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How nature-based solutions support mobility as an adaptation strategy

Cherié Forbes

cherie.forbes@uct.ac.za

University of Cape Town https://orcid.org/0000-0001-8276-9603

Petra Holden

Florian Debève Vermeiren

Saray Quirant Perez

Gerald Ngoma

Article

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How nature-based solutions support mobility as an adaptation strategy

Cherié Janine Forbes[*1], Petra Holden[1], Florian Debève Vermeiren[2], Saray Quirant Perez[3], Gerald Ngoma[1]*

1. *People in Nature & Climate Lab, African Climate and Development Initiative, University of Cape Town, Cape Town, South Africa*
2. *The Hugo Observatory, Department of Geography, University of Liège, Liège, Belgium*
3. *School of Economics and Management, University of Geneva, Geneva, Switzerland*

*Correspondence to Cherié Janine Forbes (cherie.forbes@uct.ac.za)

Abstract

Mobility and Nature-based solutions (NbS) are recognised as climate adaptation responses, yet their interactions and the implications for adaptation remain poorly understood. We investigate how NbS influence mobility in Sub Saharan Africa using 60 story-based interviews with community members involved in NbS. Combining qualitative personas with quantitative analysis, we identified nine NbS-related mobility personas capturing positive, buffering and negative roles of NbS in mobility as an adaptation strategy. The findings demonstrate that NbS influenced mobility not only through livelihood creation, but by reshaping how individuals understood future possibilities in place. Across the personas, NbS expanded climate and environmental literacy, strengthened adaptive capacity and environmental stewardship, and supported livelihoods. Rather than determining whether people leave or stay or determining mobility outcomes, NbS reshaped aspirations, capabilities and perceived future possibilities. We provide a transferable framework for understanding the role of NbS in mobility to support equitable climate adaptation across the Global South.

Keywords: Ecosystem-based adaptation; Nature-based solutions; human migration; mobility; climate adaptation; Sub-Saharan Africa; lived experience; personas

Introduction

Climate change is shaping human mobility across Sub-Saharan Africa (SSA), a region highly vulnerable to climate change [1–3]. Climate mobility does not unfold through a singular, generalised pattern of mass cross-border movement. This is an influential but misleading narrative in climate migration debates [4,5]. The relationship between climate change and mobility is mediated by context-specific processes [6,7], with expected mobility responses occurring predominantly through internal mobility, including temporary, circular, and

seasonal movement, as well as different forms of immobility [2,8,9]. Mobility decisions arise from the interaction of aspirations and capabilities, which are themselves shaped by social, political, environmental, economic and demographic drivers operating simultaneously at macro, meso and micro scales [1,10–12]. Thus, climate mobility in SSA is best understood not as a singular outcome of environmental stress, but as a socially differentiated and contextualized process shaped by multiple, interacting drivers [1,8,13–15].

A growing body of scholarship consequently conceptualises climate-related mobility as part of available adaptation actions and options [16]. In some circumstances, migration may function as a livelihood diversification strategy or as a means of reducing exposure to climate risks. In other cases, people remain in place because of attachment to land, limited resources, social obligations, or constrained opportunities [1,17,18]. When opportunities for effective in situ adaptation are limited, mobility and immobility may increasingly shift from voluntary to constrained responses [15,16]. In these cases some of the most vulnerable populations remain 'trapped' and unable to migrate despite increasing vulnerability in situ [19–22].

Nature-based Solutions (NbS) have been identified as a promising approach to addressing the interconnected dimensions of climate mobility, having the potential to reshape the social, economic, and political conditions through which human mobility decisions are made [7,23–25]. NbS are actions to protect, restore and sustainably manage ecosystems and land/waterscapes to provide benefits to both people and nature [26–29]. NbS may reduce exposure to floods, droughts, and coastal erosion, thereby countering the adverse environmental drivers of migration [24,30]. At the same time, NbS may strengthen livelihood security, create employment opportunities, promote small businesses, and increase household incomes [28]. The literature suggests that NbS can contribute to broader dimensions of human wellbeing, specifically by reinforcing socio-economic resilience by securing food, water, and livelihoods while protecting communities from physical disaster hazards [28,29,31]. Beyond physical protection, NbS improves physical and mental health, enhances social cohesion, and fosters a greater sense of security by mitigating waterborne health crises, resource-driven conflicts, crime, and the psychological trauma of displacement [28–31].

Despite existing research on how climate and environmental stress influence (im)mobility, empirical research examining how NbS shape mobility decisions and their outcomes remain limited [32–34]. Specifically, there is limited empirical evidence on how NbS may influence the decisions to leave, stay, or adapt in place and ultimately (im)mobility outcomes. It is likely that NbS influences mobility decisions and outcomes through interacting with main drivers of mobility that include environmental, social, and economic drivers [1,10–12]. In this context, existing research has paid limited attention to peoples lived experiences of how NbS

supports mobility as an adaptation strategy. This includes how NbS play a role in people's capabilities, aspirations and perceptions in ways that influence decisions to stay, leave, return or engage in seasonal mobility [11,17,35,36].

This gap is especially significant because mobility decisions are not driven by material factors alone. Research on environmental migration has shown that people interpret climatic and ecological change through lived experience, including perceptions of risk, memories of loss, obligations to family, cultural values, attachments to place, and assessments of future possibility [37–39]. Individual perceptions are therefore fundamental in defining migration drivers and shaping migration aspirations, as individuals respond not only to environmental and climatic conditions but to how they interpret political, economic, and social environments and how they understand the short- and long-term impact and consequences of environmental changes [17,35,36]. Lived-experience approaches are therefore essential for understanding how individuals themselves interpret the role of environmental change, livelihoods, wellbeing, and adaptation interventions in shaping mobility trajectories. They are also valuable for revealing differentiated experiences among vulnerable groups, whose agency, constraints, and everyday forms of adaptation may otherwise remain insufficiently visible [40–42].

We address this gap by using a story-driven sense-making approach [43,44] to investigate the role of NbS in mobility across seven diverse SSA case study sites in Ghana, Kenya, Madagascar, South Africa and Tanzania. To capture lived experiences on NbS and its interaction with mobility decisions and outcomes, we conducted 60 interviews with local community members involved in NbS programmes and community-driven or individual-led sustainable natural resource-based livelihoods. We asked respondents to narrate their decisions to leave, stay, or engage in seasonal mobility in relation to NbS. Drawing on a qualitative phenomenological analysis we iteratively compared and grouped respondent’s lived experiences into representative personas that show nine distinct NbS-related mobility adaptation personas, that explain how NbS shape respondents' capabilities and aspirations to leave, stay, return or move seasonally. We supplement this with quantitative analysis to show distributions of the main mobility drivers versus NbS-related drivers of mobility and explore the statistical relationships between NbS-related drivers of mobility and mobility decisions.

Results

Dominant NbS-related mobility contextual expressions

Analysis of the 60 stakeholder narratives identified nine representative personas describing distinct NbS-related mobility contextual expressions (Fig. 1; Fig. 2; Supplementary Table 1) through which NbS influenced mobility decisions and mobility outcomes across the seven SSA case study sites. Iterative phenomenological comparison organised these narratives into a scalable mechanism-centred framework for understanding the role of NbS in mobility while comparing lived experiences across diverse social-ecological and mobility contexts (Fig. 1). Through the persona analysis, we found that NbS influenced mobility via shaping broader social transformation processes rather than uniformly encouraging people to either migrate or remain in place. Instead of discrete stages of mobility decision-making and entry points within certain parts of the mobility process (i.e., decisions, drivers, outcomes) NbS predominantly interacted with economic, environmental, and human wellbeing drivers, and continued to have a signature throughout the mobility process (Fig. 1). There were nine dominant NbS-related mobility personas covering three main patterns: NbS-supported positive, where NbS strengthened mobility as an adaptation strategy; NbS-supported buffered, where NbS positively buffered mobility that risked failing as an adaptation strategy; and NbS negative, where NbS contributed to unsuccessful mobility adaptation (Fig. 1; Fig. 2). Some personas were distributed across the seven geographical locations whereas others were geographically specific. (Fig. 3).

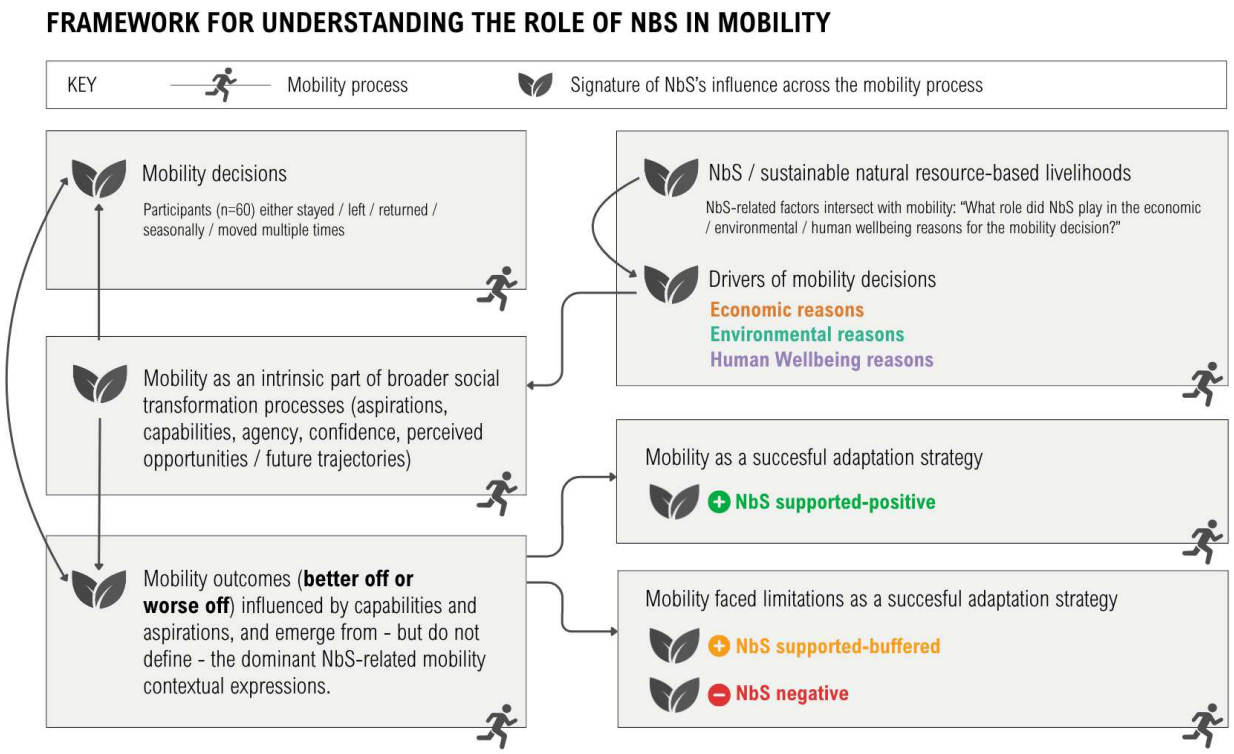


Fig. 1: ***Framework for understanding the role of NbS in mobility:*** *a transferable mechanism-centred conceptual framing of how NbS-related mobility contextual expressions emerge iteratively via thematic analysis of lived experiences across diverse social-ecological and mobility contexts. This schematic shows the organising concepts through which NbS/sustainable natural resource-based livelihoods intersect with drivers of mobility decisions (economic, environmental and human wellbeing factors) that shape mobility broader social transformation processes and outcomes of community members (n = 60) across five Sub-Saharan African countries.*

Detailed fictional stories and associated generic descriptions for each persona can be found in Supplementary Personas 1-9 and summarized in Fig. 2 and Supplementary Table 1. The personas represent recurring patterns identified across the qualitative dataset rather than fixed or mutually exclusive categories.

The summary descriptions presented below include transferable 'guiding analytical questions' capturing the transformative mechanisms represented by each persona (Supplementary Table 1). These questions emerged inductively through phenomenological comparison and abstraction of recurring mechanisms, rather than being imposed a priori from the literature, providing a practical tool for future research, policy and NbS programme evaluation.

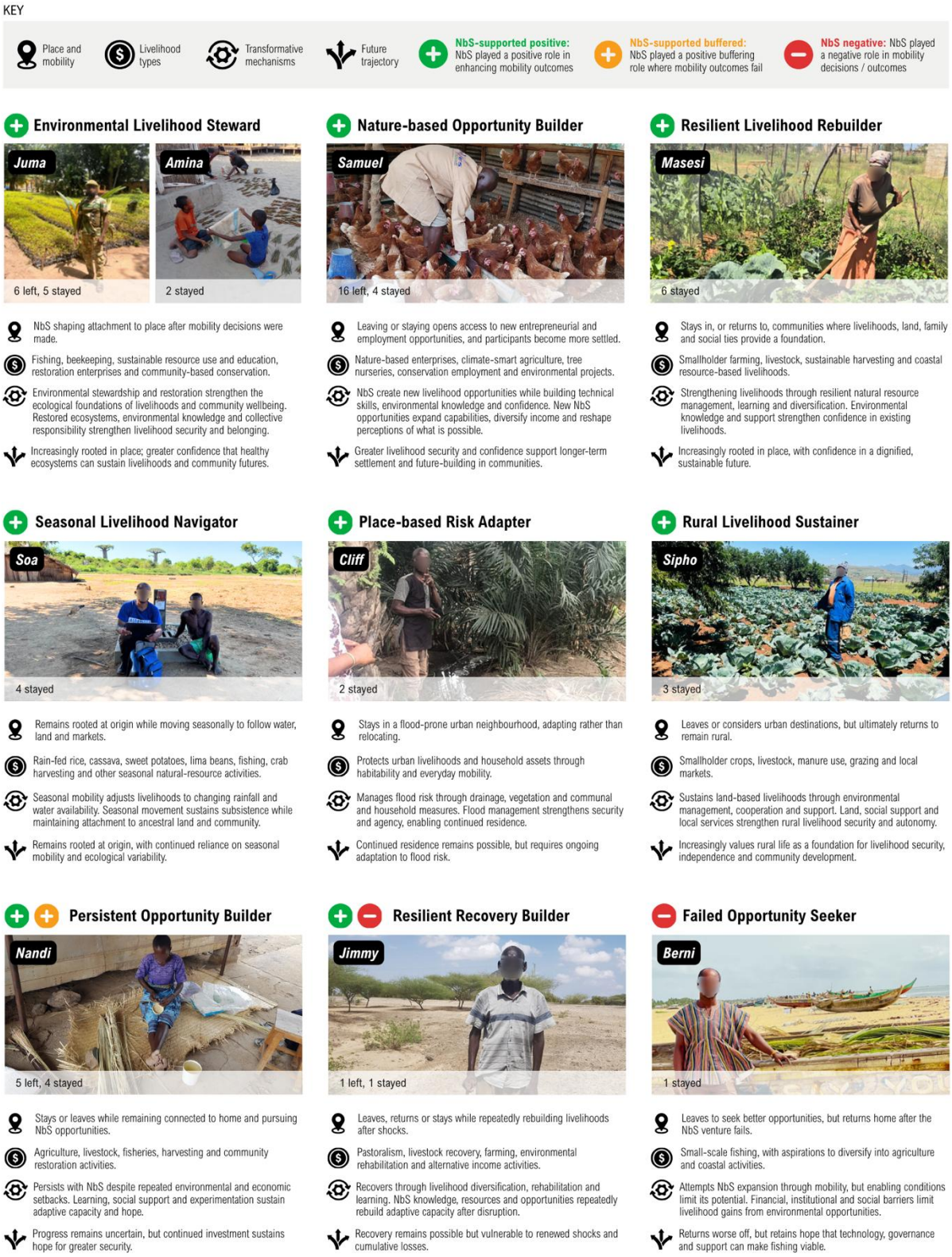


Fig. 2: ***Framework of dominant NbS-related mobility personas.*** *Each persona represents distinct NbS-related mobility contextual expressions of how NbS influence mobility as an adaptation strategy, illustrating a signature through which NbS interact with environmental pressures, livelihood opportunities and mobility decisions. The figure summarises dimensions of each persona: place and mobility context, livelihood types, a transformative mechanism associated with adaptation, and future trajectory. Together, these dimensions illustrate how NbS can shape not only whether people left or stayed, but also the aspirations, capabilities, and agency shaping their livelihood security and relationships with place that underpin mobility decisions and longer-term adaptation. Detailed fictional stories and associated generic descriptions are provided in Supplementary Personas 1-9.*

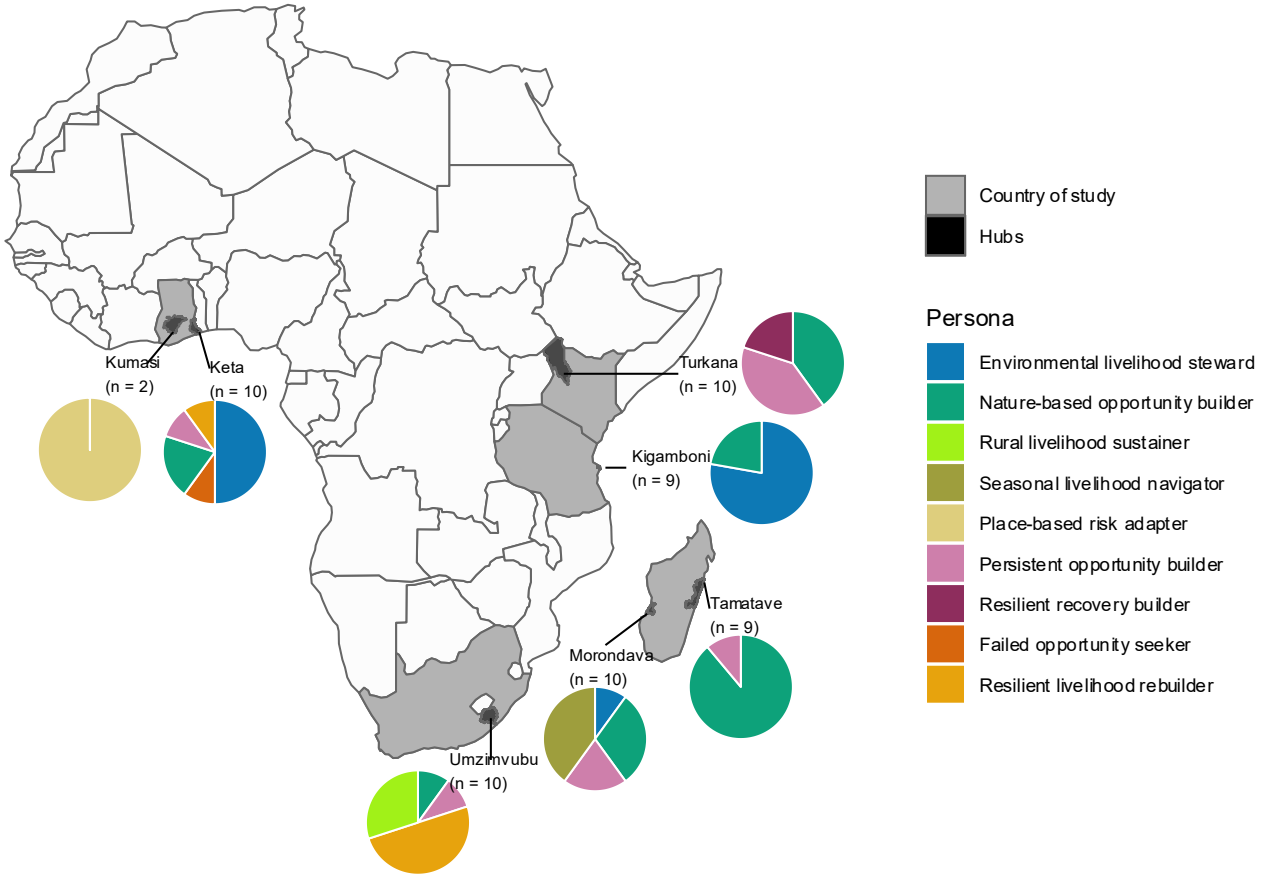


Fig. 3: Study area depicted by seven case study sites across five SSA countries *where semi-structured interviews (n = 60) were conducted with community members in Turkana (Kenya); Keta and Kumasi (Ghana); Kigamboni (Tanzania); Umzimvubu (South Africa); and Morondava and Toamasina/Tamatave (Madagascar). The pie charts show the distribution of personas per site with n representing the number of interviews conducted in each site.*

NbS-supported mobility adaptation

'Environmental Livelihood Steward (Juma/Amina)'

The guiding analytical question is 'How does stewardship anchor people to place?'. These narratives demonstrated a common adaptation strategy in which NbS strengthened long-term attachment to place through environmental stewardship after mobility decisions had already been made. Respondents migrated (left), remained (stayed), or returned (stayed) for diverse reasons unrelated to NbS, yet subsequently described conservation activities—including mangrove restoration, fisheries management, beekeeping, coastal restoration, environmental education and community stewardship—as becoming central to livelihood security and belonging.

Although stewardship was expressed differently across locations, two context-specific adaptation orientations emerged. The Juma orientation reflected individual stewardship through livelihood activities closely linked to environmental restoration, whereas Amina reflected collective stewardship, in which community conservation and shared responsibility for ecosystem management became the dominant mechanism through which NbS strengthened commitment to place.

'Nature-based Opportunity Builder (Samuel)'

The guiding analytical question is 'How do NbS create new livelihood opportunities?'. These narratives described NbS as creating new livelihood opportunities rather than restoring previous livelihoods. Respondents consistently viewed environmental restoration, conservation enterprises, climate-smart agriculture and NbS employment as opportunities that enabled them to build improved futures.

Two livelihood pathways emerged within this common NbS-related mobility contextual expression. Some respondents established entrepreneurial activities through farming, fisheries or restoration-based enterprises, whereas others developed careers through employment within conservation programmes, NGOs or government agencies. Despite these livelihood pathways, respondents shared the same underlying adaptation strategy. NbS expanded future opportunities, strengthened climate knowledge and increased confidence that remaining in, or returning to, their communities could provide livelihoods.

'Resilient Livelihood Rebuilder (Masesi)'

The guiding analytical question is 'How do people rebuild resilient livelihoods after disruption?'. These respondents described livelihood rebuilding strategies progressively undermined by climate shocks, rather than creating entirely new opportunities. Drought, flooding and environmental degradation initially weakened farming systems and motivated temporary mobility or consideration of migration. However, training in climate-smart agriculture, ecosystem restoration and environmental management reshaped respondents' understanding of what remained possible.

Rather than abandoning NbS, respondents returned, stayed, or recommitted to NbS using newly acquired knowledge supporting recovery and long-term livelihood reconstruction. They repeatedly described improved climate literacy, stronger adaptive capacity and renewed confidence that livelihoods could be rebuilt despite ongoing environmental uncertainty.

'Seasonal Livelihood Navigator (Soa)'

The guiding analytical question is 'How does seasonal mobility enable people to remain rooted?'. These narratives revealed that seasonal mobility constituted the dominant adaptation strategy. Respondents remained rooted within their communities while moving predictably to access water, productive land, mangroves, fisheries, and markets related to NbS. Rather than transforming livelihoods, NbS sustained seasonal livelihood flexibility, enabling households to adapt to changing environmental conditions while remaining socially and culturally rooted in their communities.

'Place-based Risk Adapter (Cliff)'

The guiding analytical question is 'How do people adapt vulnerable places instead of leaving them?'. Respondents described adapting to recurrent flooding through modifications to housing, grey infrastructure and neighbourhood blue-green infrastructure and practices rather than relocating. NbS influenced mobility by reducing exposure to environmental risk while enabling continued residence within flood-prone settlements.

Together, Soa and Cliff demonstrate that NbS can support immobility through fundamentally different adaptation strategies: one through seasonal mobility, the other through in situ urban adaptation.

'Rural Livelihood Sustainer (Sipho)'

The guiding analytical question is 'How are existing rural livelihoods sustained over time?'. Rather than rebuilding or creating new livelihoods, these respondents described maintaining established livelihood systems through gradual environmental management, sustainable farming and ongoing stewardship. NbS functioned by supporting continuity rather than transformation, enabling households to remain on existing trajectories despite environmental change.

'Persistent Opportunity Builder (Nandi)'

The guiding analytical question is 'How do people persist when opportunities remain uncertain?'. Respondents consistently described continuing to invest in NbS-supported buffered livelihoods despite repeated environmental, financial and social setbacks. Although agriculture, fisheries, livestock and restoration activities generated opportunities, these had not yet translated into improvements in wellbeing.

Rather than viewing NbS as unsuccessful, respondents described them as maintaining future possibilities through continued learning, organisational support and environmental restoration. SH9_TUR represented the most constrained expression of this adaptation strategy, illustrating that persistence ranged from gradual livelihood improvement to situations where opportunities remained fragile but continued to be pursued because no viable alternative existed.

NbS plays a negative role

'Resilient Recovery Builder (Jimmy)'

The guiding analytical question is 'How do people recover after cumulative livelihood loss?'. These narratives demonstrated adaptation through repeated cycles of recovery following environmental losses. Respondents rebuilt livelihoods through environmental rehabilitation, livestock recovery and restoration programmes after drought, livestock disease or resource decline undermined livelihood systems.

However, recovery trajectories differed. SH5_TUR experienced temporary improvements before renewed setbacks, whereas SH4_TUR described cumulative losses that ultimately resulted in decline. Despite these different outcomes, both narratives shared the same adaptation strategy: NbS repeatedly enabled recovery following environmental shocks.

'Failed Opportunity Seeker (Berni)'

The guiding analytical question is 'When do opportunity-seeking strategies fail?'. This persona is represented by an individual narrative (SH2_KET) where the respondent's mobility decision to return was motivated by anticipated livelihood opportunities that ultimately failed to materialise. Although NbS initially appeared capable of supporting improved wellbeing, environmental constraints, limited resources and unsuccessful livelihood transitions prevented success. Unlike Resilient Recovery Builder (Jimmy), repeated rebuilding did not occur for Failed Opportunity Seeker (Berni); instead, opportunity seeking itself became unsuccessful.

Distribution of main versus NbS-related drivers of mobility

Mobility decisions reduced vulnerability for most respondents (83%), while 16% reported increased vulnerability. Mobility decision (left versus stayed) was not associated with

wellbeing outcome (no improvement versus improved) (chi square = 0.21, p = 0.64; Fisher's exact p = 0.50). Conditions improved for 79% of those who left and 87% for those that stayed.

NbS was described as playing a positive role in the mobility process by almost all respondents (96%), in comparison to only two respondents who report a negative influence. Among respondents for whom NbS played a positive role (n=58), NbS facilitated mobility decisions toward improved conditions and reduced vulnerability (86%); but also helped address barriers, setbacks or buffered impacts that limited the effectiveness or positive wellbeing outcome of mobility (14%). This pattern did not differ by mobility decision (Chi-square = 0.23; p = 0.63; Fisher's p = 0.45) (Supplementary Table 3). Most respondents (88%) were involved in community/individual-led NbS or sustainable livelihoods whereas 28% participated in NbS projects or programmes. Of the nine personas identified, four comprised respondents involved in NbS projects or programmes whereas all nine included respondents involved in community/individual-led sustainable livelihoods.

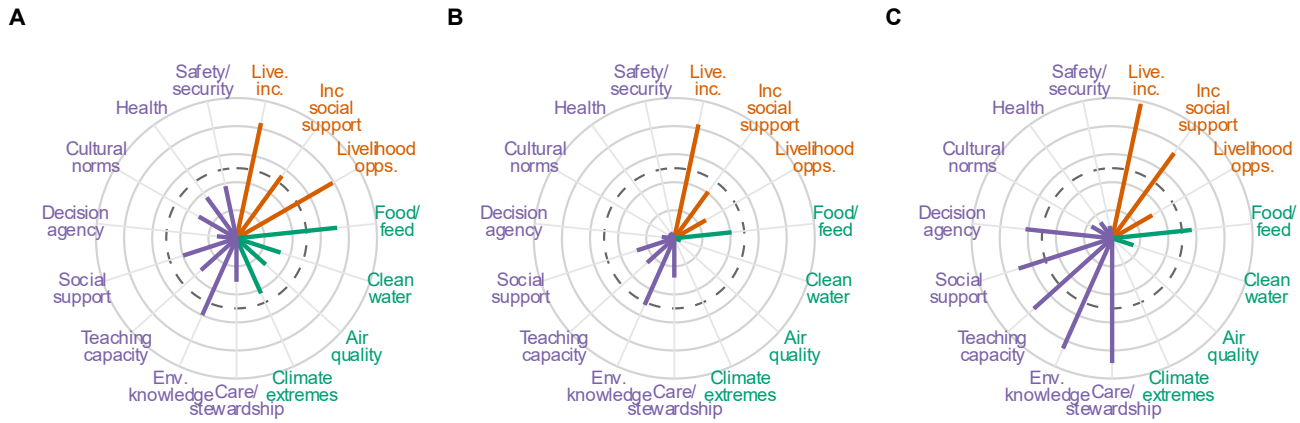


*Fig. 4: **Main and NbS attributed drivers of mobility a**) Distribution of main mobility drivers, showing the percentage of all respondents who identified each category as a main driver of mobility; **b**) Distribution of NbS attributed drivers, showing the percentage of all respondents who identified NbS as playing a role in that driver – i.e. 'prevalence'; **c**) NbS attribution rate, showing the percentage of respondents who identified a driver as a main driver who also attributed it to NbS – i.e. 'attribution'. Concentric circles indicate the percentage scale (20%, 40%, 60%, 80% and 100%). The dashed circle highlights the 50% threshold at which at least half of the respondents identified a specific driver. Full variable names and underlying frequencies are provided in Supplementary Table 2, and Supplementary Figure 1 shows, across personas, the distribution of main mobility drivers, NbS-related mobility drivers, and the proportion of respondents attributing each main mobility driver to NbS (NbS-attribution rate).*

Economic and environmental factors were the most common main drivers of mobility unrelated to NbS, followed by human wellbeing factors (Fig. 4A, Supplementary Table 2). On average 73% of respondents identified economic factors, 44% environmental factors, and 36% human wellbeing factors as main drivers. Whereas NbS-related drivers followed a

different pattern, appearing most often among economic factors (50% of cases), followed by human wellbeing (20%) and environmental factors (12%) (Fig. 4B, Supplementary Table 2). Average attribution rates were consequently highest for economic (69%) and human wellbeing (53%) drivers, and lowest for environmental drivers (18%) (Fig. 4C, Supplementary Table 2).

Among human wellbeing NbS-related factors, the highest NbS attribution rates were observed for care or stewardship for the environment and climate (89%), knowledge of the environment or climate change (86%), capacity to teach others about the environment or climate change (75%), strength of social-support networks or social cohesion (70%), and sense of agency in decision-making (62%). Rates were lowest for cultural norms (21%), physical or mental health (14%), and safety and security (9%) (Fig. 4c).

Among economic NbS-related factors, NbS attribution rates were highest for income generated through livelihood ventures (98%), followed by income or other support received through social-support networks (73%). Livelihood opportunities had a lower rate (33%). Among environmental NbS-related factors, food and feed availability had the highest NbS attribution rate at 57%, while the rates for clean-water availability (5%), air-quality conditions (0%), and climate or weather extremes (0%) were low or absent (Fig. 4c).

Interpreting NbS attribution rates (Fig. 4c) alongside prevalence (Fig. 4b) identifies two dominant mechanisms through which NbS influenced mobility, namely: income from livelihood ventures (83% prevalence, 98% attribution) and knowledge of the environment or climate change (52% prevalence, 86% attribution). Several secondary mechanisms had moderate prevalence (25–41%) with high attribution (70–89%), including income or support through social-support networks (41% prevalence, 73% attribution), care or stewardship for the environment and climate (28% prevalence, 89% attribution), capacity to teach others about the environment or climate change (26% prevalence, 75% attribution), and strength of social-support networks (28% prevalence, 70% attribution). Food and feed availability (41% prevalence, 57% attribution) and livelihood opportunities (26% prevalence, 33% attribution) both combined moderate prevalence with lower attribution. Sense of agency, though less prevalent (9%), had a moderate attribution rate (62%).

Six factors were neither prevalent nor strongly attributed to NbS (0–5% NbS prevalence, 0–17% attribution; Fig. 4b–c), despite being identified as main mobility drivers by 28–43% of respondents (Fig. 2A). These were, among environmental factors, air quality (0% NbS prevalence and attribution), clean-water availability (5% prevalence, 16% attribution), and climate or weather extremes (0% NbS prevalence and attribution); and, among human

wellbeing factors, cultural norms (5% prevalence, 17% attribution), physical or mental health (5% prevalence, 14% attribution), and safety and security (3% prevalence, 9% attribution). Prevalence fell by 26–43 percentage points between main and NbS-related drivers for these six factors, most markedly for climate or weather extremes (43% to 0%).

Relationship between main and NbS-related drivers and mobility decision

Most main mobility drivers were not associated with the decision to leave or stay (Odds ratio (ORs) 0.51-1.49; $p > 0.05$). Exceptions were livelihood opportunities and food and feed availability, both associated with a lower likelihood of leaving (OR = 0.26, 95% Confidence Interval (CI) 0.06-0.95; $p < 0.05$; OR = 0.22, 95% CI 0.06 – 0.95; $p < 0.05$), and income from livelihood ventures, associated with a higher likelihood of leaving (OR = 25, 95% CI 2.9 – 3313; $p < 0.005$) (Fig. 5a-b, Supplementary Table 4). This pattern was broadly maintained for NbS-related drivers, except that the association between income from livelihood ventures and mobility decisions was no longer statistically significant. Livelihood opportunities (OR = 0.15, 95% CI 0.03 – 0.62, $p<0.05$) and food and feed availability (OR 0.28, 95% CI 0.08 – 0.99, $p<0.05$) remained associated with a lower likelihood of leaving (Fig. 5c-d, Supplementary Table 5).

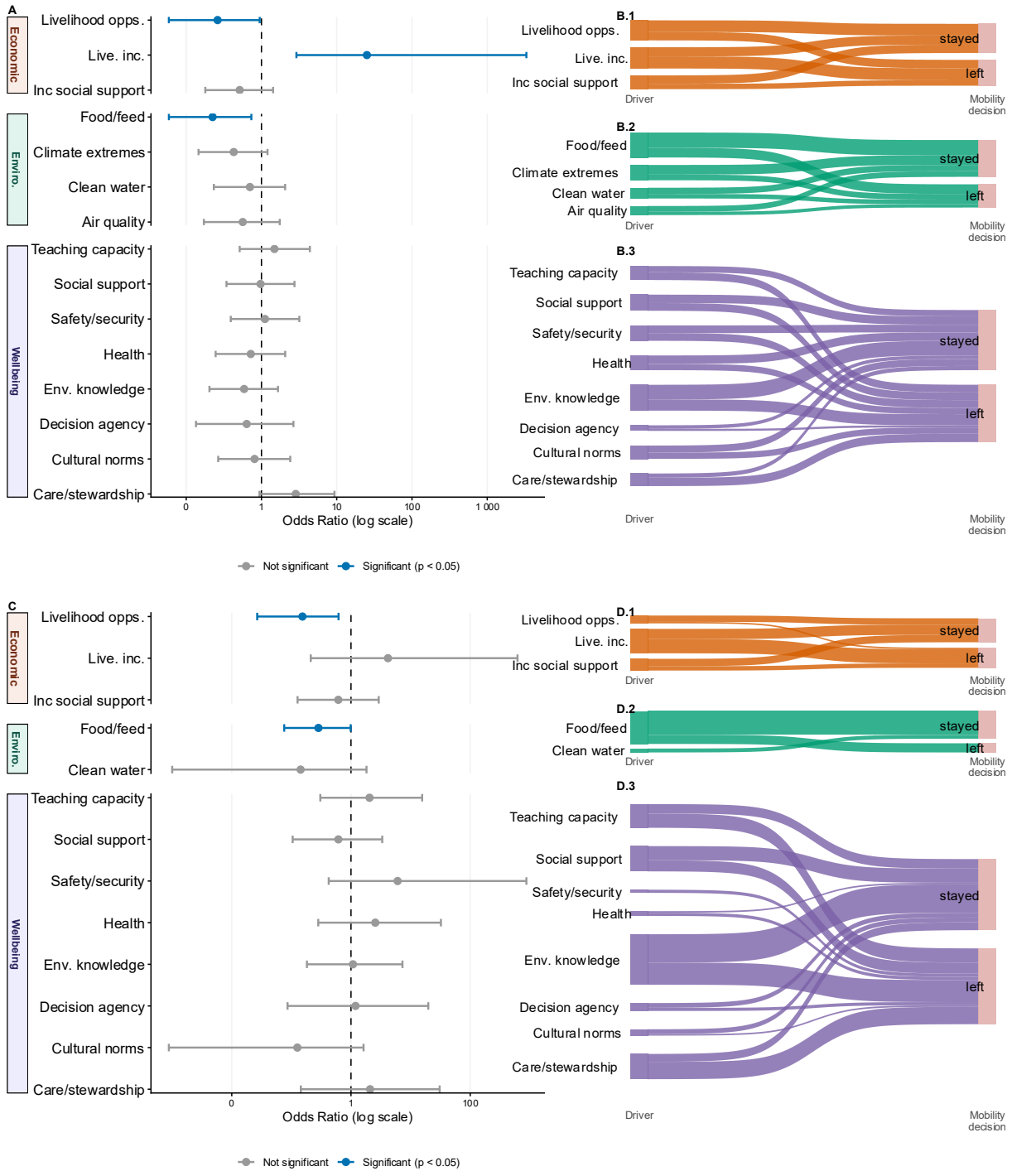


Fig. 5: Associations between mobility drivers and mobility decisions for main drivers (a-b) and NbS attributed drivers (c-d). *Panels* ***a)*** *and* ***c)*** *show odds ratios and 95% confidence intervals from bivariate logistic regression models with Firth's penalised likelihood estimation. Mobility decision (left = 1 and stayed = 0) and mobility outcome (conditions improved = 1 and conditions did not improve = 0) were modelled separately as binary dependent variables for main drivers and NbS attributed driver of mobility in panels* ***a)*** *and* ***c),*** *respectively. Logistic regression model was estimated with Firth's penalisation to reduce bias associated with sparse data and complete or quasi-complete separation arising from small subgroup counts. Panels* ***b)*** *and* ***d)*** *show sankey diagrams illustrating the frequencies associated with main* ***b)*** *and NbS attributed* ***d)*** *mobility drivers to mobility decisions (Supplementary Table 4 and Supplementary Table 5). The width of each Sankey flow is proportional to the number of respondents following that pathway. Thicker flows indicate that more respondents reported the corresponding transition between drivers and mobility decisions*

Discussion

Beyond binary mobility decision and outcomes

One of the fundamental contributions of this study is the demonstration that NbS influence mobility by shaping broader social transformation processes rather than uniformly encouraging people to either migrate or remain in place. This finding challenges the influential 'mass migration' narrative in climate debates [4,5]. Across the nine representative personas, mobility decisions—including leaving, staying (including returning), and seasonal movement—were observed within multiple personas, indicating that similar mobility decisions frequently reflected fundamentally different adaptation strategies. The quantitative analyses reinforced this interpretation. Most main mobility drivers were not associated with the binary decision to leave or stay, indicating that this distinction captures only a limited part of how NbS influence mobility (Fig. 1). Instead, NbS reshaped how respondents understood their future possibilities, thereby expanding—or in some cases constraining—the capabilities, aspirations and perceived opportunities through which different NbS-related mobility contextual expressions emerged and mobility decisions were ultimately negotiated. Consequently, staying, returning, seasonal mobility, and migration emerge as complementary expressions of agency rather than opposing outcomes.

These findings suggest that mobility decision or outcome itself cannot adequately explain how NbS shape mobility as an adaptation strategy. Thus, our framework proposed for understanding the role of NbS in mobility (Fig. 1) aligns strongly with the aspirations-capabilities framing [11]. This interpretation also complements the argument that mobility contributes to climate adaptation by enabling people to secure valued objectives such as livelihoods and wellbeing [45]. Across these personas, NbS influenced adaptation by creating livelihood opportunities, strengthening stewardship, rebuilding disrupted livelihoods, sustaining seasonal mobility, or maintaining the perceived possibility of future improvement (Fig. 2). The distinguishing dimension across personas was therefore not whether respondents left or stayed, or were better or worse off, but the dominant transformative mechanism through which NbS shaped their capabilities, aspirations and perceived future trajectories.

NbS frequently played a role in supporting income from livelihood ventures and strengthening environmental and climate change knowledge. The contrast between Nature-based Opportunity Builder (Samuel) and Resilient Livelihood Rebuilder (Masesi) illustrates how similar positive mobility outcomes can arise through different mechanisms: Samuel centred on creating new livelihood opportunities, whereas Masesi centred on rebuilding

livelihoods disrupted by environmental shocks. Similarly, Seasonal Livelihood Navigator (Soa) and Place-based Risk Adapter (Cliff) demonstrate that NbS can support rootedness through different configurations of mobility and in-situ adaptation. Elsewhere, NbS sustained hope despite repeated setbacks (Persistent Opportunity Builder (Nandi)), or facilitated recovery after recurrent losses (Resilient Recovery Builder (Jimmy)), and a case when NbS proved insufficient to overcome persistent livelihood insecurity associated with mobility processes (Failed Opportunity Seeker (Berni)).

Taken together, these findings suggest that NbS influence mobility through broader transformation processes that include changes to aspirations and capabilities through attachment to place (including translocal attachment), livelihood types and opportunities, transformative mechanisms, and future trajectories. This role can be buffering when mobility fails, enhancing where NbS supports mobility benefits and finally detrimental where NbS causes mobility to fail (Fig. 1).

How NbS influence mobility: from economic opportunities to changing future possibilities

The role of NbS in mobility was frequently attributed to economic and human wellbeing factors compared to environmental factors. This pattern is consistent with evidence that environmental change shapes mobility largely indirectly, through livelihoods, income and social conditions, rather than as a direct determinant of movement [1,14,46–48]. Income from livelihood ventures and knowledge of the environment or climate change were particularly relevant as a factor with which NbS interacted with the mobility process.

Therefore, rather than simply increasing income, perceptions and the role of NbS reshaped how respondents' interpreted future possibilities, expanding capabilities and aspirations ultimately anchoring mobility decisions to leave, stay, return, or move seasonally. The empirical narratives show that in this sample, NbS did not play a dominant role through changes to environmental conditions since respondents did not respond directly or mechanically to environmental change [14,15]. Instead, NbS primarily influenced how respondents perceived, interpreted and responded to changing conditions, suggesting that NbS programme evaluation should extend beyond ecological and livelihood outcomes to include changes in environmental knowledge, stewardship, social relationships and perceived agency as mechanisms underpinning adaptive mobility. This confirms existing understanding of the importance of climate literacy as a critical enabler for strategic adaptation [7,49–51] .

Our findings also point towards a reframing of immobility. Among Seasonal Livelihood Navigator (Soa) respondents, remaining rooted in the home community was sustained through cyclical seasonal movement rather than through continuous physical presence. Together, these findings indicate that NbS influence mobility not only by supporting livelihoods but by expanding people's perceived capabilities to adapt, consistent with the understanding of mobility as the capability to choose where to live, in which staying is itself an exercise of that capability rather than its absence [11]. Rather than acting as determinants of migration or immobility, NbS function as mechanisms through which individuals interpret environmental change, evaluate future possibilities, and negotiate mobility decisions across changing social and ecological contexts, with feedbacks between mobility decisions and outcomes (Fig. 2). These patterns are usefully read through the concept of translocality: the constitution of livelihoods across multiple, enduringly connected places, in which households maintain simultaneous social and economic ties to more than one locality rather than severing them on departure [45,52]

The Seasonal Livelihood Navigator (Soa) persona illustrates a "leave to stay" dynamic in which circular movement anchors rather than loosens the household's attachment to its place of origin, diversifying income sources, reducing exposure to agricultural uncertainty, minimizing the effects of droughts and water scarcity, and strengthening household resilience [19,51,53–56]. This reflects Black et al.'s (2011)[1] framework, where environmental change interacts with social and economic drivers to produce non-linear outcomes. Interpreted alongside the Rural Livelihood Sustainer (Sipho), where NbS supported livelihood continuity in place through gradual stewardship, the two personas indicate that rootedness can be maintained through markedly different configurations of movement and stability. Therefore, rather than representing distinct or competing responses, migration, remittances, livelihood diversification, and in-situ adaptation strategies, including NbS, are often combined by households to strengthen resilience and manage environmental and livelihood risks [57]. Because 'leave to stay' dynamics and the individual or collective basis of mobility decisions were not a primary focus of our coding, we offer this as an interpretive direction warranting dedicated analysis.

Phenomenological personas for understanding and evaluating adaptive agency

Methodologically the study demonstrates the value of phenomenological comparison representative personas. Each distinct NbS-related mobility persona captures contextual expressions through which these strategies are enacted. Further phenomenological abstraction reveals context-specific adaptation orientations and livelihood pathways (e.g.,

see Environmental Livelihood Steward Juma versus Amina, and Nature-based Opportunity Builder (Samuel); Fig. 2). By understanding lived experiences in this way phenomenological analysis preserves subjective dimensions of adaptation, including place attachment, agency and future aspirations, often flattened in macro-scale mobility analyses and closed-response surveys [37,39,58,59]. This provides a transferable persona framework for understanding how NbS shape mobility adaptation across diverse social and ecological contexts in SSA (Fig. 1 and Fig. 2). Interpreting narratives phenomenologically [60,61] therefore shifts attention from what occurred to how NbS expanded, sustained, constrained or ultimately reached the limits of people's adaptive capabilities and valued mobility choices [11,45]. Future research could scale this methodology through participatory citizen science to co-produce community-led NbS alongside existing monitoring frameworks [62,63].

Evaluating NbS through mobility outcomes alone risks overlooking how they strengthen adaptive capacity even when benefits are delayed, uncertain, or unevenly distributed. Our findings demonstrate that mobility outcomes do not, by themselves, define adaptation success. Consistent with recent evidence that similar mobility decisions can produce contrasting adaptation outcomes [64], our findings show that the same NbS-related mobility contextual expression may underpin different mobility outcomes – e.g., Persistent Opportunity Builder (Nandi) and Resilient Recovery Builder (Jimmy) (Fig. 2).

Our findings suggest that adaptation policy in SSA should evaluate whether NbS expand choice and agency [7,16,65–67], not whether people leave or stay, nor whether mobility immediately improves wellbeing outcomes. Whether individuals choose to remain through stewardship and collective action or migrate to pursue nature-based livelihood opportunities, these represent different expressions of adaptive agency rather than indicators of success or failure. Evaluation should instead focus on whether NbS strengthen the capabilities and opportunities that enable valued mobility decisions. Although only two respondents perceived NbS as negatively influencing their mobility decisions, these cases highlight that NbS are not automatically socially beneficial. Their design, governance, inclusiveness, and distributional effects shape whether they support adaptation or contribute to unintended or maladaptive outcomes, reinforcing the importance of evaluating both benefits and trade-offs [68–70].

The critical policy question is therefore not whether NbS produce mobility or immobility, but which capabilities, aspirations and opportunities NbS strengthen, for whom, and through which adaptation strategy – i.e. whether they expand people's freedom to pursue NbS and mobility pathways they value in a changing climate. This agency-centred perspective offers a transferable persona framework for designing and evaluating locally embedded NbS for supporting mobility as an adaptation strategy across diverse Global South contexts.

Methods

Study design and rationale

This study used a story-based, phenomenologically informed qualitative design to examine the mechanisms through which NbS influence (im)mobility decisions and their livelihoods and mobility outcomes across SSA. The design rests on three premises.

First, mobility decisions are not reducible to observable movement. They arise from the interaction of aspirations and capabilities, which are themselves shaped by social, political, environmental, economic and demographic drivers operating simultaneously at macro, meso and micro scales [1,10–12]. We therefore distinguish *drivers* from *mechanisms*: drivers are the five interacting domains identified by Black et al. (2011)[1], already modified by climate change; while mechanisms are the specific NbS signatures through which an NbS intervention alters one or more of those drivers, and thereby alters a mobility outcome. For this study, drawing on empirical and conceptual migration literature [1,11,71], we grouped macro-level drivers into three broad domains—economic, environmental, and human wellbeing and distinguished between context-specific drivers within each broad domain based on SSA evidence (Supplementary Methods: Research Instrument). We deliberately avoid a binary push–pull framing, which cannot accommodate cases in which an NbS simultaneously raises the capability to move and the aspiration to remain [11].

Second, immobility is socially produced rather than a residual category of non-migration, and may be voluntary, strategic or acutely constrained (*trapped* population) [17,18]. The design therefore treats staying, returning, and seasonal circulation as substantive outcomes.

Third, the subjective and relational dimensions of these decisions — risk perception, place attachment, obligation, dignity and assessments of future possibility — are routinely flattened in macro-scale modelling and closed-response survey instruments [37,39,58,59]. Accessing them requires first-person accounts of lived experience interpreted phenomenologically [60,61]. This approach therefore enables identification of the mechanisms through which NbS shape mobility adaptation strategies, rather than only the mobility decisions or outcomes that result.

Consistent with these premises, we adopted a distributed narrative sense-making approach in which respondents both narrate and interpret their own experience [43,44,72]. Respondent self-signification allows respondents, rather than analysts, assign meaning to their own accounts (van der Merwe et al., 2019).

Definition and operationalisation of NbS

NbS was defined according to the UNEP and IUCN frameworks as actions to protect, sustainably manage and restore natural or modified ecosystems that address societal challenges while delivering human wellbeing and biodiversity benefits [23,73]. For inclusion, an interview had to describe first-hand engagement with either a NbS project or programme or a community- or self-driven natural-resource-based livelihood activity. Each qualifying activity was classified against the IUCN Global Standard typology as protection, restoration, sustainable management, or design-based [73]. Interviews describing livelihood activities without ecosystem protection, restoration, sustainable management or design-based component were excluded during screening.

Study setting

Fieldwork was conducted at seven focal sites within the EU-funded ALBATROSS project's 'Climate-Resilient Development (CRD) Network Hubs', spanning five SSA countries: Turkana (Kenya); Keta and Kumasi (Ghana); Kigamboni (Tanzania); Umzimvubu (South Africa); and Morondava and Toamasina/Tamatave (Madagascar) (Fig. 3). Sites were selected purposively to capture variation in NbS–mobility relationships, including ecological settings, climate exposures, and NbS governance arrangements.

Sample and recruitment

Respondents were purposively sampled [74] if they could recount a first-hand story of a mobility or immobility decision in which NbS or natural-resource-based livelihoods played a part — with a target of approximately ten respondents per site. Recruitment was conducted by Hub-based researchers through existing community and implementing partner networks, with onward referral where appropriate. Respondents were selected based on their experience with the focal NbS at the origin and/or destination.

A total of 68 interviews were conducted. Eight were excluded during data screening prior to analysis: six from Kumasi, where the described livelihood activities did not meet the NbS inclusion criteria above, and two (from Tamatave and Kigamboni) that were not completed. The analytical sample was therefore n = 60. Sample size was guided by information power [75], given the focused study aim and specific narrative material.

Data collection

Semi-structured interviews were conducted between November 2025 and April 2026 by trained Hub researchers, in person and in the respondent's language of choice. Interviews lasted 15–45 minutes. Respondents had knowledge and experience with *NbS*. Interviews began with a single, open-ended prompt inviting respondents to recount positive or negative lived experience on (im)mobility and the role that NbS played. Following narration, respondents completed a structured self-signification sequence in which they categorised the reasons underlying their decision across three domains of drivers— environmental, economic, and human wellbeing — by selecting from a pre-specified set of factors for each (*Supplementary Methods: Research Instrument*).

Respondents then classified the mobility wellbeing outcome of their decision on a five-point signification scale: *Better off than before (long-term)*; *Better off than before (temporary fix)*; *No change*; *Worse off than before (temporary setback)*; *Worse off than before (long-term)*. Finally, each respondent supplied a title for their own story, capturing its central theme or motivation, and optionally a photograph representing it [76]. Titles and images were retained as respondent-authored artifacts and used as indicators of narrative salience.

Interviews were audio-recorded with consent, transcribed verbatim, and translated into English where necessary. Translation was performed by researchers fluent in both languages and familiar with the study context; conceptually ambiguous terms were retained in the source language with a gloss, following established guidance on meaning-preservation in cross-language qualitative research [77,78]. Each transcript was assigned a unique identifier combining the respondent number and site (e.g., SH1_KUM), which was used consistently throughout the analysis, persona construction, and reporting. TUR = Turkana (Kenya); KET = Keta and KUM = Kumasi (Ghana); KIG = Kigamboni (Tanzania); UMZ = Umzimvubu (South Africa); and MOR = Morondava and TAM = Tamatave (Madagascar).

Data availability

Pseudonymised transcripts contain potentially identifying contextual detail and cannot be made publicly available. The coded datasets will be saved to a designated repository (Zivahub Open Data) and the DOI will be shared on publication.

Data analysis

Qualitative data analysis: six-stage phenomenological persona development

Transcripts were analysed using reflexive thematic analysis [79–81] within a six-stage interpretive workflow that moves progressively from individual lived experience to a higher-order explanation of NbS–mobility mechanisms. Stages 1–2 are within-case; Stages 3–4 are cross-case; Stages 5–6 are synthetic [82]. Analysis was led by C.J.F. with independent review of coding decisions by P.H., F.D. and S.Q.P.; coding was managed manually in Excel.

Stage 1 — Familiarisation and holistic narrative coding. Each transcript was read repeatedly and interpreted as a coherent lived trajectory rather than as a set of extractable codes. Attention was given to the sequence of life events, the decision process as the respondent reconstructed it, and how environmental, economic, and human wellbeing considerations entered that process as factors/reasons for mobility decisions. The priority at this stage was preserving narrative integrity [83].

Stage 2 — Deductive coding against the NbS–mobility framework. Each transcript was then coded top-down using the study framework, organised around the question *"What role did NbS play in the economic / environmental / human wellbeing reasons for the mobility decision?"*, asked separately for each domain. Critically, only factors the respondent had already self-signified/coded were admitted to deductive coding, preserving the respondent-led logic. Researcher-added codes were permitted only where a factor was explicit and unambiguous in the narrative but had not been self-selected.

Stage 3 — Initial persona clustering and mechanism-hypothesis generation. The 60 coded narratives were compared inductively across cases [82,84] to identify recurring patterns in *how* NbS influenced outcomes. Clustering was organised around shared narrative structure and adaptation processes resulting in NbS-related mobility contextual expressions, explicitly not around demographic characteristics, livelihood type, or final mobility outcome. Economic factors were used as the analytical entry point because they were the most consistently signified influence across the dataset, and economic drivers (whilst intertwined with environmental and social pressures) are often identified as the most immediate and determining factors shaping migration decisions in SSA [21,67,85]. Provisional clusters were interrogated with three questions: did respondents describe similar mechanisms of NbS influence on mobility as an adaptation strategy; did they experience similar temporal sequences of livelihood change; and did NbS play similar roles across the broad domains? Working outward from the largest positive mobility outcome category (*Better off than before (long-term)*) and then from the negative categories (*Worse off than*

before (long-term), this stage yielded provisional personas treated as interpretive hypotheses requiring testing, not as settled categories.

Stage 4 — Iterative refinement through phenomenological comparison. Each remaining narrative was compared against the provisional personas, testing whether it expressed an existing dominant NbS-related mobility contextual expression or a fundamentally different mechanism. The guiding question shifted from *"do these respondents' narratives look similar?"* to *"do these respondents describe the same dominant NbS-related mobility contextual expression?"* This comparison produced three operations — expansion (a persona absorbing greater contextual variation without change to its underlying strategy), division (a persona split where superficially similar narratives proved mechanistically distinct), and merger (apparently different narratives recognised as different *orientations* within one strategy).

Stage 5 — Construction of representative personas. Each consolidated cluster was synthesised into a single composite phenomenological narrative (Supplementary Personas 1-9). Personas are fictional composites integrating experiences, decision processes and meanings across contributing narratives; no persona reproduces an individual respondent's account, and this construction serves both analytical and disclosure-control functions [86,87]. Each persona is accompanied by a generic description of the adaptation strategy it represents and — for traceability — an explicit list of the stakeholder identifiers from which it was derived (Supplementary Personas 1-9; Supplementary Table 1).

Stage 6 — Development of a persona framework for understanding the role of NbS in mobility. Cross-persona comparison identified nine dominant NbS-related mobility personas, capturing distinct contextual expressions of how NbS influence mobility. Personas were further differentiated by whether NbS played a supported-positive, supported-buffered, or negative role in mobility adaptation. Where applicable, a second level of abstraction captured context-specific adaptation orientations reflecting deeper phenomenological variation within a persona (e.g. individual versus communal stewardship for Juma/Amina; entrepreneurship versus employment for Samuel). Separating these levels prevented persona proliferation while retaining meaningful contextual variation.

Rigour, trustworthiness and reflexivity

We addressed trustworthiness against the criteria of credibility, dependability, confirmability, and transferability [88]. Consistent with reflexive thematic analysis, we treat the analyst's interpretive position as a resource rather than a source of contamination to be eliminated [80,89]. The interviews were conducted by Hub-based researchers embedded in the case study local communities.

Quantitative data analysis

Definition of variables

The mobility wellbeing outcome variable was self-signified/coded by respondents on a five-point scale: better off than before (long term), better off than before (temporary fix), no change, worse off than before (long-term) and worse off than before (temporary setback) (*Supplementary Methods: Research Instrument*). We recoded this variable into a binary measure of change in conditions, which classifies all respondents who reported either being better off than before (long term) or better off than before (temporary fix) as 'conditions improved' and all other respondents as 'conditions did not improve' (Supplementary Table 3). This binary clarification enabled us to address the problem of sparse observations in the original mobility outcome variable. The binary mobility outcome variable was then used as a dependent variable in all quantitative data analysis.

Mobility decision was initially coded as part of the persona development process (*Stage 2, Qualitative Data Analysis*) resulting in four mobility patterns (left, stayed, returned, temporary/seasonal movement). For the quantitative analyses, we recoded this variable according to the final mobility decision which is either to leave or stay in the origin. Respondents who stayed in their origin community and never left or subsequently returned or engaged in temporary or seasonal movement were coded as "stayed" while respondents who left their community at any point and were in a new destination were coded as "left" given their current final location is not their origin community.

Each main mobility driver was coded as a binary variable, with one indicating that the driver influenced mobility decisions of respondents and zero indicating that it did not. We coded the NbS-related drivers based on the stories provided by respondents and the self-coded responses as part of the process of developing personas, which is described in the qualitative data analysis section above (*Stage 2, Qualitative Data Analysis*). As a result, we obtained NbS-related mobility drivers with three mutually exclusive categories: yes, no and not relevant. The yes category indicated that respondents identified the driver as influencing their mobility decisions and we coded the driver as related to NbS; the no category indicated that respondents identified the driver as influencing their mobility decisions, but we code the driver as not related to NbS; and not relevant to indicate that respondents did not identify the driver as influencing their mobility decisions and therefore we could not relate the driver to NbS. We retained the 'not relevant' category as a separate category because it preserves the conditional structure of how a driver is identified and related to NbS, and it enabled a distinction between respondents for whom a driver did not influence their mobility decision from respondents who experienced the driver but did not relate it to NbS.

Mobility decision, outcome and role of NbS

We used Chi-square tests to assess whether mobility decision was associated with mobility outcome, both self-signified by respondents, with Fisher's exact test reported given small expected cell counts. For the quantitative analysis, we then restricted the sample to respondents who described NbS as playing a positive role in the mobility process (n = 58), based on qualitative coding of interview narratives. Within this subsample, we used Chi-square tests to check whether the same pattern of no association held between mobility decision and the way NbS played a positive role (facilitating improved conditions versus addressing barriers or buffering impacts).

Distribution of NbS mechanisms and NbS attribution

To characterise the role of NbS in influencing mobility decisions, we calculated, for each mobility driver, (i) the percentage of respondents identifying the driver as a main mobility driver across the entire sample (n = 58), (ii) the percentage of respondents identifying an NbS-related mobility driver as influencing mobility across the entire sample (n = 58), and (iii) the NbS attribution rate. The NbS attribution rate is the percentage of respondents who identified a given mobility driver as influencing their mobility decision and subsequently identify that driver to NbS. It was calculated as follows:

$$NbS\ attribution\ rate = \frac{N_{nbs}}{N_{main}} \times 100$$

where N_{main} is the number of respondents identifying a given mobility driver as a main driver, and N_{nbs} is the number of those respondents who subsequently attributed that driver to NbS. The NbS attribution rate reflects the relative influence of NbS within each mobility driver rather than its overall prevalence in the sample. Attribution rates were interpreted alongside the prevalence of each mobility driver to avoid overemphasising pathways with high attribution rates but low frequencies.

Associations between mobility drivers and mobility decision

We examined associations between main and NbS-related mobility drivers and mobility decisions (left versus stayed) using binary logistic regression models, with each driver fitted separately in the model as the explanatory variable. Given the relatively small sample size (n = 58), several variables had sparse cell counts which increases the potential for complete or quasi-complete separation and bias in maximum-likelihood estimates [90,91]. For example, all respondents who decided to leave their origin community identified income from livelihood ventures as an NbS-related driver (n = 28) and all respondents who identified cultural norms as an NbS-related driver decided to stay (n = 3). To address this issue, we estimated all models using Firth's penalised method [92], which reduces small-sample bias and provides finite and more reliable parameter estimates in the presence of separation [92,93]. For each

model, we report the regression coefficient, ORs, 95% CIs and p-values (Fig. 5 and Supplementary Table 4-S4).

All quantitative analyses were performed in R (v4.4.3). Data visualisation was conducted using *ggplot2* (v4.0.3) and Firth's penalised logistic regression was implemented using *logistf* (v1.26.1).

Ethics

Ethics clearance was obtained from the Bioethics Committee of the University of Bologna and from the relevant national research body in each participating country (See Supplementary Methods: Ethics).

All respondents gave informed consent, administered orally in the respondent's language where written consent was inappropriate, covering study purpose, voluntary participation, right to withdraw, audio recording, use of photographs, and data handling. Consent for use of photographic material was obtained separately. Where permission for publication is still pending, identifiable faces have been temporarily blurred. Transcripts were pseudonymised at the point of transcription; site-level and personal identifiers were removed or generalised, and personas were constructed as composites specifically to prevent re-identification of individuals in small communities.

Limitations

Four limitations bear on interpretation. First, the design relies on retrospective self-reported accounts, which are subject to recall and narrative reconstruction; the study makes claims about how respondents interpret and explain their decisions, not about counterfactual mobility outcomes. Second, the sample is purposive and, by construction, drawn from populations already engaged with NbS or sustainable natural resource-based livelihoods; those excluded from or displaced by NbS interventions are structurally under-represented, which conditions the findings on equity. Third, the emphasis on translation and the 15–45 minute interview window constrains the depth attainable compared with extended ethnographic engagement, and some conceptual nuance is likely lost across languages [78]. Fourth, personas are analytical abstractions: they are designed to be transferable, but they are derived from seven sites and should not be read as prevalence estimates for any population.

References

1. Black, R. *et al*. The effect of environmental change on human migration. *Glob. Environ. Change* **21**, S3–S11 (2011).
2. IPCC. *Climate Change 2022 – Impacts, Adaptation and Vulnerability: Working Group II Contribution to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*. (Cambridge University Press, 2022). doi:10.1017/9781009325844.
3. Vinke, K., Bergmann, J., Blocher, J., Upadhyay, H. & Hoffmann, R. Migration as Adaptation? *Migr. Stud.* **8**, 626–634 (2020).
4. Boas, I. *et al*. Climate migration myths. *Nat. Clim. Change* **9**, 901–903 (2019).
5. Gemenne, F. Why the numbers don't add up: A review of estimates and predictions of people displaced by environmental changes. *Glob. Environ. Change* **21**, S41–S49 (2011).
6. Nabong, E. C., Hocking, L., Opdyke, A. & Walters, J. P. Decision-making factor interactions influencing climate migration: A systems-based systematic review. *WIREs Clim. Change* **14**, e828 (2023).
7. Simpson, N. P. *et al*. Research priorities for climate mobility. *One Earth* **7**, 589–607 (2024).
8. Clement, V. *et al*. *Groundswell Part 2*. (World Bank, Washington, DC, 2021). doi:10.1596/36248.
9. IOM. *Africa Migration Report: Connecting the Threads, Linking Policy, Practice and the Welfare of the African Migrant*. (International Organization for Migration, Addis Ababa, 2024).

10. Carling, J. & Schewel, K. Revisiting aspiration and ability in international migration. *J. Ethn. Migr. Stud.* **44**, 945–963 (2018).
11. De Haas, H. A theory of migration: the aspirations-capabilities framework. *Comp. Migr. Stud.* **9**, 8 (2021).
12. Foresight. Migration and global environmental change: future challenges and opportunities. https://assets.publishing.service.gov.uk/media/5a74b18840f0b61df4777b6c/11-1116-migration-and-global-environmental-change.pdf (2011).
13. Adger, W. N., Fransen, S., Safra De Campos, R. & Clark, W. C. Migration and sustainable development. *Proc. Natl. Acad. Sci.* **121**, e2206193121 (2024).
14. Borderon, M. *et al.* Migration influenced by environmental change in Africa: A systematic review of empirical evidence. *Demogr. Res.* **41**, 491–544 (2019).
15. Wolde, S. G., D'Odorico, P. & Rulli, M. C. Environmental drivers of human migration in Sub-Saharan Africa. *Glob. Sustain.* **6**, e9 (2023).
16. Hoffmann, R., Wiederkehr, C., Dimitrova, A. & Hermans, K. Agricultural livelihoods, adaptation, and environmental migration in sub-Saharan drylands: a meta-analytical review. *Environ. Res. Lett.* **17**, 083003 (2022).
17. Schewel, K. Understanding Immobility: Moving Beyond the Mobility Bias in Migration Studies. *Int. Migr. Rev.* **54**, 328–355 (2020).
18. Zickgraf, C. Climate change, slow onset events and human mobility: reviewing the evidence. *Curr. Opin. Environ. Sustain.* **50**, 21–30 (2021).

19. Abu, M., Codjoe, S. N. A. & Sward, J. Climate change and internal migration intentions in the forest-savannah transition zone of Ghana. *Popul. Environ.* **35**, 341–364 (2014).
20. Appiah, S. C. Y. Climate-induced migration and climate immobility in Ghana: A socio-ecological mixed method study. *J. Migr. Health* **12**, 100364 (2025).
21. Codjoe, S. N. A., Nyamedor, F. H., Sward, J. & Dovie, D. B. Environmental hazard and migration intentions in a coastal area in Ghana: a case of sea flooding. *Popul. Environ.* **39**, 128–146 (2017).
22. Ofori, D. O. *et al.* A Systematic Review of International and Internal Climate-Induced Migration in Africa. *Sustainability* **15**, 16105 (2023).
23. *Nature-Based Solutions to Address Global Societal Challenges*. (IUCN International Union for Conservation of Nature, 2016). doi:10.2305/IUCN.CH.2016.13.en.
24. IOM. *Nature-Based Solutions and Human Mobility: Conceptual and Operational Framework*. (2026).
25. IUCN. *WCC_2016_RES_069_EN*. (2016).
26. Acreman, M. *et al.* Evidence for the effectiveness of nature-based solutions to water issues in Africa. *Environ. Res. Lett.* **16**, 063007 (2021).
27. Asamoah, S. *et al.* A review of the role of nature-based solutions in mitigating food insecurity in Africa. *Green Technol. Sustain.* **3**, 100173 (2025).
28. Enu, K. B., Zingraff-Hamed, A., Rahman, M. A., Stringer, L. C. & Pauleit, S. Review article: Potential of nature-based solutions to mitigate hydro-meteorological risks in sub-Saharan Africa. *Nat. Hazards Earth Syst. Sci.* **23**, 481–505 (2023).

29. Okello, C., Githiora, Y. W., Sithole, S. & Owuor, M. A. Nature-based solutions for water resource management in Africa's arid and sem-arid lands (ASALs): A systematic review of existing interventions. *Nat.-Based Solut.* **6**, 100172 (2024).
30. Jiagge, S. A. & Jabik, B. B. Perception of Sea Level Rise on Human Security: A Qualitative Case Study of the Keta Municipality in the Volta Region of Ghana. (2025).
31. Nyika, J. & Dinka, M. O. Integrated approaches to nature-based solutions in Africa: Insights from a bibliometric analysis. *Nat.-Based Solut.* **2**, 100031 (2022).
32. Chausson, A. *et al.* Mapping the effectiveness of nature-based solutions for climate change adaptation. *Glob. Change Biol.* **26**, 6134–6155 (2020).
33. Faivre, N., Fritz, M., Freitas, T., De Boissezon, B. & Vandewoestijne, S. Nature-Based Solutions in the EU: Innovating with nature to address social, economic and environmental challenges. *Environ. Res.* **159**, 509–518 (2017).
34. Kaczan, D. J. & Orgill-Meyer, J. The impact of climate change on migration: a synthesis of recent empirical insights. *Clim. Change* **158**, 281–300 (2020).
35. Helbling, M. & Morgenstern, S. Migration aspirations and the perceptions of the political, economic and social environment in Africa. *Int. Migr.* **61**, 102–117 (2023).
36. Hoffmann, R. & Zens, G. Interrelated drivers of migration intentions in Africa: Evidence from Afrobarometer surveys. *Environ. Dev.* **52**, 101096 (2024).
37. Adger, W. N., Barnett, J., Chapin, F. S. & Ellemor, H. This Must Be the Place: Underrepresentation of Identity and Meaning in Climate Change Decision-Making. *Glob. Environ. Polit.* **11**, 1–25 (2011).

38. Farbotko, C. & Lazrus, H. The first climate refugees? Contesting global narratives of climate change in Tuvalu. *Glob. Environ. Change* **22**, 382–390 (2012).

39. Mortreux, C. & Barnett, J. Climate change, migration and adaptation in Funafuti, Tuvalu. *Glob. Environ. Change* **19**, 105–112 (2009).

40. Ayeb-Karlsson, S. 'I do not like her going to the shelter': Stories on gendered disaster (im)mobility and wellbeing loss in coastal Bangladesh. *Int. J. Disaster Risk Reduct.* **50**, 101904 (2020).

41. Van Praag, L. How Environmental Change Relates to the Development of Adaptation Strategies and Migration Aspirations. in *Migration and Environmental Change in Morocco* 105–123 (Springer International Publishing, Cham, 2021). doi:10.1007/978-3-030-61390-7_6.

42. Van Praag, L., Lietaer, S. & Michellier, C. A Qualitative Study on How Perceptions of Environmental Changes are Linked to Migration in Morocco, Senegal, and DR Congo. *Hum. Ecol.* **50**, 347–361 (2022).

43. Kurtz, C. F. & Snowden, D. J. The new dynamics of strategy: Sense-making in a complex and complicated world. *IBM Syst. J.* **42**, 462–483 (2003).

44. Van der Merwe, S. E. *et al.* Making Sense of Complexity: Using SenseMaker as a Research Tool. *Systems* **7**, 25 (2019).

45. Sakdapolrak, P., Borderon, M. & Sterly, H. The limits of migration as adaptation. A conceptual approach towards the role of immobility, disconnectedness and simultaneous exposure in translocal livelihoods systems. *Clim. Dev.* **16**, 87–96 (2024).

46. Cattaneo, C. *et al.* Human Migration in the Era of Climate Change. *Rev. Environ. Econ. Policy* **13**, 189–206 (2019).

47. Hoffmann, R., Dimitrova, A., Muttarak, R., Crespo Cuaresma, J. & Peisker, J. A meta-analysis of country-level studies on environmental change and migration. *Nat. Clim. Change* **10**, 904–912 (2020).

48. Hunter, L. M., Luna, J. K. & Norton, R. M. Environmental Dimensions of Migration. *Annu. Rev. Sociol.* **41**, 377–397 (2015).

49. Azumah, S. B., Mahama, A., Yegbemey, R. N. & Dapilah, F. Climate Perception, Migration and Productivity of Maize Farmers in Ghana. *J. Agric. Stud.* **10**, 82 (2022).

50. Helbling, M., Auer, D., Meierrieks, D., Mistry, M. & Schaub, M. Climate change literacy and migration potential: micro-level evidence from Africa. *Clim. Change* **169**, 9 (2021).

51. Silvestri, S., Bryan, E., Ringler, C., Herrero, M. & Okoba, B. Climate change perception and adaptation of agro-pastoral communities in Kenya. *Reg. Environ. Change* **12**, 791–802 (2012).

52. Greiner, C. & Sakdapolrak, P. Translocality: Concepts, Applications and Emerging Research Perspectives. *Geogr. Compass* **7**, 373–384 (2013).

53. Antwi-Agyei, P., Stringer, L. C. & Dougill, A. J. Livelihood adaptations to climate variability: insights from farming households in Ghana. *Reg. Environ. Change* **14**, 1615–1626 (2014).

54. Langill, J. C. *et al.* Land Restoration Amid Male Outmigration: The Cases of Burkina Faso and Kenya. *Ecol. Restor.* **41**, 220–235 (2023).

55. Opiyo, F., Wasonga, O., Nyangito, M., Schilling, J. & Munang, R. Drought Adaptation and Coping Strategies Among the Turkana Pastoralists of Northern Kenya. *Int. J. Disaster Risk Sci.* **6**, 295–309 (2015).

56. Rusere, F. *et al.* Relationships between rural migration and perceptions of environmental change: Insights from Bushbuckridge, South Africa. *J. Rural Stud.* **119**, 103819 (2025).

57. Ng'ang'a, S. K., Bulte, E. H., Giller, K. E., McIntire, J. M. & Rufino, M. C. Migration and Self-Protection Against Climate Change: A Case Study of Samburu County, Kenya. *World Dev.* **84**, 55–68 (2016).

58. Adger, W. N., Barnett, J., Brown, K., Marshall, N. & O'Brien, K. Cultural dimensions of climate change impacts and adaptation. *Nat. Clim. Change* **3**, 112–117 (2013).

59. Ayeb-Karlsson, S., Kniveton, D. & Cannon, T. Trapped in the prison of the mind: Notions of climate-induced (im)mobility decision-making and wellbeing from an urban informal settlement in Bangladesh. *Palgrave Commun.* **6**, 62 (2020).

60. Smith, J., Flowers, P. & Larkins, M. *Interpretative Phenomenological Analysis: Theory, Method and Research*. (SAGE, Los Angeles London New Delhi Singapor Washingtin DC, 2022).

61. van Manen, M. *Researching Lived Experience, Second Edition: Human Science for an Action Sensitive Pedagogy*. (State University of New York Press, Albany, 1990). doi:10.4324/9781315421056.

62. Gill, J. C. *et al.* Invited perspectives: Building sustainable and resilient communities – recommended actions for natural hazard scientists. *Nat. Hazards Earth Syst. Sci.* **21**, 187–202 (2021).

63. Manteaw, B. O., Amoah, A.-B., Ayittah, B. & Enu, K. B. Climate-Informed Decision-Making in Data-Poor Environments: Managing Climate Risk Through Citizen Science Networks. *Front. Clim.* **4**, 835768 (2022).

64. Garcia, C., Sakdapolrak, P., Wehner, S. & Borderon, M. Impacts of Migration as Adaptation: Assessing Translocal Social Resilience in Eastern, Northern and Greater Accra Regions, Ghana. *Popul. Space Place* **32**, e70300 (2026).

65. Abu, M. *et al.* Social consequences of planned relocation in response to sea level rise: impacts on anxiety, well-being, and perceived safety. *Sci. Rep.* **14**, 3461 (2024).

66. Boafo, Y. A., Sackey, E. K. & Lartey, D. L. 'We live on borrowed land': coastal erosion, place-based loss, and community adaptation in Ghana's Volta Region. *Afr. Geogr. Rev.* 1–21 (2026) doi:10.1080/19376812.2026.2630635.

67. Ibrahim, B. & Mensah, H. Rethinking climate migration in sub-Saharan Africa from the perspective of tripartite drivers of climate change. *SN Soc. Sci.* **2**, 87 (2022).

68. Brumberg, H. *et al.* Global analysis of constraints to natural climate solution implementation. *PNAS Nexus* **4**, pgaf173 (2025).

69. Choy, Y. K. & Onuma, A. Forging a Symbiosis Framework: An Interdisciplinary Blueprint for Scaling Nature-Based Solutions. *Sustainability* **18**, 3154 (2026).

70. Walker, S. E. *et al.* Unintended consequences of nature-based solutions: Social equity and flood buyouts. *PLOS Clim.* **3**, e0000328 (2024).

71. Amakrane, K. *et al*. *African Shifts: The Africa Climate Mobility Report, Addressing Climate-Forced Migration & Displacement*. (2023).

72. Lynam, T. & Fletcher, C. Sensemaking: a complexity perspective. *Ecol. Soc.* **20**, art65 (2015).

73. IUCN. *IUCN Global Standard for Nature-Based Solutions: A User-Friendly Framework for the Verification, Design and Scaling up of NbS: First Edition*. (IUCN, International Union for Conservation of Nature, 2020). doi:10.2305/IUCN.CH.2020.08.en.

74. Palinkas, L. A. *et al.* Purposeful Sampling for Qualitative Data Collection and Analysis in Mixed Method Implementation Research. *Adm. Policy Ment. Health Ment. Health Serv. Res.* **42**, 533–544 (2015).

75. Malterud, K., Siersma, V. D. & Guassora, A. D. Sample Size in Qualitative Interview Studies: Guided by Information Power. *Qual. Health Res.* **26**, 1753–1760 (2016).

76. Harper, D. Talking about pictures: A case for photo elicitation. *Vis. Stud.* **17**, 13–26 (2002).

77. Temple, B. & Young, A. Qualitative Research and Translation Dilemmas. *Qual. Res.* **4**, 161–178 (2004).

78. Van Nes, F., Abma, T., Jonsson, H. & Deeg, D. Language differences in qualitative research: is meaning lost in translation? *Eur. J. Ageing* **7**, 313–316 (2010).

79. Braun, V. & Clarke, V. One size fits all? What counts as quality practice in (reflexive) thematic analysis? *Qual. Res. Psychol.* **18**, 328–352 (2021).

80. Braun, V. & Clarke, V. Reflecting on reflexive thematic analysis. *Qual. Res. Sport Exerc. Health* **11**, 589–597 (2019).

81. Braun, V. & Clarke, V. Using thematic analysis in psychology. *Qual. Res. Psychol.* **3**, 77–101 (2006).

82. Ayres, L., Kavanaugh, K. & Knafl, K. A. Within-Case and Across-Case Approaches to Qualitative Data Analysis. *Qual. Health Res.* **13**, 871–883 (2003).

83. Riessman, C. K. Narrative Methods for the Human Sciences. *Gend. Manag. Int. J.* **23**, 458–460 (2008).

84. Eisenhardt, K. M. Building Theories from Case Study Research. *Acad. Manage. Rev.* **14**, 532 (1989).

85. Jilesen, R. & Wegerif, M. Climate, Environment and Migration: Experiences of Migrants in South Africa. *Afr. Focus* **36**, 195–222 (2023).

86. Nielsen, L. *Personas - User Focused Design*. (Springer London, London, 2019). doi:10.1007/978-1-4471-7427-1.

87. Salminen, J., Guan, K., Jung, S.-G. & Jansen, B. J. A Survey of 15 Years of Data-Driven Persona Development. *Int. J. Human–Computer Interact.* **37**, 1685–1708 (2021).

88. Nowell, L. S., Norris, J. M., White, D. E. & Moules, N. J. Thematic Analysis: Striving to Meet the Trustworthiness Criteria. *Int. J. Qual. Methods* **16**, 1609406917733847 (2017).

89. Berger, R. Now I see it, now I don't: researcher's position and reflexivity in qualitative research. *Qual. Res.* **15**, 219–234 (2015).

90. Greenland, S., Mansournia, M. A. & Altman, D. G. Sparse data bias: a problem hiding in plain sight. *BMJ* i1981 (2016) doi:10.1136/bmj.i1981.

91. Salas-Eljatib, C., Fuentes-Ramirez, A., Gregoire, T. G., Altamirano, A. & Yaitul, V. A study on the effects of unbalanced data when fitting logistic regression models in ecology. *Ecol. Indic.* **85**, 502–508 (2018).

92. Kosmidis, I. & Firth, D. Jeffreys-prior penalty, finiteness and shrinkage in binomial-response generalized linear models. *Biometrika* **108**, 71–82 (2021).

93. Chang, S. *et al.* Environmental, climatic, and situational factors influencing the probability of fatality or injury occurrence in flash flooding: a rare event logistic regression predictive model. *Nat. Hazards* **116**, 3957–3978 (2023).

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