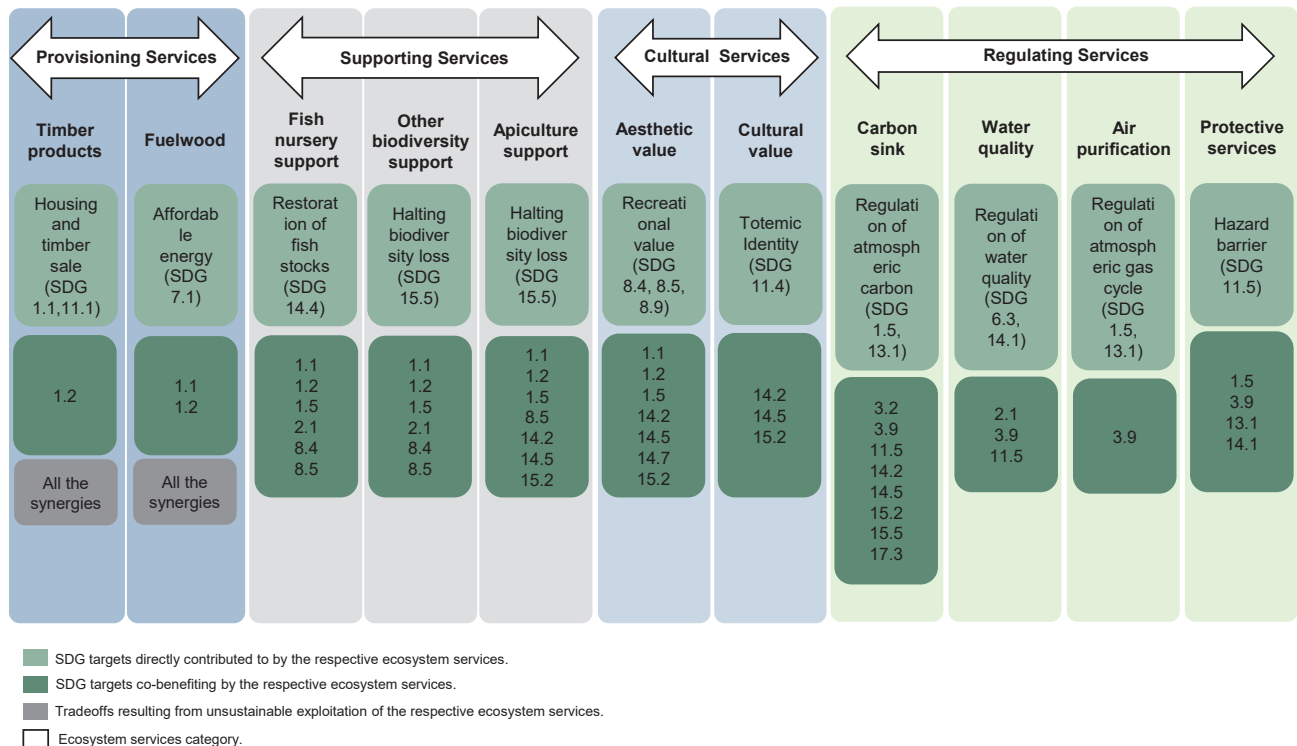


**Figure 5.** A relationship evaluation framework representing the mangrove-SDG co-benefits and tradeoff. Numbering represent SDG targets promoted by the respective ecosystem services. (Framework adapted from Singh *et al.*, 2017).

**Table 2.** A distribution table of the disaggregated co-relations between age, gender, level of education, duration of residence in the study area and the knowledge of the synergies between mangroves and development.

| | | | Gender | Age | Education | Period of residence | Local development | National development | International development |
|---|---|---|---|---|---|---|---|---|---|
| Spearman's *rho* | Gender | Correlation Coefficient | 1.000 | -.074 | -.202** | -.010 | .035 | .027 | .010 |
| | | Sig. (2-tailed) | . | .157 | .000 | .849 | .510 | .610 | .852 |
| | | n | 366 | 366 | 366 | 366 | 366 | 366 | 366 |
| | Age | Correlation Coefficient | -.074 | 1.000 | -.351** | .329** | .042 | .017 | .023 |
| | | Sig. (2-tailed) | .157 | . | .000 | .000 | .419 | .748 | .657 |
| | | n | 366 | 366 | 366 | 366 | 366 | 366 | 366 |
| | Education | Correlation Coefficient | -.202** | -.351** | 1.000 | -.137** | -.240** | -.206** | -.186** |
| | | Sig. (2-tailed) | .000 | .000 | . | .009 | .000 | .000 | .000 |
| | | n | 366 | 366 | 366 | 366 | 366 | 366 | 366 |
| | Period of residence | Correlation Coefficient | -.010 | .329** | -.137** | 1.000 | .127* | .074 | .115* |
| | | Sig. (2-tailed) | .849 | .000 | .009 | . | .015 | .158 | .028 |
| | | n | 366 | 366 | 366 | 366 | 366 | 366 | 366 |
| | Local development | Correlation Coefficient | .035 | -.042 | -.240** | -.127* | 1.000 | .388** | .193** |
| | | Sig. (2-tailed) | .510 | .419 | .000 | .015 | . | .000 | .000 |
| | | n | 366 | 366 | 366 | 366 | 366 | 366 | 366 |
| | National development | Correlation Coefficient | .027 | .017 | -.206** | .074 | .388** | 1.000 | .533** |
| | | Sig. (2-tailed) | .610 | .748 | .000 | .158 | .000 | . | .000 |
| | | n | 366 | 366 | 366 | 366 | 366 | 366 | 366 |
| | International development | Correlation Coefficient | .010 | .023 | -.186** | .115* | .193** | .533** | 1.000 |
| | | Sig. (2-tailed) | .852 | .657 | .000 | .028 | .000 | .000 | . |
| | | n | 366 | 366 | 366 | 366 | 366 | 366 | 366 |

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

majority did not know what carbon sequestration is, with most referring to it as '*the dark soil within the mangroves*' while others simply called it '*clean atmosphere*'.

A common assertion among community members that '*if not for mangroves, we would not be living where we live due to flooding and shoreline erosion*' indicated an understanding of the protective functions of mangroves. This was, however, not reflected in the link to development with shoreline protection and ocean hazard barrier ranking among the least (less than 2 % of the respondents) contributors to development (Fig. 4).

On the general views on the roles of mangroves in development, the majority of the community supported similar views that: '*Our parents paid our school fees through mangrove-related income. The forest provided timber for construction of boats for fishing, furniture, house construction, and fuel energy, and today we take our children to school thanks to the same ecosystem. To us, therefore, mangroves mean timber, fish, and a beautiful environment*'. This was coherent with the results (Fig. 4), where the majority (35.9 %) of the community members in Vanga perceive mangroves as a source of income.

### Disaggregating community knowledge socio-demographically

Knowledge (dependent variable) was disaggregated by gender, age, level of education, and period of residence within the study area (independent variables). Spearman's *rho* was used to determine whether frequency of mentioning co-benefits is related to age, level of education, gender or period of stay within the study area. Results established no perfect coefficient among dependent and all independent variables (Table 2). Education however had a significant negative coefficient with the knowledge of the synergies in all development levels at $p \le 0.01$ while migration had a significant positive correlation with knowledge at local and international level at ($p \le 0.05$) (Table 2). This implied a significantly better knowledge of the synergies among community members with less education and better knowledge of the synergies among respondents who had stayed longer in the study area. No perfect or significant coefficients were established between gender and age with knowledge of the synergies at any development level (Table 2).

## Discussion

The mangrove ecosystem was selected for its vital protective functions, social-economic elevation potentials, and its role in regulating ecological processes, which make them critical to achievement of the SDGs (Huxham *et al.*, 2017; UN-DESA, 2017; Singh *et al.*, 2017). Studies suggest that the critical nature of protecting and restoring mangroves is reflected in SDG 14 (life below water), but the ecosystem has the potential of supporting the achievement of several other SDGs (UN-DESA, 2017). The diverse nature of these benefits results in a number of co-benefits and tradeoffs contingent to community perceptions, which influence utilisation and eventuality of the development agenda (Nazarea *et al.*, 1998; Cinner and Pollnac, 2004).

### Community knowledge of the synergies and tradeoffs between mangroves and SDGs

Local support strongly underpins conservation success, and is influenced by the perceptions of the impacts of governance frameworks on the community (Bennett and Dearden, 2014). Ecosystem services frameworks present viable mechanisms for assessing the effectiveness of governance, by providing mechanisms for understanding different views of local communities and their support for conservation interventions (Afonso *et al.*, 2022). This study adopted the ecosystem services framework for assessing community knowledge on the roles of mangroves in

sustainable development. Results indicate that community members in Vanga have a limited understanding of the role of mangroves in development, with the majority linking the ecosystem to income and revenue generation. This reaffirms the findings by Afonso *et al.* (2022) that suggested that community members do not acknowledge the existence of ecosystem services that do not bring a direct economic benefit.

Moreover, as similarly found by Owuor *et al* (2019), that community members exhibit limited understanding of the ecosystem functionality despite having knowledge of the ecosystem services, the findings from this study show that despite identifying 16 ecosystem services (Fig. 2), community members could only explain the roles of consumable benefits in development. Critical ecosystem services like shoreline protection and ocean hazard barrier, despite being identified as vital for the existence of ocean adjacent communities, were not considered major contributors to development (Fig. 4).

Carbon sequestration, *hewa kaa* in local parlance, was however, identified as a major contributor to international development but the majority of those who mentioned this ES lacked understanding of the how this worked. The frequent reference to carbon sequestration was therefore probably a result of the proceeds from a carbon offsetting project in neighboring villages in Gazi Bay.

In the socio-demographic disaggregation of community knowledge of the roles of mangrove to development, it was found that period of residence within the study area and education significantly influence knowledge of the link between mangroves and development. Education had a significant negative correlation with knowledge of the synergies at all development levels while period of residence within the study area had a significant positive correlation with knowledge at all development levels. Cinner and Pollnac (2004) and Okello *et al* (2019) similarly found that education and migration influenced community perceptions. The negative coefficient between education and knowledge could be attributed to education-related cultural dynamics, as pointed out by the respondents in FGDs, *'the educated have no time to get dirty in the mangrove mud. Whenever they need anything from the mangroves or the ocean, they pay the uneducated casual laborers to get them on their behalf'.* The positive coefficient between knowledge and period of residence within the study area, on the other hand, is

logical since longer stays imply more interactions with the ecosystem, hence a better understanding of them.

## Relating community knowledge to the 'ideal' link between mangroves and the SDGs

A review of secondary data on the 'ideal' mangrove-SDG relationship indicated a gap in community knowledge. Contrary to the community perspective that was limited to income and livelihood related goals SDG 1, SDG 2, SDG 3 and SDG 8, expert analysis established greater links between mangroves and sustainable development. The influence of regulating services was found to contribute to at least 17 SDG targets, either directly or as reinforcement to co-benefiting targets. In its protective functions, the ecosystem buffers shoreline erosion, strong wave actions, storm, and other climate change related hazards (Barbier, 2016). This strengthens resilience against climate-related and other extreme events (SDG 1.2, 1.5, and 13.1), reducing health risks (target 3.9) (Singh *et al.*, 2017). As an efficient carbon sink, nations can include mangrove restoration efforts towards the operationalization of integrated policies and plans for adaptation to adverse impacts of climate change (SDG 1.5, 13.1, and 13.2) (UNEP, 2015; Government of Kenya, 2018). This provides a basis for sustainable management of coastal ecosystems through carbon offsetting, promoting SDG targets 14.2 and 14.5, and hence halting deforestation and biodiversity loss (targets 15.2 and 15.5) while also contributing to the mobilization of financial resources (SDG 17.3) (Windham-Mayers *et al.*, 2018; Wylie *et al.*, 2016). Through water purification, mangroves control the introduction of solid waste into the ocean mitigating marine pollution (SDG 14.1 and 12.4) which improves water quality (SDG 6.3). This reduces illness and death from water pollution and related hazards (SDG 3.9 and 11.5), and biodiversity loss (SDG 15.5) which ensures nutritious food contributing towards SDG 2.1 (Diz *et al.*, 2020; Diz *et al.*, 2019). Air purification reduces the exposure of the poor and those in vulnerable situations from atmospheric toxic gasses (SDG 1.5, 13.1) which prevents their illnesses and deaths from air pollution-related hazards (SDG 3.9) (Fig. 5; Appendix 1).

Supporting services comprising of fish nursery and other biodiversity support maintain biodiversity abundance (Sandilyan and Kathiresan, 2012) towards achievement of SDG 14.4 and 15.5. Achievement of the two targets ensures opportunities for eradicating poverty (SDG 1.1), sufficient and nutritious food for SDG 2.1, environmentally friendly income generation by local communities (SDG 8.4 and 8.5), combating poverty and other economic shocks among local communities (SDG 1.2 and 1.5) (Diz *et al.*, 2020) (Fig. 5; Appendix 1).

Cultural ES identified in this study include aesthetic and cultural values of the mangrove ecosystem. Aesthetic value creates a sense of identity with environmental beauty which provides a basis for conservation through social reciprocity (Carlson, 2005), promoting eco-tourism and employment opportunities towards SDG 8.9, 8.4, and 8.5 (Friess, 2017). This could motivate local communities to tradeoff extractive forest benefits with environmental aesthetics, enhancing sustainable management and protection of marine and coastal ecosystems (SDG 14.2) and halting ecosystem degradation (SDG 15.2), hence making steps towards conserving of at least 10 % of coastal and marine areas (SDG 14.5). By creating employment opportunities, communities are also cushioned against poverty and other economic challenges, contributing to SDG 1.1, 1.2, 1.5, and 14.7. Cultural value, on the other hand, invokes a totemic sense of belonging (SDG 11.4) that can deter degradation around cultural areas (Cooper *et al.*, 2016). As in the case of Kayas of the south coast of Kenya, the fear of taboos and wraths of the spirits dissuade community members from destructive practices around the cultural sites. Mangrove areas are in the process conserved, contributing to the achievement of SDG 14.2, 15.2, and 14.5; all of which create a basis for the realization of all the benefits of mangroves within and around the cultural areas (Fig. 5; Appendix 1).

Provisioning mangrove functions, on the other hand, promote the achievement of at least 4 SDG targets and tradeoff with at least 17. Timber products provide opportunities for income generation, reducing poverty towards achievement of SDG 1.1, which potentially reduces the number of people living in poverty thus contributing towards SDG 1.2. Timber harvesting also ensures affordable housing for the local poor contributing to SDG 11.1. Fuelwood provides affordable energy for SDG 7.1, creating a market context for SDG 1.1 and 1.2. In so doing, unsustainable timber and fuelwood extraction result in ecosystem degradation which deters all the benefits of mangroves. This is worsened by the fact that these two ecosystem goods are the most valued by local community members. The community depends on wood products for house construction, income generation and primary source of fuelwood among mangrove adjacent communities (Huxham *et al.*, 2017) (Fig. 5; Appendix 1).

## Conclusions

Results suggest a gap in community knowledge of the roles of mangroves in development. This, his we conclude based on the perception that mangrove resources are inexhaustible and the limited understanding of mangrove benefits beyond extractible services. Moreover, the role of mangroves in development is less understood as one progresses from local level, where provisioning services are more valued, to international level where regulatory services and other indirect benefits are of greater value. As such, the adoption of procedural justice in the framing and implementation of development and governance frameworks is recommended. This means placing the primary natural resource users and their contextual socio-demographic dynamics at the center of decision making from inception to implementation.

Moreover, it is evident that development from a community perspective means livelihood and income generation. It is therefore important that governance and development strategies are sustainably refined to reflect the needs and desires of local communities to improve acceptability and cost-effectiveness. In this process, resource managers should endeavor to promote viable options to the destructive harvesting of forest products to reduced extractive pressure on the ecosystem while promoting community livelihoods.

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# APPENDIX

**Appendix 1.** Descriptive text on the SDG targets supported by the mangrove ecosystem services.

| SDG targets supported by the mangrove ecosystem services | Description | Related ecosystem service |
|---|---|---|
| **SDG 1** | | |
| 1.1 | Eradication of extreme poverty | Timber products |
| 1.2 | Reduction of, at least but half, the number of people living in poverty | Fish nursery and biodiversity support |
| 1.5 | Building resilience of the poor and those in vulnerable situations and reducing their exposure and vulnerability to climate-related extreme events and other economic, social and environmental shocks and disasters | Protective functions, Carbon sequestration |
| **SDG 2** | | |
| 2.1 | Ending hunger and ensuring access to sufficient and nutritious food by all | Fish nursery, Biodiversity support |
| **SDG 3** | | |
| 3.9 | Substantial reduction of the number of deaths and illnesses from hazardous chemicals and air, water, and soil pollution and contamination | Protective functions, Carbon sequestration |
| **SDG 6** | | |
| 6.3 | Improvement of water quality by reducing pollution | Water purification |
| **SDG 7** | | |
| 7.1 | Ensuring universal access to affordable and reliable energy services | Fuelwood provisioning |
| **SDG 8** | | |
| 8.4 | Progressive improvement of global resource efficiency in consumption and production, endeavoring to decouple economic growth from environmental degradation | Fish nursery and biodiversity support |
| 8.5 | Achievement of full and productive employment and decent work for all women and men, including for young people and persons with disabilities | Fish nursery and biodiversity support |
| 8.9 | Devising and implementation of policies to promote sustainable tourism, job creation, and promotion of local culture and products | Cultural and aesthetic services |
| **SDG 11** | | |
| 11.1 | Ensuring access for all to adequate, safe, and affordable housing and basic services | Timber products |
| 11.4 | Strengthening efforts to protect and safeguard the world's cultural and natural heritage | Cultural and aesthetic services |
| 11.5 | Reduction of the number of deaths and people affected by disasters, including water-related disasters), co-benefiting | Regulating services, Carbon sequestration |
| **SDG 13** | | |
| 13.1 | Strengthening resilience and adaptive capacity to climate-related hazards and natural disasters in all countries | Ocean hazard barrier; Carbon sequestration |

| SDG targets supported by the mangrove ecosystem services | Description | Related ecosystem service |
|---|---|---|
| **SDG 14** | | |
| 14.1 | Prevention and significant reduction of marine pollution of all kinds, in particular from land-based activities | Regulation of water quality |
| 14.2 | Sustainable management and protection of marine and coastal ecosystems to achieve healthy and productive oceans | Biodiversity and fish nursery support |
| 14.4 | Science-based restoration of fish stocks | Fish nursery and biodiversity support |
| 14.5 | Conservation of at least 10 percent of coastal and marine areas | |
| **SDG 15** | | |
| 15.2 | Promoting the implementation of sustainable management of all types of forests, halting deforestation and degradation | Cultural and aesthetic services; Carbon sequestration |
| 15.5 | Taking urgent action to halt the loss of biodiversity | Fish nursery and biodiversity support |
| **SDG 17** | | |
| 17.3 | Mobilization of additional financial resources for developing countries from multiple sources | Carbon sequestration |