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Enabling pathways for sustainable livelihoods in planned relocation

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The planned relocation of entire communities to less hazard-exposed destinations is an increasingly salient climate change adaptation strategy but often results in maladaptive livelihood outcomes. There needs to be understanding of how planning decisions affect outcomes—relocated people's access to sustainable livelihoods, including physical, economic, natural, human, social and cultural assets. Here, drawing on data from 14 completed flood-related relocation cases, we use fuzzy-set qualitative comparative analysis and find that planning decisions, alone and taken together, contributed to sustainable livelihood outcomes. Relocation processes initiated and driven by community members had better outcomes than government-driven processes, adding a global comparative perspective to prior findings. Speed and transfer dynamics were also critical, with different implications for small and large communities. As a result, multiple pathways of planning decisions can lead to better outcomes, highlighting potential entry points for policy to promote more sustainable and people-centred planned relocation.

Fourteen million people were forcibly displaced by floods worldwide in 2020[1] and flood displacement risk exacerbated by sea-level rise is expected to increase by 50% with each degree of global warming[2]. Disaster displacement has serious psychosocial, economic and cultural costs[3,4]. Hence, communities and governments are seeking opportunities to avoid displacement by proactively adapting to climate change, including through the permanent movement of whole communities to less-exposed shared destination sites[5]. This phenomenon has many names, here called planned relocation, and is increasingly recognized as both a unique form of 'climate mobility'[6] and a unique adaptation option with transformative potential[7]. Yet relocation may also subject relocated people to maladaptive outcomes, such as new hazard vulnerabilities, unemployment, food insecurity, marginalization or heritage loss[8,9]. Given potential adverse consequences, planned relocation is often considered a 'measure of last resort' after all other adaptation options are exhausted[10–12].

Nonetheless, preparing for relocation is an emerging priority for governments and communities facing sobering climate change realities. Fiji recently developed national guidelines[13] and other island states are developing similar frameworks. While particularly salient in the Pacific, planning for relocation is underway globally[9,14]. Given that relocation outcomes are often negative, stakeholders designing policies need practical strategies to reduce harm and more effectively promote human security[12]. This underscores the importance of research that explicitly links processes and outcomes and addresses the motivational question: how do relocation planning decisions affect people?

Most empirical research on hazard-related planned relocation is case studies of single examples, with a few recent comparative exceptions[5,9,15–18]. With few global comparative studies, general lessons are largely drawn from the more mature comparative scholarship on development-induced displacement and resettlement (DIDR)[19–22]. However, the applicability of DIDR to hazard-related relocation is limited, as the drivers for relocation, nature of coercion, actors and funding sources often differ[21]. To provide more relevant and widely

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Table 1 | Definitions and ranges of outcomes and relocation planning decision factors

		Definition	Range
Relocation planning decisions	Community engagement	Frequency and inclusivity of community participation during (1) initiation, (2) site selection and (3) site development phases	Cases range from government or NGO initiated/driven to community initiated/driven
	Proximity	Number of kilometres between origin and destination sites	Cases range from close to far
	Scale	Number of households relocated	Cases range from small to large
	Speed	Number of years from initiation to physical move of most people (50%) to the new site	Cases range from fast to slow
	Transfer dynamics	Level and quality of transfer dynamics synchronicity (1) before (was this a partial relocation?), (2) during (was there collective interim housing?) and (3) after (disperse to multiple sites?)	Cases range from staggered to synchronized
Relocation outcomes (relocation related changes in access to assets for sustainable livelihoods)	Human	Evidence about changes in relocating people's access to and availability of services for education (schools), health (hospitals, clinics) and/or skill building	Cases range from fully positive to fully negative human outcomes
	Social	Evidence of changes in relocating people's dynamics of community cohesion, family relationships and/or friendships	Cases range from fully positive to fully negative social outcome
	Cultural	Evidence of changes in relocating people's connection to land, tradition, heritage, religion and/or ritual	Cases range from fully positive to fully negative cultural outcomes
	Natural	Evidence of changes in relocating people's access to resources (for example ocean, forests, rivers), food security, land quality and/or hazard exposure	Cases range from fully positive to fully negative natural outcomes
	Physical	Evidence of changes in relocating people's access to housing, infrastructure, amenities, water and/or energy	Cases range from fully positive to fully negative physical outcomes
	Financial	Evidence of changes in relocating people's access to opportunities for income, markets and/or savings	Cases range from fully positive to fully negative financial outcomes
	Overall	Overall changes in relocating people's access to human, social, cultural, natural, financial and physical assets from before to after relocation	Cases range from fully positive to fully negative overall outcomes

See Supplementary Section 1 for examples and Table 1 of Supplementary Section 2 for calibration details. Outcome definitions adapted from ref. 19.

applicable insights for effective hazard-related planned relocation policy, comparative analysis is essential.

To address this gap, we conducted a comparative analysis of all cases in a global database[14] that met certain criteria: a common climate change-related hazard (floods), completed implementation, only one origin and destination site and adequate documentation. Through synthesis of available scholarly and grey literature, we systematically identified, coded and calibrated information on relocation planning and outcomes for each case. See Table 1, Methods and Supplementary Sections 1 and 2.

To assess outcomes, we considered diverse conceptual frameworks previously applied to hazard-related relocation, including sustainable livelihoods[19], livability[18], well-being[23], reconstruction of impoverishment risks[24,25] and durable solutions[26] (Supplementary Section 3). The sustainable livelihoods approach (SLA)[27], as previously applied in Fiji[28], Sri Lanka[29] and Mozambique[30], is well-aligned with our objectives and has important advantages for assessing changes in access to assets as a result of relocation[22], including relevance to comparison across cases with different baselines and community-scaled, multidimensional consideration of human needs (natural, social, financial, human and physical). We extend the SLA (hereafter, SLA+) with cultural dimensions, understudied aspects of livelihoods[31] essential to consider in relocation contexts[19]. SLA+ provides a well-grounded framework for an initial assessment of the overall 'success' of a relocation (Table 1), recognizing that any approach is incomplete, subject to multiple interpretations and grounded in a particular time and place[9].

Past research identifies several factors that impact relocation outcomes, including hazard, planning, stakeholder and governance considerations (Supplementary Section 4). Here, we test the role of five factors that are potentially important, consistently measurable across cases and viable for possible planning intervention: community engagement, distance, speed, scale and transfer dynamics (Table 1). Our expectations for the roles of each factor follow. First, we expect that processes where community members are engaged at all stages, including whether where and how to relocate, are associated with positive outcomes, based on increased control and agency[11]. Second, closer distance between origin and destination sites is associated with positive outcomes because relocations across short distances may minimize trauma and enable access to sites of economic and cultural importance[32,33]. Third, the speed of relocations (from initiation to physical move) shapes livelihood outcomes[23,34]; faster processes may minimize disruption, whereas slower processes may minimize errors and enable more meaningful community engagement[18]. Fourth, scale (the number of households) is associated with outcomes; smaller relocations benefit from tight-knit shared identity, whereas larger relocations face fewer inefficiencies and thus benefit from economies of scale[18]. Fifth, transfer dynamics also affect outcomes[18,35]; a staggered approach, starting with relocating only those most in need, can decrease social and financial costs[36] and allow for voluntary immobility[8], while a synchronized approach can help minimize social disarticulation[37]. On the basis of the available literature, each of these factors is critical for outcomes, yet these factors co-occur, are interdependent and are mutually reinforcing. Therefore, a deeper appreciation of how pathways or combinations of factors result in both positive and negative livelihood outcomes is essential for creating evidence-based planned relocation policies.

To explore how these five planning decision factors, alone and in combination, contributed to sustainable livelihood outcomes, we used fuzzy-set qualitative comparative analysis (fsQCA)[38]. The fsQCA is a set theory-based analytical technique for clustering[39]. It is well suited for medium-sized samples (10–50 cases) that are challenging to study with other methods[38]. Importantly, fsQCA retains knowledge of case complexity yet enables generalizability. It can be used as a tool for identifying patterns within primary research or for systematic review of published studies[40]. When statistical meta-analyses are not viable

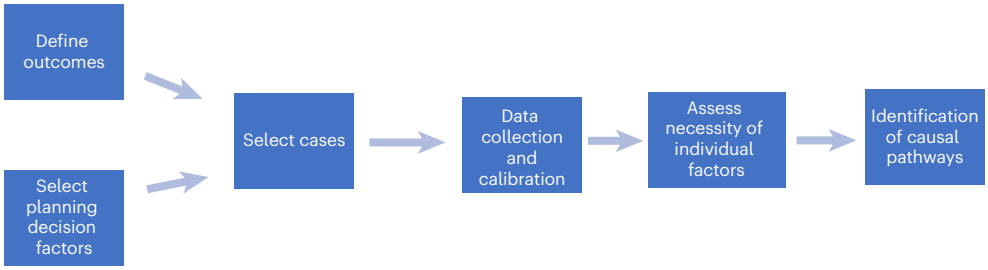

Fig. 1 | Fuzzy-set qualitative comparative analysis process. The steps in the fsQCA process are described in detail in the Methods.

given case heterogeneity and intervention complexity[40], fsQCA can provide complementary, configurational, insights[41,42]. Hence, here we use fsQCA as a systematic approach to narrative synthesis of available literature, as explained in Fig. 1 and Methods.

Across the 14 cases, community engagement and speed mattered the most for positive livelihood outcomes, with key differences by community scale. For larger communities, relocating quickly with high levels of engagement led to more positive outcomes. For smaller communities, relocating slowly with synchronized transfers alongside high levels of engagement led to more positive outcomes. Surprisingly, close site proximity was not important for livelihood outcomes in these cases. Our findings confirm prior findings about the importance of community engagement and advance an understanding of how pathways of relocation decisions affect sustainable livelihood outcomes in the understudied context of climate change-related hazards, with implications for improving planned relocation policy.

Relocation planning decision and outcomes of 14 cases

Fourteen planned relocations, located in North, South and Central America, Asia, Australia and the Pacific, varied in planning and outcome conditions (Fig. 2 and Table 2). Outcomes varied within and across cases along human, social, cultural, physical, financial and natural SLA+ categories. Cultural dimensions fared the worst, with 8 of 14 cases exhibiting negative outcomes. Conversely, physical, human and natural dimensions were more often positive, while financial and social outcomes were mixed. The tendency for cultural outcomes to skew negative and physical outcomes to skew positive aligns with results from other relocations initiated in the context of dam construction, development and disaster[19]. Outcome categories also probably vary in importance among cases. We use the unweighted, average score across categories as a starting point to identify insights for policy and practice, recognizing the potential added value of alternative approaches (Methods and Table 7 of Supplementary Section 2).

Conditions and pathways for improved sustainable livelihoods

We use fsQCA to identify if any conditions explain variation in relocated peoples' livelihood outcomes. Following standard practice, we first examine whether any individual decision factors are necessary for improved livelihood outcomes, on the basis of two 'goodness of fit' measures: consistency to assess predictability and coverage to assess relevance. Neither the presence nor absence of any single condition exceeded the commonly accepted consistency threshold of 0.9 for necessity, implying that no single factor was observed in all the cases achieving positive livelihood outcomes (Table 3). Similarly, neither the presence nor absence of any single condition exceeded the consistency threshold as necessary to achieve negative outcomes (Table 4 of Supplementary Section 2). While no conditions meet the threshold for necessity, community initiated and driven (0.805), synchronized transfer (0.748) and small-scale (0.742) individual conditions had the highest consistency scores for positive outcomes, suggesting their relative importance.

The fsQCA identified a solution with two pathways of condition combinations that are sufficient for improved livelihood outcomes (Fig. 3). The first pathway involved larger communities with stronger engagement and faster timelines, while the second involved smaller communities with stronger engagement, slower timelines and synchronized transfers. This solution has high scores for consistency (0.979) and coverage (0.688), implying that the pathways are empirically important and explain variation in most of the cases. Several of the cases have outcome scores close to the crossover threshold of 0.5. However, this does not influence the consistent relationship between these pathways and positive overall outcomes. Adjusting the threshold to the average value of 0.6, for instance, impacts only Pattonsburg, which did not feature in either pathway; a sensitivity test removing this case led to the identical solution (Table 7 of Supplementary Section 2).

From these results, three themes emerge. The first confirms insights from previous literature about the vital importance of community engagement across the relocation process. The second is a new result about contrasting paths for small and large communities. Finally, the third challenges conventional assumptions about the role of distance for sustainable livelihood outcomes.

Community engagement enhances livelihood outcomes

This comparative analysis demonstrates that community engagement is critical for improving overall outcomes in planned relocations, confirming our first suggestion and reinforcing insights from comparative DIDR scholarship[21,22]. Community engagement is the individual condition with the highest consistency score and it features in both pathways of the multifactor solution (Fig. 3). Further, the importance of community engagement withstands robustness checks (Table 7 in Supplementary Section 2). Cases initiated and driven by community members (high engagement) with overall positive livelihood outcomes are Vunidogoloa, Grantham, Valmeyer, Allenville, Soldier's Grove and Lateu, while cases driven by governments or non-governmental organizations (NGO) (low engagement) with overall negative livelihood outcomes are La Barquita, Kananke Watta and Kandholhudhoo. Thus, in this analysis, the results are symmetrical: engagement by community members is critical for improved livelihood outcomes and its absence contributes to the opposite outcome.

However, one case complicates this pattern. Despite El Choncho community initiating and driving the relocation process, overall outcomes were negative. In this case, the government provided only construction materials[43] to the community. A conceptual model of stakeholder interactions suggests that cases with 'mutual agreement' between community members and external actors generally face fewer obstacles than 'self-reliant' communities[5]. Other research suggests that 'polycentric' governance systems with a balance between bottom-up and top-down initiative may be most adaptive[44] and associated with transformative outcomes[9] in relocation contexts. Thus, the absence of meaningful support from government[45] may help to explain why community engagement was not associated with positive outcomes in El Choncho. While community engagement is undeniably important, it is not sufficient on its own.

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Fig. 2 | Locations of the 14 cases of flood-related planned relocation. Credit: Base map data ©2022 Google

Further, conceptions of 'community engagement' varied across reviewed literature. While we measured the construct consistently here, this variation raises questions about who counts (for example, 'Do chiefs, mayors or local government officials count as community members?')[46] and existing power dynamics (for example, 'Whose voices are amplified or suppressed during decisions of whether, where and how to relocate?')[47]. Further, ideas of meaningful engagement varied, as not all participatory processes are equal; engagement exists along a 'spectrum' from passive information sharing to local initiative[11] or a 'ladder' of citizen participation with increasing 'rungs' from tokenism to control over decision-making[48]. Opportunities for participation also evolve over time and are required not only at initiation but also at later stages of site selection and development[49]. There is a tendency to treat community engagement as binary but these comparative findings paint a more multidimensional landscape. Deeper examination of community engagement is needed, including regarding inclusivity, quality and stage of the process.

Contrasting paths for small and large communities

Community engagement resulted in overall positive livelihood outcomes in both multifactor pathway solutions: on a more rapid timeline in larger communities and on a slower timeline in smaller communities that transfer together (Fig. 3). All three cases where relocations occurred quickly were large communities (>50 households), where the community was responding to an urgent disaster—riverine floods in Grantham and Valmeyer and tsunami-linked coastal floods in Mondo. These larger disaster response cases involved a 'window of opportunity' cognitive frame necessitating quicker timelines[50]. In contrast, cases of slower relocations in smaller communities (Lateu, Vunidogoloa) were more proactive, in anticipation of future risk (sea-level rise) and reaction to past impacts (coastal flooding, coastal erosion and saline intrusion limiting potable water). Thus, the contrasting influences of speed are related to a community's need for urgent disaster response.

The fact that both slow and fast speeds contributed to overall more positive livelihood outcomes is somewhat surprising but it helps to explain mixed findings in the literature. The combination of timing and transfer dynamics also helps; synchronized transfer did not appear in the pathway of larger communities relocating quickly but was important for smaller communities relocating slowly. This suggests a relationship between speed and transfer dynamics: as the interval between initiation and completion elongates, there is greater need for cohesion measures such as interim temporary housing to keep the community together (for example, Allenville)[37]. There may also be a connection between scale and transfer dynamics: synchronicity is essential for small tight-knit communities with a shared identity, whereas large populations lacking cohesion before relocation have less need for efforts to preserve community integrity during transfer. Some relocations are so rapid that the distinction between synchronized and staggered is not meaningful. Synchronized transfer is not a universal 'principle for positive relocation' as previously suggested[37] but one that matters for small, tight-knit communities and/or for longer relocations.

The role of distance

Counter to our expectation and contrary to dominant views in the literature[32,33], close proximity between origin and destination sites did not appear among the most important single conditions or in either multifactor solution pathway leading to more positive livelihood outcomes. This may be a consequence of the relatively short distances, ranging from 200 m to 16 km, for the 14 cases in this sample. It could also be that the impacts of coastal and riverine floods on communities are a function of topography as much as absolute distance. For example, the relocation in Denimanu involved a destination just 500 m inland but a higher elevation of 20 m above sea level[28]; vertical and horizontal distances are not always correlated and vertical distance may be ultimately more important for reducing exposure. Additionally, the idea of 'distance' can be measured by metrics other than metres and kilometres; cultural and jurisdictional distance may matter for indigenous and other communities with strong attachment to place. Many Fijian cases,

Table 2 | Summary of the dataset

Case	Outcome conditions (SLF)							Planning conditions				
	Overall	Human	Social	Cultural	Natural	Financial	Physical	Speed (yr)	Distance (km)	Scale (households)	Community engagement	Transfer dynamics
Grantham, Australia	0.90	0.80	0.6	1.00	1.00	1.00	1.0	0.05 (1)	0 (0.2)	0.60 (115)	1.00	0.20
El Choncho, Colombia	0.37	0.20	0.4	0.20	0.60	0	0.8	0.27 (2)	0 (0.7)	0.05 (10)	1.00	0.80
La Barquita, Dominican Republic	0.47	0.80	0.2	0.20	0.60	0.20	0.8	0.57 (3)	0.73 (3)	1.00 (1500)	0	0.40
Vunidogoloa, Fiji	0.77	1.00	1.0	0.20	0.80	1.00	0.6	0.95 (8)	0.50 (1)	0.15 (26)	0.80	1.00
Denimanu, Fiji	0.43	0.20	0.6	0.80	0.20	0.40	0.4	0.05 (1)	0.01 (0.4)	0.09 (19)	0.20	0.40
Vunisavisavi, Fiji	0.38	0.50	0	0	0.60	0.60	0.6	0.57 (3)	0 (0.07)	0.03 (4)	0.40	0.20
Kandholhudhoo, Maldives	0.47	0.80	0.4	0.40	0.40	0.20	0.6	0.69 (4)	1.00 (20)	0.97 (600)	0	0.20
Mondo, Solomon Islands	0.63	1.00	0.6	0.20	0.60	0.40	1.0	0.05 (1)	0.05 (2.9)	0.55 (80)	0.80	0.60
Kananke Watta, Sri Lanka	0.47	0.80	0.2	0.40	0.60	0.60	0.2	0.12 (1.5)	0.19 (1.4)	0.09 (18)	0	0
Valmeyer, United States	0.77	1.00	0.8	0.60	1.00	0.20	1.0	0.27 (2)	0.67 (2.7)	0.73 (200)	1.00	0.40
Soldier's Grove, United States	0.70	1.00	0.2	1.00	0.60	0.80	0.6	0.79 (5)	0.05 (1)	0.11 (22)	1.00	0.80
Allenville, United States	0.67	0.40	0.6	0.80	0.60	0.60	1.0	0.57 (3)	1.00 (12)	0.25 (35)	1.00	0.80
Pattonsburg, United States	0.57	1.00	0.4	0.40	0.60	0.60	0.4	0.69 (4)	0.95 (5)	0.50 (50)	0.80	0.80
Lateu, Vanuatu	0.80	0.60	0.8	0.80	1.00	0.60	1.0	0.95 (8)	0.05 (1)	0.04 (8)	1.00	0.80
Average across cases	0.60	0.72	0.49	0.50	0.66	0.51	0.71	0.47 (3.3)	0.37 (3.7)	0.37 (191.9)	0.64	0.53

Outcome and planning conditions for 14 relocation cases, organized by alphabetical order of country. Speed, distance and scale are calibrated scores, with raw data before calibration in parentheses. The overall outcomes column is the average of the six dimensions of the SLA+ framework.

Table 3 | Necessity of individual conditions in explaining variation in cases with positive livelihood outcomes

Planning conditions			Consistency	Coverage
Community engagement	Presence	Community initiated and driven	0.805	0.751
	Absence	Government or NGO initiated and driven	0.336	0.564
Transfer dynamics	Presence	Synchronized	0.748	0.849
	Absence	Staggered	0.598	0.760
Scale	Presence	Large	0.492	0.800
	Absence	Small	0.742	0.760
Distance	Presence	Far	0.453	0.708
	Absence	Close	0.687	0.670
Speed	Presence	Slow	0.660	0.841
	Absence	Fast	0.679	0.769

Leftmost column describes each planning decision, while third column describes cases where the condition is present or absent.

for example, involved moves where absolute horizontal distance may matter less than whether the move takes place within the same *mataqali* or administrative unit of customary land tenure, ensuring that the move "did not challenge territorial sovereignty, protected connection to place, had historical precedent and enabled continuity of everyday practices and livelihoods, including small-scale farming and fishing" (p. 332)[51]. The addition of cultural dimensions to the SLA+ framework enables consideration of these broader distance conceptions.

An important caveat to whether distance matters is translocality[52]—many relocated people maintain multiple place attachments and return daily to origin sites for ritual, pleasure or income generation. For example, the site of Old Valmeyer became dedicated open space for recreation and farming[53], while Kandholhudhoo is used by Dhuvaafaru fishers as a hub for fishing operations[54]. Such mobile and dynamic translocal lifestyles are common and may be important, independent of any relocation. History is also

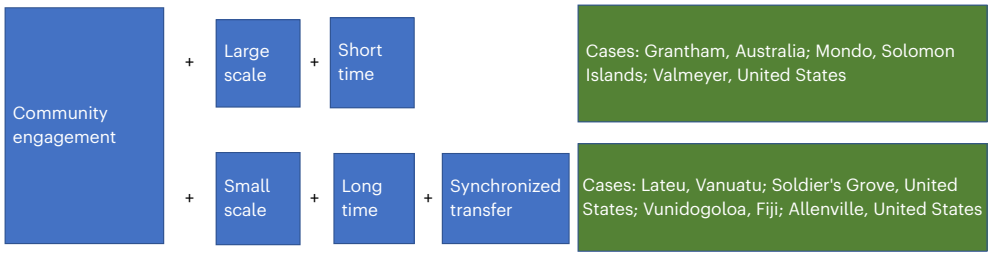

Fig. 3 | Pathways of condition combinations explaining variation in cases with positive outcomes. The overall solution has consistency of 0.979 and coverage of 0.688. The first pathway has consistency of 1.000 and raw coverage of 0.336, while the second pathway has consistency of 0.972 and raw coverage of 0.504.

critical; some communities have relocated previously and new destination sites may be historical origins[51]. This raises questions about whether and in what ways the absolute distance between origin and destination sites matters. Rather than trying to minimize distance, an equally important consideration for relocation planners may be to facilitate everyday translocal agency between sites through the provision of transportation or site selection along major transit routes.

Future research directions

Global comparative research about pathways to better livelihood outcomes in hazard-related planned relocation is a ripe area and future work is urgently needed to expand understanding of relocation outcomes and planning decisions. We considered the role of community engagement, site distance, duration, scale and transfer dynamics but further enquiry should consider the effect of other relocation planning, hazard, stakeholder and governance factors on outcomes (Supplementary Section 4), particularly persistence of hazard impacts, financial compensation[9] and level of government support (including regulative, normative and cultural-cognitive elements[50]). Additionally, we investigated outcomes through the lens of sustainable livelihoods plus cultural considerations (SLA+), which we offer as a concrete, multidimensional path forward toward measuring the highly contested question of relocation 'success'. Still, the application of other relocation-specific outcome measurement theoretical frameworks (Supplementary Section 4) and 'success' typologies[9] is needed to advance knowledge about planned relocations. We weighted dimensions of sustainable livelihood outcomes equally but further research may also study differential weighting based on community priorities. Future in-depth case studies may consider explicitly measuring social, human, financial, physical and natural as well as underdocumented cultural dimensions of livelihoods, to facilitate more standardized comparative syntheses.

Acknowledging tensions about whether outcomes and planning decisions can be measured in a comparable way across cases (and populations within cases), this fsQCA provides a foundation for further research about pathways to better relocation outcomes. Other complementary methods are needed to advance case knowledge and verify these findings. In-depth single case studies with primary data collection are critical, yet there is also value in the complementary insights from a systematic, comparative and configurational approach.

Further comparative research may also consider alternative case selection criteria. Our analysis excluded cases where communities have not yet moved to the destination site. Future work could assess how speed influences outcomes in cases with very protracted timelines (for example, Alaskan Native village of Newtok awaiting relocation for decades[55]). Additionally, our analysis excluded cases with multiple origin and destination sites but future analyses may focus on how larger distances in these spatially complex relocations (for example, in the Carteret Islands[24], Mozambique[30]) influence outcomes.

Implications for policy and practice

Planned relocations are fraught undertakings and not always the appropriate response. Relocation planners should consider communities' voluntary immobility intentions[8], alongside insights for how to improve relocation practice. When relocation is needed, careful planning and policy-making are essential to ensure communities are not left in worse circumstances. Cases initiated and driven by community members result in better outcomes than cases initiated and driven by external actors. Confirming our proposals and results from other studies[9,19], this finding underscores the importance of community autonomy for effective climate adaptation[56]; relocation planners should prioritize increased community control through meaningful, inclusive engagement at all stages. Scale and speed are also critical but vary across contexts: in small communities, community engagement over slower timelines with synchronized transfers led to better outcomes, whereas in larger communities, community engagement on faster timelines led to improved outcomes. These patterns, hidden until revealed through the analytical tool of fsQCA, point to new options for improving relocation.

Governments have committed to enhancing action on planned relocation across levels: nationally (for example, Fiji's Guidelines)[13] and internationally (for example, the Paris Agreement's Task Force on Displacement, Sendai Framework for Disaster Risk Reduction, Nansen Initiative Protection Agenda)[12]. Fulfilling such commitments requires improved empirical insights about what pathways minimize harm and lead to improved livelihood outcomes for relocating persons. As climate change increases the intensity and frequency of floods and other hazards, understanding past experience may inform future international guidance and practical toolkits[10] and provide an essential foundation for proactive, principled and people-centred relocation planning.

Online content

Any methods, additional references, Nature Portfolio reporting summaries, source data, extended data, supplementary information, acknowledgements, peer review information; details of author contributions and competing interests; and statements of data and code availability are available at https://doi.org/10.1038/s41558-023-01753-x.

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Methods

Our research approach consisted of four steps: (1) selection of outcome and causal conditions; (2) selection of relevant case studies; (3) data collection and coding of case study characteristics; and (4) comparative analysis using fsQCA.

Selection of outcome and causal conditions

We first drew on relevant literature to understand how past studies have measured outcomes and causal conditions in planned relocations. While there is no consensus about which conceptual framework is most applicable for assessing hazard-related relocation outcomes, a range of approaches were identified in the literature from diverse disciplinary perspectives (Supplementary Section 3). Each conceptual framework has advantages and disadvantages, as most were developed for other purposes. Some frameworks are better suited to assess outcomes at the level of a whole community, such as livability, whereas others are more tailored to individual scales, such as well-being. Some frameworks miss key dimensions specific to hazard-related relocation outcomes, such as cultural aspects, governance or exposure reduction. Many of these frameworks were developed to understand outcomes in analogous development resettlement, forced migration or disaster recovery contexts and have limited applicability for climate or hazard-related planned relocation cases. Here, we selected the SLA[27] to understand how access to various assets changes as a result of relocation[22]. SLA is well suited as an outcome measure because it: (1) can be used at the community scale, (2) enables comparison across cases with different baselines and (3) allows for multidimensional consideration of human needs (natural, social, financial, human and physical, with the addition of cultural dimensions to make SLA+[19,28]).

For causal conditions, we reviewed literature to identify diverse planning, hazard, community stakeholder and governance factors that past research suggests impact relocation outcomes (Supplementary Section 4). In considering these factors, we narrowed our focus to a subset that met three criteria: (1) suggested to be important for sustainable livelihood outcomes specifically, (2) consistently measurable across these 14 cases and (3) viable areas for possible planning intervention. Table 1 in Supplementary Section 4 provides details regarding factor selection.

Case selection

Until recently, a global database of hazard-related planned relocation cases did not exist, constituting an obstacle to comparative research. In this analysis, we draw from a new database of planned relocation cases initiated after 1970 published by the Platform on Disaster Displacement and the Kaldor Center in 2021[14]. While we were revising this manuscript, a mapping of success typologies in managed retreat programmes was published[9], providing another compilation of cases for future comparative analyses.

From the global database, we selected planned relocation cases that met certain selection criteria. Case selection involves trade-offs between more cases for increased sample and fewer cases to ensure consistency across cases and meaningful comparisons. Our case criteria were: (1) the physical relocation has already occurred ('completed' in the database), (2) relocation from one site of origin to one destination ('type A' in this database[14]), (3) one of the identified natural hazards was floods (including in the context of riverine settings, coastal erosion and tsunamis) and (4) adequate documentation. When this search was conducted in January 2021, the database included 73 cases identified from the initial mapping of English language literature that met these first three conditions. (Note that after a June 2021 review of Spanish, French and Portuguese literature, the database now has 14 additional cases meeting criteria (1) to (3) for a total of 87 cases.) However, most (81%) of these original 73 cases did not meet the criterion of adequate documentation, which were as follows: (1) at least one piece of evidence for nearly all six SLA+ suboutcome conditions and five relocation planning decision factors and (2) at least one article using a consistent data collection method of interviews with key stakeholders. We recognize that the adequate documentation criterion may have biased selection towards cases in the developed and English-speaking world and cases that were more well-known and thus more well-resourced, which constitutes a limitation to this research. We ultimately selected the 14 cases of planned relocation that met these criteria, varying in completion year between 1981 and 2016.

Data collection and coding of causal and outcome conditions per case

To gain in-depth knowledge of all 14 selected planned relocations, the coding team (E.R.B. and A.B.) conducted case study literature reviews through: document identification, data extraction by theme, content analysis and calibration and narrative synthesis.

Document identification. In January–March 2021, we identified diverse documents—including academic articles, white papers, government planning materials and media articles—through systematic searches on Google Scholar, Google and Google News. We used these search engines, rather than Scopus or Web of Science because we wanted to capture evidence and develop case knowledge about relocation outcomes and planning factors from documents produced by government actors (for example, US Army Corps of Engineers), the media (for example, radio shows and local newspapers) and community members (for example, blogs and YouTube videos) in addition to academic researchers (for example, peer-reviewed papers and unpublished theses). To identify relevant and diverse documents, we used search terms 'Village/Community of origin, Country' and 'Relocation' or 'Resettlement' or 'Retreat' and considered the top 25 results in each search engine. We scanned each document and selected only those where the discussion of the relocation case was substantive; documents containing one to two sentences about the case were not included. All documents referenced for case descriptions and calibration decisions are listed in Table 1 of Supplementary Section 1.

Data extraction by theme. Using the qualitative data analysis tool NVivo (QSR International), the coding team then systematically extracted all relevant data per relocation case, which were categorized into themes pertaining to background context, planning decision factors and outcomes. For background, we considered evidence about the hazard(s) involved, the process duration (years of relocation decision initiation and completion of the physical move), the locations origin and destination site and additional geographic and socioeconomic context. For relocation planning decisions, we considered evidence about community engagement, distance, scale, speed and transfer dynamics (see Table 1 for definitions). For outcomes, we considered evidence about relocated people's change in access to assets required for SLA+, including physical, economic, natural, human, social and cultural categories (see Table 1 for definitions, aligned with the SLA+ assets adapted from previous studies[19,27,28]). To ensure robustness, we used NVivo's percentage agreement calculator and found an average of 84% agreement for the extraction of relevant outcome and causal conditions across the two members of the coder team.

For some cases, information about all outcome and causal conditions was not available in the reviewed documents. If we were unsure about a specific calibration decision or if less information was available, we contacted the authors of reviewed documents for further information and verification. We triangulated with Google Earth to verify the distances between origin and destination sites and used these estimates if there was a discrepancy. While some cases have experienced multiple relocations over time, we considered only the distance between the most recent origin and destination sites.

Content analysis and calibration. Next, we undertook a content analysis of the available data for each relocation decision factor and outcome category. For each of the six outcome categories, we made evaluative judgments of negative or positive valence of the evidence following the approach of refs. 19,28. For example, we coded increased access to electricity through the installation of solar panels in the destination site as a positive physical outcome, while we coded a decrease in access to health centres as a negative human outcome. On the basis of theoretically informed and predetermined calibration criteria (Table 1 of Supplementary Section 2), we aggregated available evidence and assigned each case a score per outcome category and relocation planning decision factor. Cases had differing quantities of evidence for each category, which we accounted for through a six-point scoring system based on percentages of available evidence (discussed below). To ensure robustness, two members of the research team undertook the coding procedure for each case independently. Then, both team members collectively reviewed each case, allowing for a consensus interpretation through 'negotiated agreement' to establish intercoder reliability[57].

Narrative synthesis. After coding all the outcome and relocation planning conditions, we then summarized our coding into narratives for each of the 14 cases. Supplementary Section 1 contains information on all cases, including a short description, replication evidence for calibration of causal and outcome conditions and a list of references for each case, while Supplementary Section 2 summarizes the calibration approaches used for causal and outcome conditions and descriptive statistics across cases.

Assessing causality through fsQCA

To determine what pathways lead to more positive or negative livelihood outcomes, we compared patterns across 14 cases using fsQCA. This involved multiple steps: calibration, assess necessity and sufficiency, robustness tests and case verification. All analyses were conducted using fs/QCA V.3.0 software[58].

The fsQCA is a comparative-case analytic method developed by refs. 38,59 on the basis of principles of Boolean algebra and fuzzy-set theory. It examines set memberships of cases (determined from qualitative and quantitative data) to identify if conditions are necessary or sufficient for explaining outcomes. While there are many relevant approaches in the universe of analytical techniques, including principal component analysis and cluster analysis[39,60], among others, fsQCA had several critical advantages for this analysis. First, it "both bridge[s] and transcend[s] the qualitative–quantitative divide"[61]: as for case study approaches, the method retains in-depth case complexity but like large-sample statistical approaches, it enables some degree of generalizability through robust comparisons. Second, it is ideal for medium sample sizes, which are usually defined as being between 10 and 50 cases[38]. Third, it allows for complex causality where multiple conditions act in combination to influence an outcome. Fourth, this approach identifies multiple pathways to the same outcome that coexist ('equifinality'), addressing concerns about local context dependence. Finally, in contrast to the earlier qualitative comparative analysis variant that requires 'crisp' condition and outcome scores (binary 0 or 1), the more recent fsQCA approach allows for nuanced scoring along a 'fuzzy' scale (range from 0 to 1). The fsQCA applications are increasing rapidly[62], including recent papers examining post-typhoon relocations[18] and shelter projects[49] in the Philippines, post-tsunami recovery in India[63] and post-hurricane recovery in New Orleans[64]. The fsQCA has also been used[41,42,65] for meta-analysis when questions are about configurations of case study literature (as in this study) rather than effect size[66]. Qualitative comparative analysis is a useful method when quantitative meta-analysis falls short, such as when interventions are complex and when there is heterogeneity between cases that cannot be explained through statistical methods. In such circumstances, fsQCA can "replace standard fall back on narrative synthesis and usefully suggest ways in which a combination of characteristics are associated with improved outcomes" (p.13)[40].

Calibration. To apply this method, we first undertook a process known as calibration: we converted the raw case data into set membership scores ranging from 0 to 1 using predefined criteria for both outcomes and relocation planning factors (Table 1 of Supplementary Section 2). For livelihood outcomes, each case was assigned a score for all six asset categories along a fuzzy-set six-point scale. As explained in Table 1 of Supplementary Section 2, we considered all the available evidence for each suboutcome category and assigned scores of 0, 0.2, 0.4, 0.6, 0.8 or 1 on the basis of per cent of available evidence indicating positive or negative outcomes. For relocation planning factors with quantitative data (scale, speed and distance), we used the standard approach to direct calibration using the fs/QCA 3.0 software function 'calibrate' which uses log-odds[59]. The remaining two factors were calibrated indirectly using six-point scales based on case knowledge. Community engagement measured the frequency and inclusivity of involvement of relocating community members at three stages of the process: initiation, site selection and site development. Transfer dynamics measured the level and quality of synchronicity of transfer dynamics at three stages of the process: decision, during move and destination. Table 1 of Supplementary Section 2 provides further details on calibration approaches.

Assess necessity and sufficiency. We then assessed the necessity and sufficiency of conditions in explaining outcomes. In fsQCA, necessary and sufficient relationships can be defined in terms of set relations. Necessary relationships occur when a condition is observed in (nearly) all cases with the outcome; this implies that the set of cases with the outcome is a subset of the cases with the condition. Sufficient relationships occur when the outcome is observed if the condition, or combination of conditions, is present; in other words, these cases are a subset of cases with the outcome. Both necessity and sufficiency analyses use two measures commonly used to assess a QCA: consistency and coverage. Consistency measures the strength of the relationship between condition and outcome or the degree to which one set is a perfect subset of another. Values range from 0 to 1 and, while there are no universally defined standards, a value of 0.9 is the generally accepted cutoff point for reliable analysis of necessity[67] and 0.8 for sufficiency[68]. Coverage, by contrast, measures how well a subset condition explains an outcome, again with values ranging from 0 to 1. A highly consistent condition with low coverage has low empirical importance. Consistency is related to predictability and somewhat analogous to a correlation coefficient, whereas coverage is related to relevance and somewhat analogous to an R^2 value, although the QCA community cautions against such comparisons.

Following ref. 38, we first undertook an analysis of the necessity of each individual condition (Table 3 and Tables 3 and 4 of Supplementary Section 2). We tested for both the presence and absence of each condition in explaining cases with more positive livelihood outcomes and, as a robustness check, also tested for more negative livelihood outcomes. Since no conditions were necessary for either positive or negative outcomes, we followed standard practice and next analysed the sufficiency of combinations of conditions.

To analyse sufficiency, we used fs/QCA software to generate a 'truth table' of all possible combinations of causal conditions (Table 5 of Supplementary Section 2). Each row represents a possible combination of conditions; since our analysis has five conditions, there are 2^5 or 32 possible rows. Each case is assigned to its corresponding row, while some rows are not represented by real cases and are called 'logical remainders'. The higher the number of conditions included in an analysis, the higher the number of rows and therefore also logical remainders. Analyses with many conditions and few cases face

challenges with limited diversity and validity of results, making the ideal ratio four to five conditions for 12–16 cases, as in our analysis[69]. Following a procedure known as minimization, which is the logical simplification of set relations among conditions and the outcome, the truth table rows are assessed for sufficient combinations of conditions.

The fsQCA software generates three types of solutions (complex, parsimonious and intermediate) representing different treatments of remainders as counterfactuals; see Table 6 of Supplementary Section 2. We follow commonly accepted practice[68] and focus on the intermediate solution based on theoretically informed assumptions about the connections between the presence or absence of conditions and the outcome. In this analysis, the intermediate solution assumes that the presence of community engagement and absence of distance are associated with better outcomes and gives preference to these factors when there were tied prime implicants but no assumptions are made for speed, scale or transfer dynamics given the absence of consensus in the theoretical literature.

Robustness tests. Next, we conducted a series of robustness tests, including changes in consistency thresholds, calibration approaches and removal of cases[41,70]. Given that this analysis includes 14 cases, we only considered a frequency threshold of one case per row[68]. We also undertook additional robustness tests with differing approaches to calibration of the outcome condition. In the primary analysis, we used the unweighted mean to provide a holistic measure of outcomes across all six SLA+ categories. However, recognizing that this averaging approach may lessen the influence of extremes and has the tendency to bring cases to the 0.5 threshold score, we also considered alternative weighting approaches through robustness tests. We considered: (1) all minimum outcomes (cases calibrated to the lowest score of the six SLA+ categories), (2) all maximum outcomes (each case calibrated to the highest score of the six SLA+ categories) and (3) a combination of minimum and maximum outcomes (cases with on average negative outcomes calibrated to the lowest score, while cases with on average positive outcomes calibrated to the highest score). Table 7 of Supplementary Section 2 includes results of all robustness tests.

Case verification. Finally, we examined each pathway to ascertain if it challenges or refines existing insights from individual cases and broader literature. We qualitatively compared across case studies to better understand these pathways and identify future research directions.

Limitations. Our analysis is limited by the availability of data in documents summarizing these relocation cases. Our coding is designed to capture information about outcomes and planning decisions in these documents, which may be distorted by biases of the authors and entities that published the studies and by pernicious or misleading socioeconomic forces such as colonialism.

There are also challenges arising from the heterogeneity of sources, including the range of years of case completion and document publication. Each publication reflects circumstances at the time when each was written, which vary by document and may not reflect the status of the case at present. Thus, the passage of time is a compounding factor, as the assessment of outcomes may vary widely depending on whether the assessment in each document took place one year or one decade after the completion of the physical move. Supplementary Section 1 includes a table with dates of each publication considered per case to capture this variation. To ameliorate biases, future research efforts should monitor and evaluate relocation outcomes longitudinally over time.

Additionally, the measurement of each construct has limitations and results should be interpreted accordingly. For example, we measured speed as the duration of time between initiation and the physical move of most people but this fails to capture how the construction of physical infrastructure and services may have lagged behind or proceeded the movement of people. Similarly, we measured scale as number of households but other proxies for this construct could be the spatial size of the lots and homes. Additionally, the way factors such as speed and distance are perceived varies across cultural contexts—what is considered 'slow' in Australia may be considered 'fast' in Vanuatu, for example. Future research considering alternative measurements for each construct is needed.

Further, our analysis is limited by the focus on the community scale; relocating communities are not homogenous and both relocation planning decisions and outcomes may vary for people of different ages, genders, abilities, relationship to land, status as renters or owners and status as long-term residents or newcomers, among other axes of diversity[11,28,71,72]. Further research is needed to better understand relocation outcomes for individuals with differing intersectional identities.

Finally, we acknowledge that there are limitations to the types of insights generated from the analysis of a medium sample of 14 cases, from relying on search engines for document identification, from using fsQCA for a configurational meta-analysis and from our scoring approaches. Additional research methods, including both larger sample statistical meta-analyses and in-depth single case studies, are needed to verify and extend these findings about pathways towards more sustainable livelihood outcomes in planned relocations.

Data availability

The authors declare that the data supporting the findings of this study are available within the paper and its Supplementary Information.

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E.R.B. conceived the research, through discussions with C.B.F. and G.W.-P. E.R.B. and A.B. collected and analysed the data. E.R.B. wrote the paper with inputs from G.W.-P. and C.B.F.

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