Empowering citizen-led adaptation to systemic climate change risks

Oliver, T. H. ORCID: https://orcid.org/0000-0002-4169-7313, Bazaanah, P., Da Costa, J., Deka, N., Dornelles, A. Z., Greenwell, M. P. ORCID: https://orcid.org/0000-0001-5406-6222, Nagarajan, M., Narasimhan, K., Obuobie, E., Osei, M. A. and Gilbert, N. (2023) Empowering citizen-led adaptation to systemic climate change risks. Nature Climate Change, 13. pp. 671-678. ISSN 1758-6798 doi: 10.1038/s41558-023-01712-6
Available at https://centaur.reading.ac.uk/112301/

Empowering citizen-led adaptation to systemic climate change risks

Tom H. Oliver[1]*, Prosper Bazaanah[2], Jeff Da Costa[1], Nabajyoti Deka[3,4], Andre Z. Dornelles[1], Matthew P. Greenwell[1], Magesh Nagarajan[4], Kavin Narasimhan[5], Emmanuel Obuobie[2], Marian A. Osei[2], Nigel Gilbert[5]

[1] *School of Biological Sciences, Whiteknights campus, University of Reading, RG6 6AS, UK*

[2] *CSIR-Water Research Institute, Ghana*

[3]*Faculty of Management Studies, Delhi University*

[4] *Indian Institute of Management, Nagpur, India*

[5] *Department of Sociology, University of Surrey, Guildford GU2 7XH, UK*

**Corresponding author details: Prof. Tom H. Oliver, email: t.oliver@reading.ac.uk ; Tel: +44 7704107925*

Abstract

The increasing impacts of climate change instigate the need for adaptation. However, most adaptation initiatives focus on actions by government or businesses, despite growing calls for communities on the frontline of climate risks to be involved in planning and selecting strategies. Here, we appraise a pilot process using participatory systems mapping with citizens to identify 1) diverse threat vectors for local climate impacts and 2) context-relevant interventions to protect households and communities while 3) considering synergies and tradeoffs with other socially desirable outcomes. We tested the pilot process in communities in the lower Volta Basin in Ghana, the Assam region in India, and Southern England. From participants' perspectives, the process increased awareness of- and preparedness for climate change impacts and raised essential learning points for upscaling citizen-led adaptation approaches. These include understanding multiple outcomes of interventions, barriers, and enablers to implementation, and sensitivity of co-design to regional geography and socio-cultural context.

In the face of major current and ongoing climate impacts, there is increased recognition of the need for urgent adaptation planning [1,2]. The overwhelming majority of global tracked climate finance is still targeted to mitigation over adaptation, yet there is an increasing shift in science-policy focus towards adaptation, with a view to assisting communities cope with inevitable climate impacts [2]. Yet, most planned climate change adaptation initiatives, such as from the UN Sendai Disaster Risk Reduction Framework and the UK Climate Change Risk Assessment, lead to actions by national government and local government [3]. There is also action focused at the private-sector level [4], but few well-coordinated initiatives facilitating direct action from individual citizens, despite fragmented autonomous actions at this level.

'Systemic' risks (i.e. cascading risks across socio-ecological systems influenced by political, economic, social, and technological context)[5], are exacerbated by climate change. It has been recommended to move beyond 'top-down' objective risk assessment approaches and involve key stakeholders, including citizens from communities that will be impacted by such risks [6-8]. Citizen-led approaches (sometimes termed 'community-based' approaches; albeit often needing 'top-down' facilitation) enable local people, especially those most vulnerable to climate impacts, to determine the objectives and means of adaptation practices[9,10]. Empowering citizens to develop adaptation strategies can give them personal agency to protect themselves and their communities, representing an essential route to reducing climate change impacts on health and prosperity [8,11]. Engagement with the knowledge-base around climate change impacts increases the salience of climate change risks and may also prompt a more active role in citizenship, for example pressuring governments into action (i.e. catalysing stronger institutional adaptation)[12]. Despite this, current advice on adaptation to climate change for local communities is sparse, and rarely involves participatory approaches with citizens co-producing their own adaptation plans well-informed by up-to-date evidence [8,10,13,14].

In terms of assessing local impacts, there are an increasing number of approaches aiming to improve capacity to measure exposure on finer scales, e.g. high resolution modelling [15,16]. Yet, assessing vulnerability needs to go beyond biophysical data to include social and demographic data [17,18]. In addition to direct impacts from climate change such as flooding and heatwaves, there are a number of indirect threat vectors from climate change (e.g. food and energy insecurity) that create major impacts [19]. Most quantitative modelling currently has limited capacity to assess these cascading systemic risks [20,21].

Developing a more systemic risk assessment of climate impacts, co-developed with citizens– helping them identify appropriate adaptation actions they can take, is the aim of a project called 'EMPOWER' [22]. Here, our objective is to critically appraise this inclusive adaptation planning process, which uses participatory systems mapping with local citizens to identify the diverse context-dependent threat vectors for climate change impacts. This is followed by identifying interventions to protect citizens, their households and communities from the consequences of climate change (Fig. 1). We trialled this process in three very different geographical, social and political contexts: the lower Volta Basin in Ghana, the Assam region in India (three villages in Majuli Island- the world's largest inhabited river Island), and Southern England (Reading, Oxford and Wallingford). Participants in the UK volunteered in response to information cascaded through local civil society groups involved in climate/environment action, and were selected to balance age and gender and location. In Ghana and India, participants were recruited by direct visits to villages, with selection based on age, gender, occupation, and income (see *Methods*).

The overall project had four specific objectives: 1) pilot a new participatory approach to co-develop adaptation strategies with citizens, aiming to empower them to protect themselves from direct and indirect effects of climate change; 2) draw on multiple perspectives to analyse climate change adaptation options in light of their feasibility, along with ethical considerations, identifying who are the key actors to engage with and when, and assessing complementarity

across interventions, i.e. by taking a 'systems thinking' approach; 3) reconcile adaptation options with multiple desired outcomes over the longer term (e.g. environmental protection, livelihoods and community development), 4) draw lessons from the methodological development carried out in different regional contexts. In this article, we demonstrate the results of the process and identify learning points for upscaling citizen-led adaptation approaches[10].

We present here aspects relevant to the critical appraisal of the EMPOWER pilot process, with results selected from across the three case studies that exemplify these, namely: i) context dependency of climate impacts and adaptation, ii) constraints on the uptake of climate change adaptation interventions, iii) multifunctionality of interventions, and iv) effectiveness in increasing climate change impact awareness and preparedness.

Climate Impacts and Adaptation in local context

The case studies across three countries identified different threats from climate change, as expected given their different geographic, socioeconomic and socio-cultural contexts (further information in Extended Data Fig. 1). Participatory systems maps for all case studies can be found in Table S1. Communities in the Lower Volta Region of Ghana face climate threats including bush fires, drought, flooding, coastal erosion, sea level rise, salt water intrusion and invasive alien species (Table S2). Villages on Majuli Island in Assam region of India also face major challenges from flooding and erosion impacting housing and vulnerable subsistence agriculture close to the Brahmaputra river, along with additional impacts on pottery and boatmaking livelihoods (Fig. 2). Urban areas in Southern England face direct threats such as flooding and heat stress, though there was a greater focus in the workshops on indirect threats such as food and energy supply disruption. The scales of context-dependence differed between our case study regions, with climate impacts broadly similar between the three English

towns/cities, yet with fine-scale context dependence based on the location of participants' homes (for example, whether they were in a street prone to flooding). In contrast, the three villages in the Majuli Island, India, showed quite different overall hazards and vulnerabilities in relation to the different sources of livelihood (Fig. 2). As such, the most appropriate climate change adaptations (and their constraints), differed between the three villages, despite their close proximity. For example, in Banoria chapori, agriculture and livestock rearing are major occupations and these are threatened by climate change due to soil erosion and declines in soil quality from inundation with sand from Brahmaputra river flooding. Villagers are adapting by focusing on livestock rearing, seeking to understand the most appropriate climate-resilient practices and how to access government support. In Salmora, in contrast, the main income traditionally comes from pottery-making and boat-making. River meandering and flooding has reduced availability of soil for pottery making, while government bans on deforestation to conserve forests means lower availability of Azhar trees, whose timber is specifically required for boat-making (a case where national climate mitigation conflicts with local livelihoods). As a consequence, villagers are trying to adapt by finding alternative sources of income such as farming, fishing, livestock rearing, weaving and producing handicraft items.

Constraints and multifunctionality of adaptations

Many participants were already actively adapting to climate change[23] and our second workshop provided an opportunity to share the interventions they were pursuing and how they achieved them (full list of interventions across case studies in Table S3). For example, citizens already had in place actions related to flood-resistant agricultural practices in the Indian villages of Kulamua chapori and Salmora, while in Banoria chapori villagers had stilt houses and rescue boats. In the Lower Volta Basin in Ghana, existing measures included farmland irrigation, tree planting (both to reduce temperatures and for windbreaks), decongesting waterways (by

removal of aquatic weeds and reducing waste dumping), and building seawalls using sandbags. In the UK, measures with wide uptake included lobbying local government for flood protection measures, storing food and reducing dependency on the national energy grid and supermarkets (Fig. 3).

In all case studies, there were also interventions that were recognised as important but not being fully pursued. In the second workshop, we explored the specific constraints faced by participants. These included cost, time, knowledge and skills, although in some cases interventions not pursued as they were deemed not relevant, for example if the participant perceived themselves to reside in a low flood risk zone. The constraints differed by type of intervention; for example, in the UK, the main reasons for not implementing off-grid energy generation to avoid energy supply disruption and price-spikes, were land- and building-ownership and financial costs [24] (Fig. 3). After deliberation within groups, participants developed their own 'personal adaptation plan' identifying which specific interventions they intended to pursue, how they might achieve them and the expected timeframe (see *Methods*, and Box S1 for an example of one of these plans).

Before the second workshop, the project team reviewed the interventions identified in the participatory systems mapping and collated background evidence of potential co-benefits and trade-offs; for example, in terms of impacts on biodiversity, health, social cohesion and other socially desirable objectives. The participants discussed and extended this analysis in the second workshop (e.g. Fig. 4 for adaptations to reduce flooding in Ghana). Importantly, some of these identified trade-offs and synergies featured in participant decisions on whether to personally pursue an intervention (i.e. as part of their 'personal adaptation plan' also developed in the second workshop).

Increasing climate impact awareness and preparedness

The project evidenced some success in terms of increasing awareness and (self-reported) preparedness for climate change. Before the workshop, when participants were asked if they felt aware of the impacts of climate change on themselves, their households and communities the number agreeing or strongly agreeing was 75% in Ghana (n = 20 respondents), 83% India (n = 29) and 70% in the UK (n = 20). After the workshop, these proportions increased to 100% in Ghana (n = 15), 95% India (n = 18) and 86% in the UK (n = 14; Fig. 5). An additional question to the UK participants asking directly whether they felt engaging in the project had improved their understanding of climate change impacts resulted in 86% agreeing (n = 14; Extended Data Fig. 2) and a similar question to Ghanaian participants resulted in 100% agreeing (n = 21; Table S4).

In terms of perceptions of preparedness for the impacts of climate change, before the workshops the number of participants agreeing or strongly agreeing they felt prepared was 75% in Ghana (n = 20 respondents), 79% India (n= 29) and 0% in the UK (n = 20). After the workshop, these proportions increased to 100% in Ghana (n = 15), 83% India (n = 18) and 43% in the UK (n = 14; Fig. 5). An additional question to UK participants revealed that 79% agreed that the project had helped them make plans for climate change adaptation (Extended Data Fig. 2). Additional questions to Ghanaian participants found that 96% of them found the methodology and recommendations useful for their work (n = 24; see Table S4 and Supplementary Discussion for example testimonials).

Discussion

To assist vulnerable communities in determining climate adaptation practices [6-11,13] this study used participatory systems mapping with citizens to identify diverse threat vectors from climate change across three countries. Our approach differs from other participatory approaches, such as those specifically targeted to informing climate-resilient farming [e.g. 25] or using scenario

building [e.g. 26] (see Supplementary Discussion). Participants co-developed climate adaptation actions, by identifying interventions within a group and then selecting those they felt most appropriate to pursue individually, to protect themselves, their households and communities from context-dependent climate change impacts. Here, we discuss key considerations for the potential upscaling of such citizen-led adaptation planning, particularly in terms of implementation constraints, understanding multiple outcomes and how to target the facilitation of such initiatives, especially in light of context-dependent sensitivities.

Knowledge and skills deficits were highlighted as an important constraint for climate adaptation, as found in other studies [27,28], and here particularly in terms of a perceived need for training to implement particular interventions (e.g. prevention of livestock diseases in Kulamua and Banoria Chapori in India). Improving knowledge and skills, of course, does not always necessarily lead to action, and 'value-action gaps' are commonly identified for pro-environmental/pro-social behaviours [29] including climate change mitigation [30,31]. Other constraints also exist such as psychological barriers, e.g. sunk costs into unsustainable practices and the perceived risks of change [32], as well as economic constraints [e.g. 33]. The participatory approach piloted here might be expected to help overcome some of these issues, for example by citizens sharing with peers their experiences on how they already personally implemented certain adaptation actions [34]. This shares information on cost-effective implementation and potentially builds motivation to overcome psychological barriers. To enable agency and help the translation of intentions into action, we also facilitated citizens to identify local climate change threats and appropriate interventions themselves, and provided technical assistance to enable them to be as clear, specific and coherent as possible with regards to the steps to achieve these (including anticipating barriers that might need to be overcome). Our process led to an increased sense of awareness and preparedness of climate change impacts (Figure 5). We note, importantly however, that we only evaluated the intentions for interventions,

and follow up work is needed to assess final implementation, as well as collating further learning on the practical challenges and successes experienced by participants (see Supplementary Discussion).

In line with other studies attempting to understand the barriers to effective climate adaptation [13,14,27,35], we also found a lack of capacity for local facilitation (e.g. by NGOs or local government) as a significant constraint. Other constraints included ownership of housing or land, and control over more systemic issues such as food and energy supply. All these reinforce the need for complementarity between citizen-led and 'top-down' (e.g. state-led) approaches [8,17,36,37]. Rather than encouraging citizens to 'pass the buck' to other actors, we suggested interventions be framed in ways that were actionable for them. So, for example, if an intervention required action from national government (e.g. putting in place flood defenses), then we encouraged identification of specific actions that citizens could take, such as communications and campaigning, to prompt action from other actors. Nonetheless, the project clearly supported the view [13,14,35] that 'bottom-up' action by citizens alone is insufficient and there is a need for increased facilitation, training and funding for certain interventions that require a more structural 'top-down' approach, e.g. by local and national government.

The adaptation plans that citizens made in our project were influenced by considering synergies and trade-offs with other socially desirable outcomes. Interventions were analysed in terms of their multifunctionality (e.g., how they help reduce risks from other threats and/or provide general benefits) as well as trade-offs[38]. Some constraints on interventions were related to trade-offs with climate change mitigation, for example procuring air conditioning units for houses was mostly perceived as a non-viable intervention due to their high energy usage. Another example was developing local energy supplies isolated from national grids and how this may be less efficient because it would require more material use, and so is problematic from a

broader sustainability perspective. There have been several high-level analyses of trade-offs and synergies between sustainability goals [2], and we argue here that such analyses could greatly benefit from being conducted at the level of individual interventions adopted by citizens. The consideration of multiple outcomes is a key element of taking a 'systems thinking approach' to problem solving [39], and valuable to apply to climate change adaptation planning. Another element of systems thinking is the consideration of different values and perspectives of multiple types of stakeholders. More inclusive approaches allow consideration of fairness and equity to be brought to the fore, such as the extent to which certain sectors of the population may not have capacity to put actions in place [34]. Furthermore, it is important to consider interventions in a holistic way; for example, whether multiple interventions need to be put in place to work together, and if there is a specific ordering required. We recommend that such systems-thinking approaches be incorporated into the design of citizen-led climate change adaptation initiatives (e.g. of the kind that could be facilitated by local or national governments [40] or international bodies like the UN).

The targeting of citizen-led adaptation initiatives is also of paramount importance, given that engaging whole populations of citizens may be prohibitive in terms of costs. Our project did not aim for a representative mix of citizens due to time constraints, though this could be done through sortition processes [41]. In targeting a representative subset of the population, the hope might be that knowledge, competencies, motivation and benefits gained in the process spill over to others; for example, through sharing of insights between family members, friends and colleagues, or by participants subsequently directly helping vulnerable neighbours. An alternative approach to sortition is to preferentially target vulnerable populations [42], such as those in flood risk zones or with homes susceptible to heat shock. This may also include stratification by vulnerable demographics such as the elderly and those in poverty; for example combining hydrological modelling of household flood risk [43] with thermal image analysis of heat

extremes[44], intersected with sociodemographic data. This would help address the fact that the largest adaptation gaps exist among lower income population groups [2]. Note, many in these population subsets may also experience (economic and social) impediments to participation and are less likely to volunteer, thus pro-active approaches such as door-to-door campaigning, with tailored communication to build trust and respect, and appropriate financial support, may be required.

Any methodology might also need to be adjusted according to participants awareness and scepticism about climate change, i.e. the process of operationalising climate change adaptation goes beyond facilitating identification of threats and interventions, it demands additional prior steps to recognise climate change as a problem, to then build motivation and engagement. Hence, although we trialled our methodology in three countries, generalisation to further demographics and contexts may entail appropriate refinement. General shortfalls of participatory processes (e.g. time and cost commitments, susceptibility to advocacy from facilitating researchers, ensuring equality of voice to all stakeholders etc.) also need careful consideration in terms of expanding such approaches more widely (Supplementary Discussion).

Finally, any attempt to ‘scale up’ citizen-led adaptation protocols should be aware of context-dependent sensitivities. Our project revealed different needs with regards to i) use of technology (online workshops versus in-person) depending on local infrastructure and capacity, ii) language and translation requirements, iii) gender issues (Extended Data Fig. 1; India report), and iv) acknowledgement of strong context-dependency of climate change threats within countries.

In conclusion, we identify at least three essential dimensions to improve the feasibility of scaling-up adaptation actions to climate change: 1) synergy between top-down knowledge provision, coordination and financial support, with agency by citizens to identify and overcome barriers to effective community-based adaptation, 2) integration with systems-thinking approaches to understand synergies and trade-offs associated with interventions, including the

sharing of learning amongst peers, and, 3) facilitation that is sensitive to regional geography and socio-cultural context, enabling appropriate understanding of specific climate threats and interventions while building mutual trust and respect.

Acknowledgements

We thank all the dedicated participants involved in the workshops across the three countries. The project was funded by a UKRI UK-India partnership (Ref: 2021COPA&R13Oliver).

Author Contributions

T.H.O, N.G., M.N., and E.O. led the study design and planning with inputs from P.B., J.D.C., N.D., A.Z.D., M.P.G., K.N., and M.A.O. All co-authors participated in the workshops using participatory systems mapping and subsequently contributed to the article writing and review

Competing Interests

The authors declare no competing interests

Figure Legends/Captions

Fig. 1, Summary of the standardized elements of the EMPOWER project [22] process. For more details see Methods. The bottom boxes show the conceptual framework used to develop participatory systems maps

for each case study working group.

Fig. 2, Locations and characteristics of the three case study villages in the Assam region of North East India. Despite their proximity the three villages face different hazards and vulnerabilities to climate change. The map was generated using QGIS software using image layer source Google Maps.

Fig. 3, UK participant intentions to pursue climate adaptation interventions. From 24 participants in total, the chosen interventions are categorised by a) general, b) housing, c) food, d) energy. Doughnut charts show examples of the reasons people choose not to pursue four specific interventions.

Fig. 4, Examples of the various co-benefits and trade-offs of interventions to reduce flooding as identified by the 24 Ghanaian participants.

Fig. 5, Responses from before-and-after-project surveys for three case studies. The survey evaluates participants' self-reported awareness (panels A-C) and level of preparedness (D-F) for climate change impacts. Total participant numbers are 24, 29 and 24 for Ghana, India and UK respectively, with numbers providing specific responses shown within each bar.

References

1 Demski, C., Capstick, S., Pidgeon, N., Sposato, R. G. & Spence, A. Experience of extreme weather affects climate change mitigation and adaptation responses. *Climatic Change* **140**, 149-164, doi:10.1007/s10584-016-1837-4 (2017).

2 IPCC. IPCC Sixth Assessment Report: Climate Change 2022: Impacts, Adaptation and Vulnerability https://www.ipcc.ch/report/ar6/wg2/. (2022).

3 Warren, R. F. *et al.* Advancing national climate change risk assessment to deliver national adaptation plans. *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences* **376**, 20170295, doi:doi:10.1098/rsta.2017.0295 (2018).

4 UN Global Compact and UN Environment Programme. Business and Climate Change Adaptation: Toward Resilient Companies and Communities https://www.iccr.org/sites/default/files/resources_attachments/businessandclimatechangeadaptation.pdf. (2012).

5 Sillmann, J. *et al.* ISC-UNDRR-RISK KAN Briefing note on systemic risk, Paris, France, International Science Council, https://doi.org/10.24948/2022.01. (2022).

6 IRGC. International Risk Governance Council. IGRC Guidelines for Emerging Risk Governance. https://irgc.org/publications/core-concepts-of-risk-governance/. (2015).

7 Eriksen, S. *et al.* Adaptation interventions and their effect on vulnerability in developing countries: Help, hindrance or irrelevance? *World Development* **141**, 105383, doi:https://doi.org/10.1016/j.worlddev.2020.105383 (2021).

8 Pisor, A. C. *et al.* Effective climate change adaptation means supporting community autonomy. *Nat. Clim. Chng.* **12**, 213-215, doi:10.1038/s41558-022-01303-x (2022).

9 Ampaire, E. L. *et al.* Institutional challenges to climate change adaptation: A case study on policy action gaps in Uganda. *Environmental Science & Policy* **75**, 81-90, doi:https://doi.org/10.1016/j.envsci.2017.05.013 (2017).

10 Forsyth, T. Community-based adaptation: a review of past and future challenges. *WIREs Climate Change* **4**, 439-446, doi:https://doi.org/10.1002/wcc.231 (2013).

11 Woroniecki, S. Enabling Environments? Examining Social Co-Benefits of Ecosystem-Based Adaptation to Climate Change in Sri Lanka. *Sustainability* **11**, 772 (2019).

12 Nared, J. & Bole, D. *Participatory research and planning in practice*. (Springer Nature, 2020).

13 Moser, S. C. & Ekstrom, J. A. A framework to diagnose barriers to climate change adaptation. *PNAS* **107**, 22026-22031, doi:doi:10.1073/pnas.1007887107 (2010).

14 Eisenack, K. *et al.* Explaining and overcoming barriers to climate change adaptation. *Nat. Clim. Chng.* **4**, 867-872, doi:10.1038/nclimate2350 (2014).

15 Bhave, A. G., Mishra, A. & Raghuwanshi, N. S. A combined bottom-up and top-down approach for assessment of climate change adaptation options. *Journal of Hydrology* **518**, 150-161, doi:https://doi.org/10.1016/j.jhydrol.2013.08.039 (2014).

16 Travis, W. R., Smith, J. B. & Yohe, G. W. Moving toward 1.5°C of warming: implications for climate adaptation strategies. *Curr. Opin. Env. Sust.* **31**, 146-152, doi:https://doi.org/10.1016/j.cosust.2018.03.003 (2018).

17 Conway, D. *et al.* The need for bottom-up assessments of climate risks and adaptation in climate-sensitive regions. *Nat. Clim. Chng.* **9**, 503-511, doi:10.1038/s41558-019-0502-0 (2019).

18 Araos, M. *et al.* Equity in human adaptation-related responses: A systematic global review. *One Earth* **4**, 1454-1467, doi:10.1016/j.oneear.2021.09.001 (2021).

19 Chatham House. Climate change risk assessment 2021 https://www.chathamhouse.org/2021/09/climate-change-risk-assessment-2021/04-cascading-systemic-risks. (2021).
20 International Science Council. Systemic Risk Briefing Note by International Science Council, United Nations Office for Disaster Risk Reduction and Risk-KAN working groups https://www.undrr.org/publication/briefing-note-systemic-risk. (2022).
21 Arribas, A. *et al.* Climate risk assessment needs urgent improvement. *Nature Communications* **13**, 4326, doi:10.1038/s41467-022-31979-w (2022).
22 EMPOWER project. https://www.empower-project.org/ (accessed 5th May). (2023).
23 Berrang-Ford, L. *et al.* A systematic global stocktake of evidence on human adaptation to climate change. *Nat. Clim. Chng.* **11**, 989-1000, doi:10.1038/s41558-021-01170-y (2021).
24 Moritz, M. *et al.* Emergent sustainability in open property regimes. *PNAS* **115**, 12859-12867, doi:doi:10.1073/pnas.1812028115 (2018).
25 Clarkson, G. *et al.* Stimulating small-scale farmer innovation and adaptation with Participatory Integrated Climate Services for Agriculture (PICSA): Lessons from successful implementation in Africa, Latin America, the Caribbean and South Asia. *Climate Services* **26**, 100298, doi:https://doi.org/10.1016/j.cliser.2022.100298 (2022).
26 Schmitt Olabisi, L. *et al.* Scenario Planning for Climate Adaptation in Agricultural Systems. *Agriculture* **10**, 274 (2020).
27 Piggott-McKellar, A. E., McNamara, K. E., Nunn, P. D. & Watson, J. E. M. What are the barriers to successful community-based climate change adaptation? A review of grey literature. *Local Environment* **24**, 374-390, doi:10.1080/13549839.2019.1580688 (2019).
28 Clar, C., Prutsch, A. & Steurer, R. Barriers and guidelines for public policies on climate change adaptation: A missed opportunity of scientific knowledge-brokerage. *Natural Resources Forum* **37**, 1-18, doi:https://doi.org/10.1111/1477-8947.12013 (2013).
29 Barr, S. Environmental Action in the Home: Investigating the 'Value-Action' Gap. *Geography* **91**, 43-54, doi:10.1080/00167487.2006.12094149 (2006).
30 Gifford, R. D. & Chen, A. K. S. Why aren't we taking action? Psychological barriers to climate-positive food choices. *Climatic Change* **140**, 165-178, doi:10.1007/s10584-016-1830-y (2017).
31 Whitmarsh, L., Seyfang, G. & O'Neill, S. Public engagement with carbon and climate change: To what extent is the public 'carbon capable'? *Global Environmental Change* **21**, 56-65, doi:https://doi.org/10.1016/j.gloenvcha.2010.07.011 (2011).
32 Gifford, R. The dragons of inaction: Psychological barriers that limit climate change mitigation and adaptation. *American Psychologist* **66**, 290-302 (2011).
33 Antwi-Agyei, P., Dougill, A. J. & Stringer, L. C. Barriers to climate change adaptation in sub-Saharan Africa: evidence from northeast Ghana & systematic literature review. (2013).
34 Owen, G. What makes climate change adaptation effective? A systematic review of the literature. *Global Environmental Change* **62**, 102071, doi:https://doi.org/10.1016/j.gloenvcha.2020.102071 (2020).
35 McGonigle, D. F. *et al.* A Knowledge Brokering Framework for Integrated Landscape Management. *Frontiers in Sustainable Food Systems* **4**, doi:10.3389/fsufs.2020.00013 (2020).
36 Kirkby, P., Williams, C. & Huq, S. Community-based adaptation (CBA): adding conceptual clarity to the approach, and establishing its principles and challenges. *Climate and Development* **10**, 577-589, doi:10.1080/17565529.2017.1372265 (2018).
37 Butler, J. R. A. *et al.* Integrating Top-Down and Bottom-Up Adaptation Planning to Build Adaptive Capacity: A Structured Learning Approach. *Coastal Management* **43**, 346-364, doi:10.1080/08920753.2015.1046802 (2015).

38 Torhan, S. *et al.* Tradeoffs and Synergies Across Global Climate Change Adaptations in the Food-Energy-Water Nexus. *Earth's Future* **10**, e2021EF002201, doi:https://doi.org/10.1029/2021EF002201 (2022).
39 Oliver, T. H. *et al.* Knowledge architecture for the wise governance of sustainability transitions. *Environmental Science & Policy* **126**, 152-163, doi:https://doi.org/10.1016/j.envsci.2021.09.025 (2021).
40 Mees, H. L. P., Uittenbroek, C. J., Hegger, D. L. T. & Driessen, P. P. J. From citizen participation to government participation: An exploration of the roles of local governments in community initiatives for climate change adaptation in the Netherlands. *Environmental Policy and Governance* **29**, 198-208, doi:https://doi.org/10.1002/eet.1847 (2019).
41 Mulvad, A. M. & Popp-Madsen, B. A. Sortition-infused democracy: Empowering citizens in the age of climate emergency. *Thesis Eleven* **167**, 77-98, doi:10.1177/07255136211056997 (2021).
42 Sullivan, C. & Meigh, J. Targeting attention on local vulnerabilities using an integrated index approach: the example of the climate vulnerability index. *Water Science and Technology* **51**, 69-78, doi:10.2166/wst.2005.0111 (2005).
43 Hossain, M. K. & Meng, Q. A fine-scale spatial analytics of the assessment and mapping of buildings and population at different risk levels of urban flood. *Land Use Policy* **99**, 104829, doi:https://doi.org/10.1016/j.landusepol.2020.104829 (2020).
44 Lee, S., Moon, H., Choi, Y. & Yoon, D. K. Analyzing Thermal Characteristics of Urban Streets Using a Thermal Imaging Camera: A Case Study on Commercial Streets in Seoul, Korea. *Sustainability* **10**, 519 (2018).
45 Participatory System Mapper. https://prsm.uk (accessed 8 May). (2023).
46 Makondo, C. C. & Thomas, D. S. G. Climate change adaptation: Linking indigenous knowledge with western science for effective adaptation. *Environmental Science & Policy* **88**, 83-91, doi:https://doi.org/10.1016/j.envsci.2018.06.014 (2018).
47 Harrington, L. J., Frame, D., King, A. D. & Otto, F. E. L. How Uneven Are Changes to Impact-Relevant Climate Hazards in a 1.5 °C World and Beyond? *Geophysical Research Letters* **45**, 6672-6680, doi:https://doi.org/10.1029/2018GL078888 (2018).
48 Behnassi, M. & El Haiba, M. Implications of the Russia–Ukraine war for global food security. *Nature Human Behaviour* **6**, 754-755, doi:10.1038/s41562-022-01391-x (2022).
49 Benton, T. G., Froggatt, A. & Wellesley, L. The Ukraine war and threats to food and energy security: Cascading risks from rising prices and supply disruptions, Research Paper, London: Royal Institute of International Affairs, https://doi.org/10.55317/9781784135225. (2022).
50 Dayamba, D. S. *et al.* Assessment of the use of Participatory Integrated Climate Services for Agriculture (PICSA) approach by farmers to manage climate risk in Mali and Senegal. *Climate Services* **12**, 27-35, doi:https://doi.org/10.1016/j.cliser.2018.07.003 (2018).
51 Mansbridge, J. J. Time, Emotion, and Inequality: Three Problems of Participatory Groups. *The Journal of Applied Behavioral Science* **9**, 351-368, doi:10.1177/002188637300900217 (1973).
52 David, M. Problems of participation: The limits of action research. *International Journal of Social Research Methodology* **5**, 11-17, doi:10.1080/13645570110098037 (2002).
53 Kamols, N., Foth, M. & Guaralda, M. Beyond engagement theatre: challenging institutional constraints of participatory planning practice. *Australian Planner* **57**, 23-35, doi:10.1080/07293682.2021.1920993 (2021).

Methods

The EMPOWER project used a novel process to investigate the feasibility of climate change adaptation measures from a citizen-led, community-based approach. Climate change risks and potential interventions were framed from the perspectives of individuals, households and communities, and collaborative workshops were carried out aided by facilitators trained in participatory systems mapping. Below is a summary of the standardised elements of the methodology (see Fig. 1 main text) conducted in the project. Across all three case studies there were some bespoke elements where the method was tailored to local context. These are detailed in part below and more information on specific-case study methods can be found in individual country reports (Extended Data Fig. 1). The three case study regions are: the lower Volta Basin in Ghana, the Assam region in India, and Southern England, with trials in different locations in each region. The case study regions were selected so we could pilot the process in three very different geographical, social and political contexts (which are described in each country report; see Extended Data Fig. 1). This helped us understand the degree to which methods need to be locally tailored, and to explore how the outcomes (e.g. the personal adaptation plans) differed contingent on regional and local context.

Selection of participants

For the UK, participants were recruited from the city/towns of Oxford, Reading and Wallingford. These locations were chosen as all three face direct climate-based threats, particularly in the form of flooding due to increased/extreme rainfall as well as indirect threats to food security. In order to recruit participants to the project, a one page flyer for the EMPOWER project, with background information and an online link to express an interest was circulated through academic networks, local civil society groups involved in climate/environment action and local government contacts. Hence, given their self-selection it is likely that our UK participants are more knowledgeable of climate science and motivated for climate change adaptation than the average UK citizen (please see Discussion in main text about representativeness of participants). We sought 12 participants

per location (ten for Oxford), aiming to produce a broadly even distribution of sex and age. There were a few drops outs leading to 24 participants in total (Table S5).

For Ghana, a total of 24 participants were selected from 22 communities distributed across the upstream (9 communities) and downstream (13 communities) areas of the Lower Volta Basin (LVB). The LVB was chosen for this project due to the vulnerability of the citizens to climate change threats such as sea level rise, flooding, coastal erosion and drought, among others. Participants were recruited through the Development Institute, a non-governmental organisation that deals directly with the communities on matters of climate change, with support from the Water Resources Commission, a government agency with mandate to manage water resources in Ghana including the LVB. The participants were drawn from a range of occupations including fishing, farming, teaching, civil servants and business men/women (traders). The selection targeted equal number of males and females and even distribution of ages. However, the actual number of females who participated in the meetings was 7 out of the 12 recruited for the meeting (Table S5). The recruited females who could not attend made arrangements with male community members to take their places at the workshops.

For India, the participants were recruited from three villages: Salmora, Kulamua, and Banoria Chapori in the river island of Majuli. The selection of these villages was based on the extent to which the community members have been vulnerable to the impact of climate change, especially the impact of flood and erosion, as observed during a preliminary field visit and also based on various secondary data sources. Further, these villages display contrast in the extent and nature of the climate change impacts, mostly attributed to local context, which made them a suitable site for this study. For instance, the relative extent of devastation caused by floods in Salmora is more severe than Kulamua village and Banoria Chapori. Given that primary occupations of the community members are different (Fig. 2), the way climate change impacts the livelihood of the community members in the three villages also differs. The selection of participants was conducted

with the help of a local NGO, The Ayang Trust in Majuli, Assam, that was familiar with the socio-economic situation of the villages. A total of 30 participants (10 from each village) was sought (with one drop out, final participant numbers were 29; Table S5), and based on initial briefing by the village leader and the NGO, participants volunteered to be part of the project and the workshop. In selecting from these volunteers, it was ensured that the participant group in each village consisted of individuals with diverse background in terms of age, gender, occupation, and income.

Provision of background information

For the UK, participants received a briefing pack three days before the first workshop, outlining various climate change threats (along both direct and indirect pathways) tailored to the regions of Oxford, Wallingford, and Reading. This document aimed to provide participants with a non-exhaustive, easily accessible summary of systemic risks from climate change and to support them in the upcoming project activities. Hydrometeorological hazards projected to increase in frequency and intensity in the Thames Valley included severe flooding events, increased risk of heatwaves, storms (cyclones, snow, rain, hail), soil erosion and degradation, and combined severe weather events. Indirect climate change impacts with diverse effects across social, economic and environmental systems are relevant to aspects such as agriculture, food security, transport, logistics, etc. The briefing pack also summarised some information about the workshops including their overall aim.

For Ghana, workshops were carried out in-person. No detailed briefing packs were shared with participants ahead of the workshops but an oral summary of the project and the objectives of the workshops were provided to participants at the time of recruitment and prior to the workshop, to enable participants to decide on their participation. Further details on the project's objectives, outputs and outcomes as well as the objectives of the workshops were shared in advance via a

phone call, and also presented to participants at the beginning of the first workshop. In addition, a presentation on climate change threats to the Lower Volta Basin was made to the participants, to provide context to the workshops. Participants had the opportunity to ask questions and received clarifications on climate change issues and regarding the EMPOWER project itself.

For India, the participants were briefed about climate change and its threats in general (e.g., global warming, irregular rainfall, etc.), and about the impact of climate change in Majuli island in particular (e.g., floods, erosion). The briefing was done with the help of images in a paper hand-out and a simultaneous verbal explanation by the facilitator in the local language. Considering the limited literacy rate in the villages, a clear yet detailed description of climate change threats and their impacts was provided to allow the participants to become familiar with the subject matter. For example, while discussing climate change threats and impacts, it was explained how global warming is leading to melting of glaciers in the Himalayan Mountains, which in turn can be associated to more devastating floods in the Brahmaputra Valley. The participants were told that the increased flooding can impact livelihood, agriculture, health, and food security. Finally, the purpose of the project and their role as participants in the workshops were explained.

Workshops

The UK workshops were conducted online, using the Participatory System Mapper software (PRSM [45]), whilst Ghana and India workshops were conducted in-person with outputs later transcribed into the PRSM software. The PRSM software provides a platform to easily draw networks (or 'maps') of systems whilst simultaneously interacting with other individuals. Using PRSM, groups of people, each from their own computer (or tablet), can collaborate in the drawing of a map. They may be sitting around a table, discussing the map as it is created face-to-face, or working remotely, using video conferencing or the chat feature that is built into the application. Groups of people can participate live because every edit (creating nodes and links,

arranging them, annotating them, and so on) is broadcast to all the other participants as the changes are made. PRSM is continually developed and is freely available and open source.

PRSM can help users to identify key factors that affect some focal factor(s) that users care about, and the causal links between these factors. It can be used in slightly different ways depending on the focus of a study: it can focus on the dynamics of a system (e.g., the direction of flows of material/information/energy and feedback loops between factors) or it can emphasise interventions to disrupt flows to the links in the map. As the EMPOWER project primarily focused on the immediate climate change impacts upon citizens and not on complex change over longer time periods (such as how climate change can affect the national economy and then affect livelihoods), we did not emphasise capturing complex feedback loops. Nonetheless, compounding effects of primary threat vectors were explored (e.g., how widespread local flooding and wider transport system disruption might interact to impact housing, food and energy supply). The PRSM software enabled the objectives of the project to be achieved in more practical terms by:

1. Ensuring the inclusion of important climate change threat pathways from evidence review (e.g., climate change models and historic impacts described in the briefing pack).

2. Including local knowledge of participants (e.g., lived experiences of climate change impacts in the studied areas) [46] and the sharing of perspectives on climate change adaptation.

3. Allowing participants to develop ownership in terms of identifying salient threats and selecting interventions, in order to increase agency and motivation.

4. Helping citizens to identify the most important interventions for them, allowing for context dependency in their own situation (e.g., where they work/live, and allowing plurality of values and perspectives).

5. Guiding citizens to develop their own personal adaptation plan, which is both time-bound and specific, to increase the likelihood that actions are completed.

In the first online workshop, participants worked together to explore how the impacts of climate change might play out in their respective local areas. The workshop started with a general introduction to the aims of the project, expected outputs, and relevant information about the three case studies in the UK, Ghana, and India.

In the UK, participants were then invited into virtual breakout rooms by the three towns/cities: Reading, Oxford and Wallingford. In each breakout room, two facilitators from the EMPOWER team introduced an initial participatory systems map, containing a primary factor (health, wellbeing and livelihood of the participant, their household and community) and several supporting factors (housing conditions, working conditions, stable financial income, food and water access).

After a brief tutorial on how to use the PRSM software, participants were asked to add to the map by considering how climate change threats (e.g., heatwaves) would impact the health, wellbeing, and livelihood of themselves, their households, and their community and how this was mediated by supporting factors (e.g., how housing conditions are affected by extreme temperatures; Fig. 1). Further supporting factors were added during the workshops after discussion (these being energy supply, mobility and social cohesion). The background materials provided to participants had outlined various climate change threats tailored to the local regions and, during the workshop, the facilitators prompted participants where necessary to ensure that no important obvious impact pathways for climate change threats (along both direct and indirect pathways) were missing.

In addition to the identification of climate change threats, participants were encouraged to design interventions ('adaptation actions') that they could pursue as actions to reduce the impacts of climate change from an individual and local perspective. Participants discussed climate change threats and interventions with each other using the briefing pack provided as reference and also shared experiences of previous climate-based threats and how they had mitigated the effects of these threats. Quality assurance of data input was ensured by participants having the opportunity to review the maps developed in the PRSM software before and during workshop 2 to ensure they accurately captured their inputs.

Following workshop 1, the EMPOWER project team collated information on the interventions, specifically researching possible trade-offs and synergies to provide background for discussion in workshop 2. In this second workshop, the interventions identified during the first workshop were reviewed aiming to: i) share thoughts and experiences on implementation of interventions, ii) discuss how additional benefits from the implementation of interventions might be gained and trade-offs avoided, iii) detail which interventions participants intend to pursue and why.

In the breakout rooms by town/city, four sessions of approximately 30 minutes each were conducted, organised by the following climate change supporting factors: a) general interventions, b) housing and workplace conditions, c) food and water access and d) energy supply. These were selected as they covered the majority of interventions. There was time for participants to discuss their experiences in terms of how they may have implemented some of these interventions, sharing what worked and what was challenging. This was followed by online surveys organised by supporting factors. The surveys were used to assess participants' intentions to implement interventions based on three main options: 'I already have this intervention in place', 'I plan to do it in the future', and 'I do not plan to do this'. Depending on the answers given, a series of

conditional questions were asked to better understand how, when, and why participants intend or do not intend to pursue interventions. If participants already had interventions in place, we gathered information on agency: ‘it was something I actively organised myself’ or ‘it was already existent’. For plans to carry out interventions in the future, further details on ‘how’ and ‘when’ were asked: ‘within next three months’, ‘within next six months’, ‘by this time next year’, or ‘other’. Answers to the question ‘how’ and the option ‘other’ were collated as free text responses. Finally, if participants indicated that they did not intend to implement interventions, they were asked to select from a series of options as to why not: ‘It is too expensive’, ‘I don't have ownership / rights to do this’, ‘I don't consider it to be relevant or important’, ‘I don't have time to do this’, and/or ‘other reason’. Participants could select multiple options and were encouraged to provide free-text answers in case they selected ‘other reason’. After the workshop, UK participants were sent a ‘personal adaptation plan’ including their responses for the interventions they had shown preference for pursuing, their proposed approach and expected timings.

Workshops in Ghana and India followed a broadly similar approach, albeit being in-person. The main bespoke differences to the methodology above included the following. For Ghana, the three breakout groups for workshop 1 were constituted in a manner that each group had equal number of participants from communities located in the upstream and downstream areas of the Lower Volta Basin. Each of the breakout sessions was followed with a short plenary where a member of each group briefly presented the group’s key outputs to all the participants for discussions. It emerged from the plenary sessions that some climate change threats identified by the participants were specific to the upstream and downstream communities, even though most threats were common. For example, the threats of coastal erosion, sea level rise and saltwater intrusion are specific to communities in the downstream of the LVB as these areas are bounded in the south by the east coast of Ghana. This understanding informed the constitution of the breakout groups in the second workshop. Two groups were formed; an upstream group consisting of participants

from communities located in the upstream areas of the LVB and a downstream group made up of participants from the downstream areas. Follow-up surveys were conducted after each workshop via telephone calls, to obtain participants' feedback on the workshops.

For India, Workshop 1 was conducted in-person in the three villages (Salmora, Banoria Chapori, and Kulamua) separately and in three different sessions. The first workshop began with a general introduction about the EMPOWER project, its objectives, and the expected outcomes. Relevant details, which also included information about the workshops in the UK and Ghana, were also provided to the participants. Subsequently, the workshop procedure was explained to participants, including how the participatory systems mapping would be conducted. An initial Participatory Systems Map written in Assamese (local language), was shown to the participants for ease of understanding and explained verbally. As in the other case studies, this initial map contained a primary factor (health, wellbeing and livelihood of the participant, their household and community) and several supporting factors (housing conditions, working conditions, stable financial income, food and water access). The methodology to conduct the participatory systems mapping exercise included identification of climate change threat factors in the context of Majuli Island, the impact of the factors on the livelihood, health and well-being of the community members, and the inter-connections between the factors. Conscious efforts were made by the facilitator to seek inputs from all the participants. The participants in each of the villages actively took part to identify potential interventions as climate change adaptation measures. The second workshop was conducted in the same villages approximately one month later. The interventions identified in Workshop 1, which were broadly classified under homogenous categories, were explained to the participants. For each of the interventions, the participant's willingness to undertake the intervention including its benefits and trade-offs were captured.

Project evaluation

A standardised set of questions was asked of participants in all three countries, with some additional extra questions for UK and Ghana. The UK case study used online evaluation forms, whereas Ghana and India used hard copy forms. The standard questions, sent before any workshops or briefing information, assessed participants' baseline awareness of- and preparedness for- climate change risks. We used a Likert scale of five possible answers to a statement or question: 'strongly disagree', 'disagree', 'neutral', 'agree', and 'strongly agree'.

Participants responded to two statements:

1. I am aware of the ways in which climate change will impact me and my household.

2. I am prepared for climate change impacts in terms of an action plan to reduce risks.

These questions were repeated after the second workshops. Additional statements for UK participants in the second workshop included :

3. The EMPOWER workshops improved my understanding of the way climate change will impact me and my household.

4. The EMPOWER workshops helped me to make clearer plans for improving my adaptation to climate change impacts.

Finally, two free-text questions with the aim to inform further improvement of the methodology were put to participants:

5. Do you feel that the workshops were valuable? If yes, in what way(s)?

6. Do you have suggestions for improvement or extensions of the EMPOWER project?

Additional evaluation elements for the Ghana case study included questions on the usefulness of the methodology, shared experiences and practices for participants, awareness of climate change impacts and knowledge about climate risk factors and adaptation measures (Table S4).

Human subject research

EMPOWER Participants were not compensated for their time, and we attempted to make the workshops as efficient as possible, e.g. holding workshops within villages to reduce travel costs. Human subjects approval for the survey research was granted by the School of Biological Sciences Ethics Committee at the University of Reading (reference SBS21-21 03). Informed consent was obtained from all research participants. All methods were performed in accordance with the relevant guidelines and regulations.

Data Availability

All data generated or analysed during this study are included in this published article (and its supplementary information files).

Ethics declarations

The authors declare no competing interests. This study has been approved by the School of Biological Sciences Ethics Committee at the University of Reading (reference SBS21-21 03).

Methods-only References

45 Participatory System Mapper. https://prsm.uk (accessed 8 May). (2023).

46 Makondo, C. C. & Thomas, D. S. G. Climate change adaptation: Linking indigenous knowledge with western science for effective adaptation. *Environmental Science & Policy* **88**, 83-91, doi:https://doi.org/10.1016/j.envsci.2018.06.014 (2018).

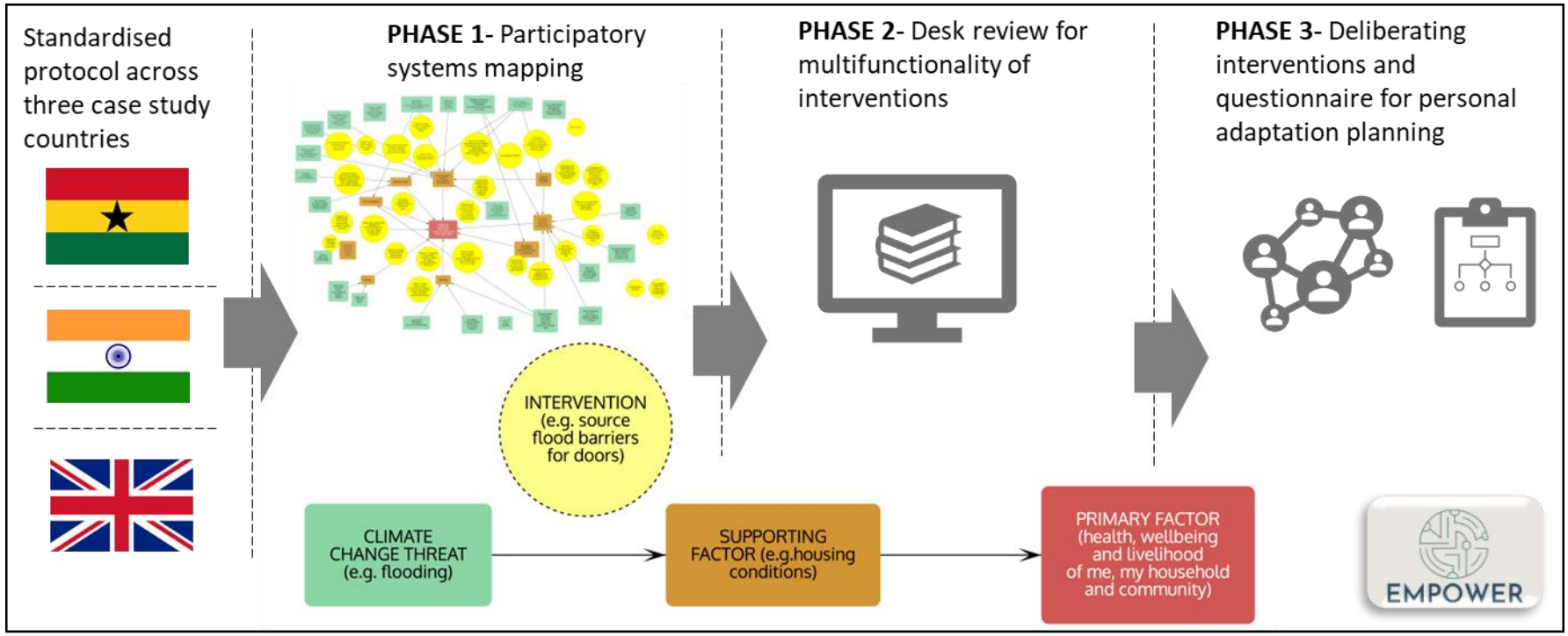
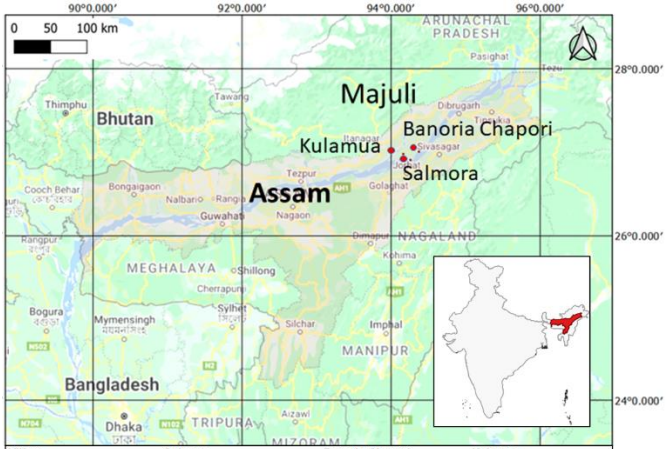


Fig. 1, Summary of the standardized elements of the EMPOWER project [22] process. For more details see Methods. The bottom boxes show the conceptual framework used to develop participatory systems maps for each case study working group.



Village	Salmora	Banoria Chapori	Kulamua
Location and livelihood	A village on the bank of River Bramhaputra, supported by pottery-making, boat-making, carpentry	A village in the bank of River Bramhaputra, supported by agriculture, livestock rearing	A village along the bank of River Kherkutia, supported by agriculture, handloom and craft-making
Key climate change hazards and vulnerabilities	Floods displacing homes, riverbank soil erosion impacting pottery making, reduced availability of Azhar trees for boatmaking, river meandering affecting river access	Sand deposits during flooding impacting soil quality for agriculture, soil erosion from river meandering, change in rainfall pattern affecting crops	Flooding displacing homes and inundating crops, change in rainfall pattern affecting crops, soil erosion affecting agriculture
Existing adaptations	Flood resistant subsistence farming, storing food in locations safe from flooding, tree planting	Increasing height of stilt housing, keeping ropes to make boats from banana tree, tree planting	Stilt housing, cultivating alternative crops based on seasonal changes, gaining knowledge on alternative livelihoods, planting trees
Planned adaptations	Education of young generation for self subsistence, developi enterpreurial skills to market products	Learn scientific approach to farming, learn modern ways to livestock rearing, gain awareness on various government schemes	Revive livestock rearing, reduce use of chemical fertilizers, adopt organic farming
Key constraints on further adaptation	Financial resources to construct stilt houses, skills and finances to pursue alternative income options, government support to source soil for pottery, location of village situated in high	Training programs on modern ways of farming, awareness and training on scientific approaches to livestock rearing	Government support for training in modern practices of livestock rearing and disease prevention

Fig. 2, Locations and characteristics of the three case study villages in the Assam region of North East India. Despite their proximity the three villages face different hazards and vulnerabilities to climate change. The map was generated using QGIS software using image layer source Google Maps.

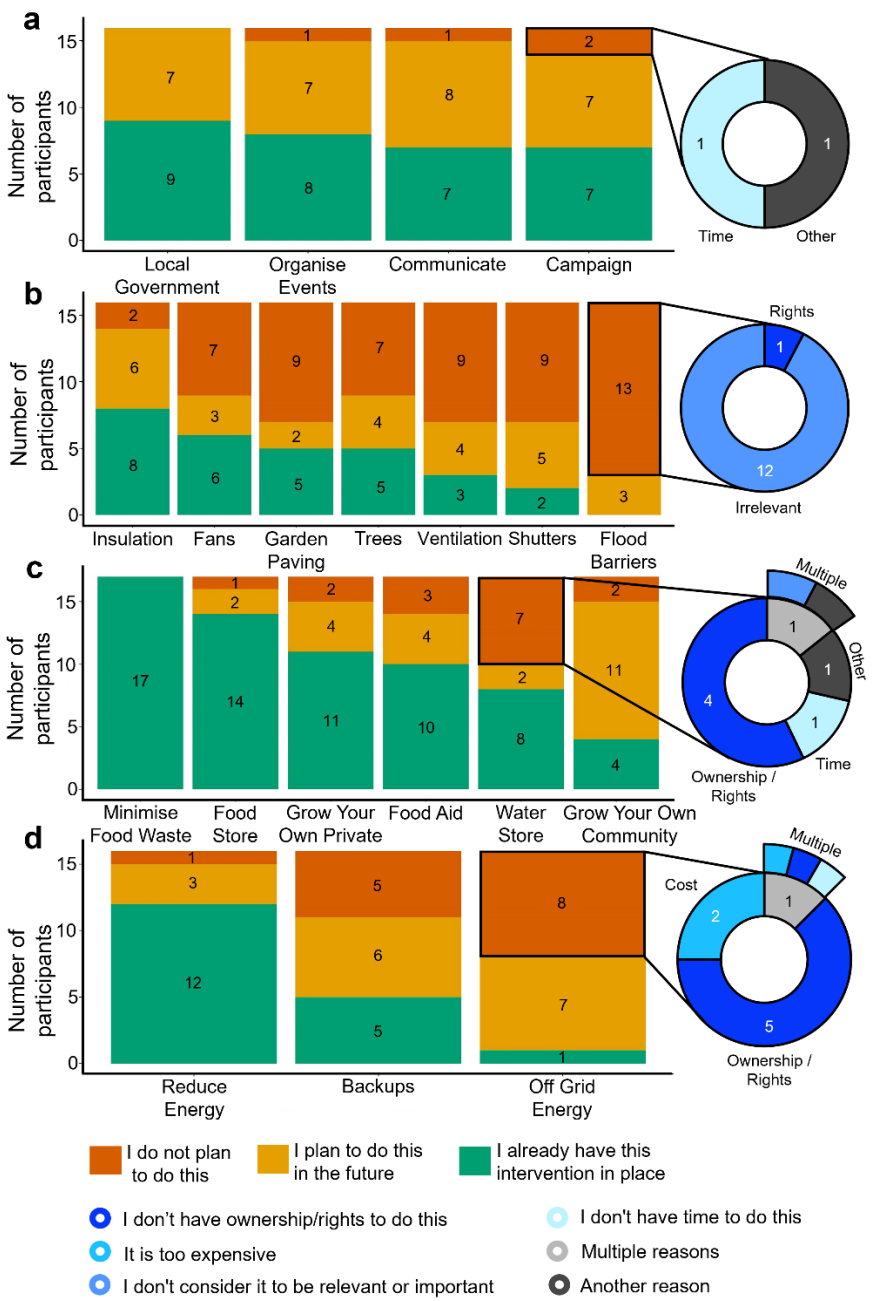

a
b
c
d
Number of participants
Local Government
Organise Events
Communicate
Campaign
Time
Other
Insulation
Fans
Garden Paving
Trees
Ventilation
Shutters
Flood Barriers
Rights
Irrelevant
Minimise Food Waste
Food Store
Grow Your Own Private
Food Aid
Water Store
Grow Your Own Community
Multiple
Ownership / Rights
Reduce Energy
Backups
Off Grid Energy
Cost
I do not plan to do this
I plan to do this in the future
I already have this intervention in place
I don't have ownership/rights to do this
I don't have time to do this
It is too expensive
Multiple reasons
I don't consider it to be relevant or important
Another reason

Fig. 3, UK participant intentions to pursue climate adaptation interventions. From 24 participants in total, the chosen interventions are categorised by a) general, b) housing, c) food, d) energy. Doughnut charts show examples of the reasons people choose not to pursue four specific interventions.

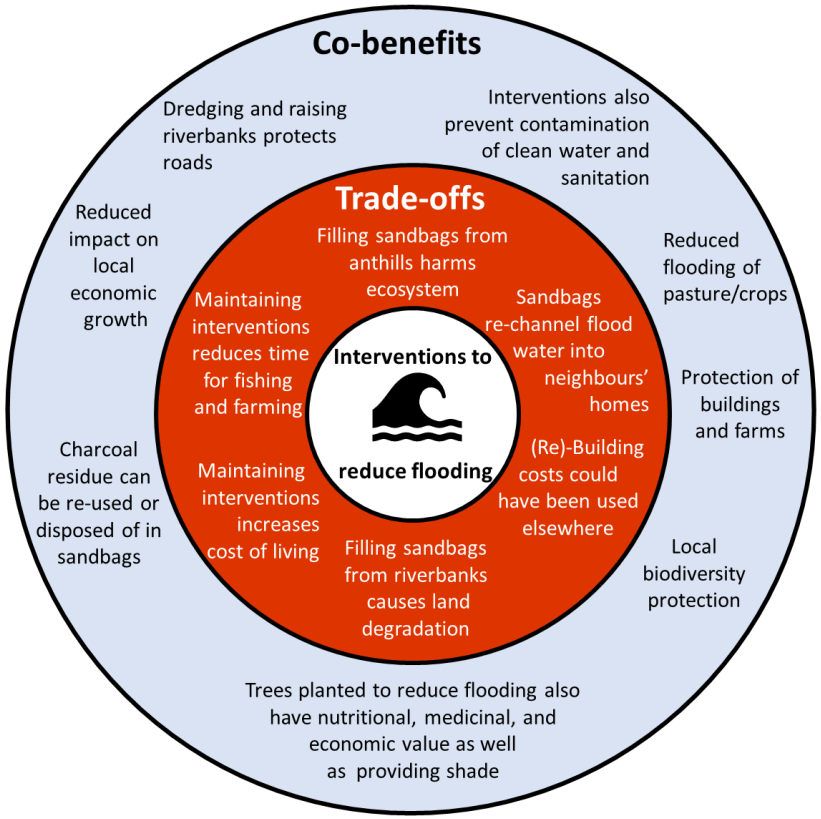


Fig. 4, Examples of the various co-benefits and trade-offs of interventions to reduce flooding as identified by the 24 Ghanaian participants.

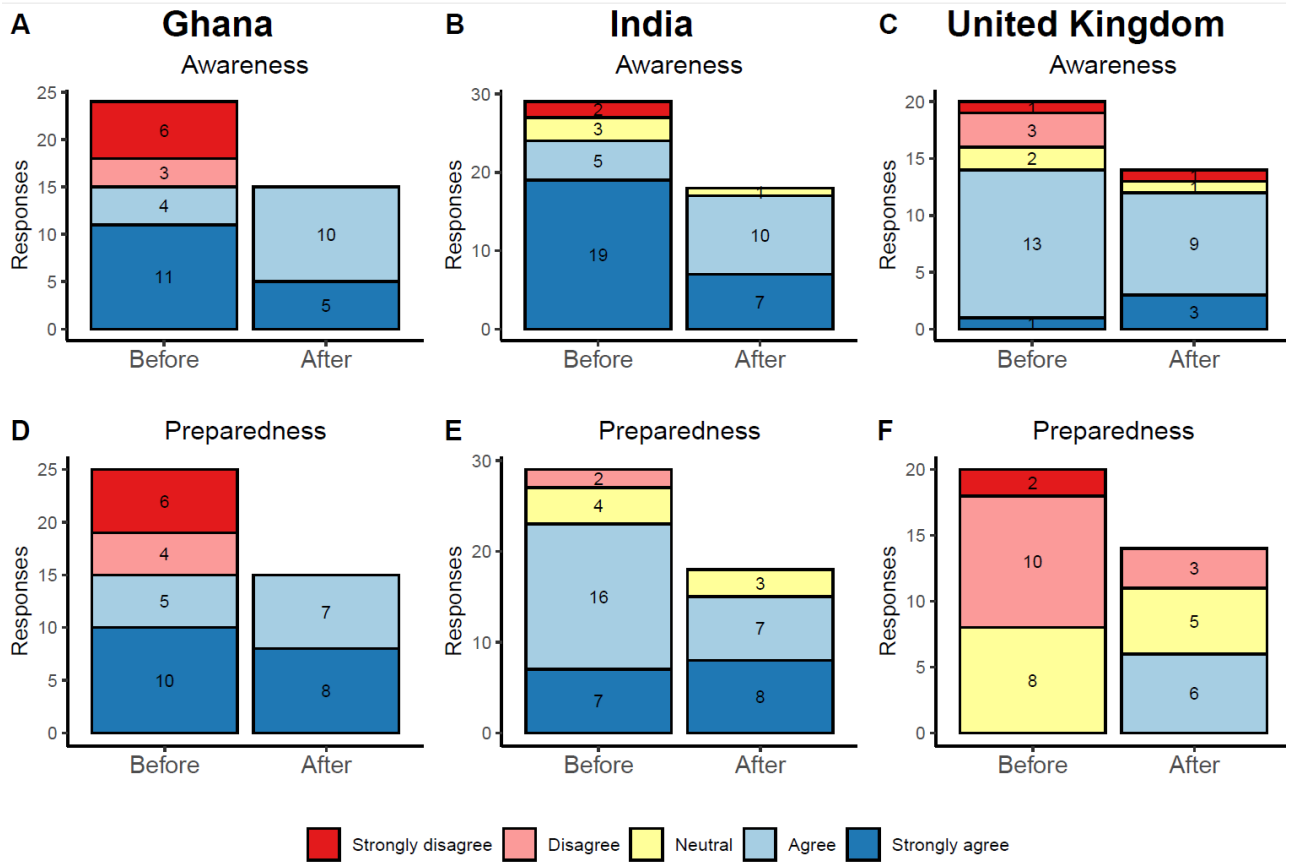
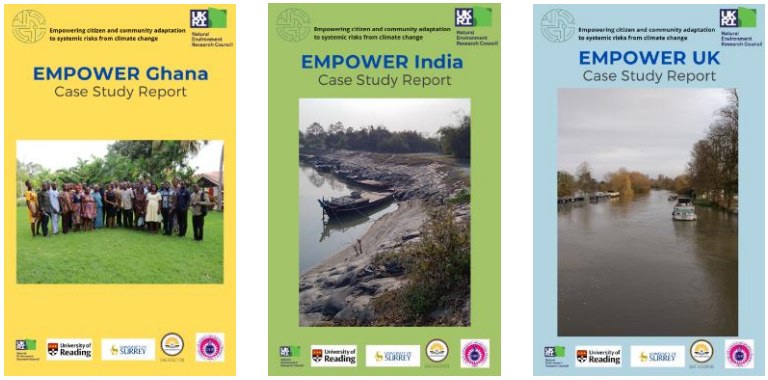
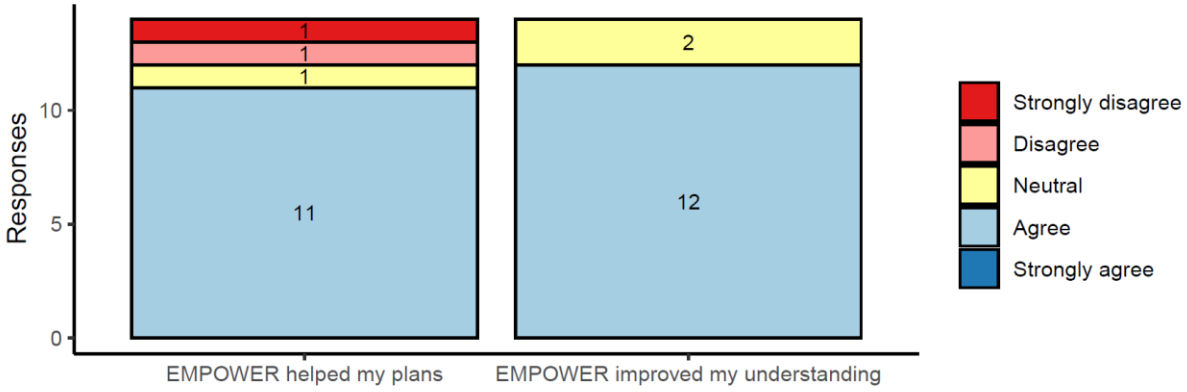


Fig. 5, Responses from before-and-after-project surveys for three case studies. The survey evaluates participants' self-reported awareness (panels A-C) and level of preparedness (D-F) for climate change impacts. Total participant numbers are 24, 29 and 24 for Ghana, India and UK respectively, with numbers providing specific responses shown within each bar.

Extended data Figure 1, Individual country reports. Detailed Background to the country case studies can be found in the reports shown below, available for download at https://www.empower-project.org/resources/



Extended data Figure 2, Responses to evaluation survey of UK participants after the EMPOWER workshops**.** These responses assess the degree to which they felt the project helped them make plans for climate change adaptation and improved their understanding of potential climate change impacts.

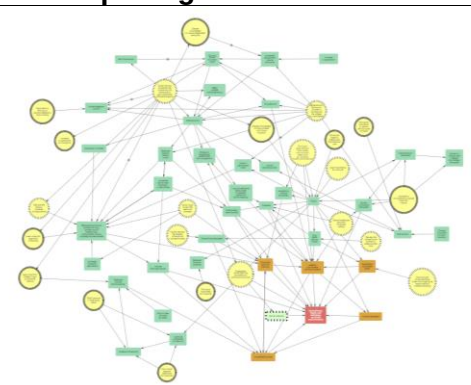
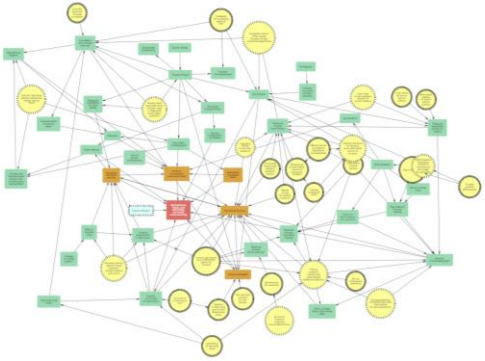


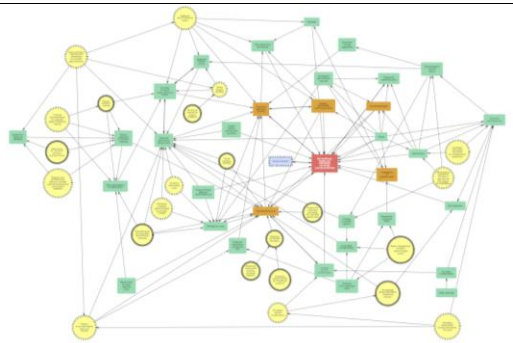
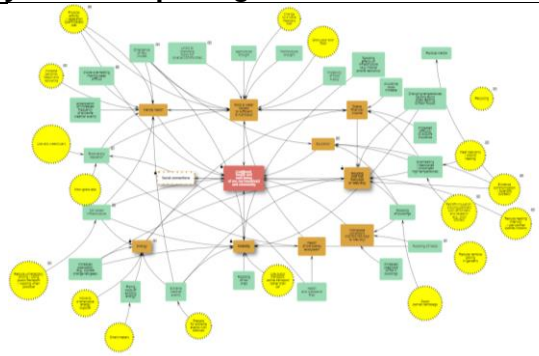
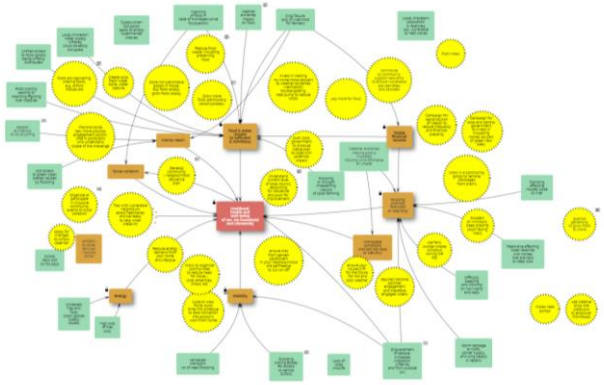
Supplementary Information

This Supplementary Information contains:

- Table S1: Participatory systems map links for all EMPOWER case studies
- Table S2: Climate threats affecting the downstream and upstream communities of the Lower Volta
- Table S3: Complete list of climate change adaptation interventions identified across all three EMPOWER case studies
- Table S4: Additional evaluation to the Ghana participants on various aspects of relevance and impact of the project process
- Table S5: Country case study participant numbers, gender and age ranges
- Box S1: Anonymised example of a personal adaptation plan from a UK participant
- Supplementary Discussion

Table S1: Participatory systems map links for all EMPOWER case studies

Country	Location	Participatory systems map image	URL for interactive viewing
India	Banoria Chapori		https://prsm.uk/prsm.html?room=LGI-BTU-SBC-BCV
India	Salmora		https://prsm.uk/prsm.html?room=FRP-SXY-XJC-RMQ

India	Kulamua		https://prsm.uk/prsm.html?room=OMH-GNN-ZQJ-FZG
Country	**Location**	**Participatory systems map image**	**URL for interactive viewing**
UK	Reading		https://www.prsm.uk/prsm.html?room=RBL-OEI-TGA-GIV
UK	Oxford		https://www.prsm.uk/prsm.html?room=PMH-HGU-HRK-JDX

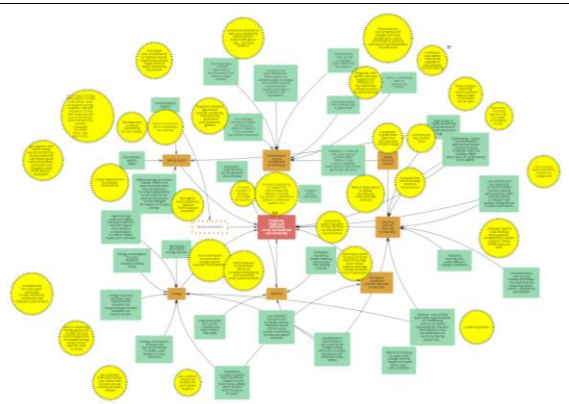
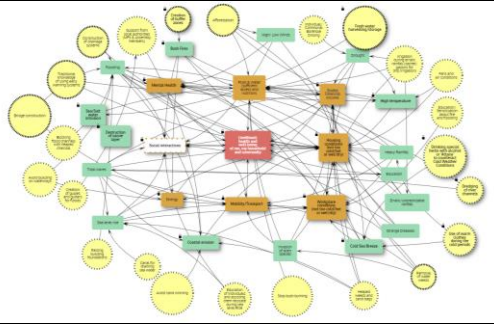
UK	Wallingford		https://prsm.uk/prsm.html?room=SZG-NDJ-KKY-XBB
Country	**Location**	**Participatory systems map image**	**URL for interactive viewing**
Ghana	Lower Volta Region		https://prsm.uk/prsm.html?room=EHC-XQM-UCZ-DTD

Table S2: Climate threats affecting the downstream and upstream communities of the Lower Volta

Downstream communities (Ada East, Anloga, Sokpoe, Agave, Ada foah, Ave-Seva, Akatsi North, Tosukpo, Fuveme, Ave-Dakpa, Sikor, Bleamezado, Dikato, Agorbledokoe)	**Upstream communities** (Agbetikpo,Dove, Volo, Mafi-Tsakpo, Ayiwata , Awadiwoe)
Bush fires	Bush fires
High/low winds	High/low winds
Drought	Drought
Erratic (unpredictable) rainfall	Erratic (unpredictable) rainfall
High temperature	High temperature
Heavy rainfall	Heavy rainfall
Cold sea breeze	Cold sea breeze
Invasion of alien species	Invasion of alien species
Flooding	Flooding
Coastal erosion	
Sea level rise	
Tidal waves	
Saltwater intrusion	

Table S3: Complete list of climate change adaptation interventions identified across all three EMPOWER case studies. The abbreviation LBV refers to Lower Volta Basin.

Intervention	Threat	Climate Driver	Supporting Factor	Country	Location
Afforestation	High/low winds	Wind	Housing conditions	Ghana	All
Avoid sandwinning	Coastal erosion	Heavy rainfall, Tides	Housing conditions, Workplace conditions	Ghana	Downstream of LVB
Blocking flood channels and filling with sand bags	Flooding	Heavy rainfall	Mobility and transport	Ghana	All
Creation of buffer zones	Bush fires	High temperature	Food and water security, energy	Ghana	All
Dredging of river channels	Tidal waves	Combination of lunar cycle and rising sea levels	Workplace conditions	Ghana	Downstream of LVB
Drink local alcoholic drink (akpeteshi) to counteract cold	Cold sea breeze	Heavy rainfall, strong winds	Mental health, workplace and housing conditions	Ghana	All
Evacuation; canal for draining sea water	Sea level rise	Sea level rise	Mobility and transport, workplace and housing conditions	Ghana	Downstream of LVB
Fans, air conditioning and ventilation (open windows)	High temperature	increasing day and night time temperatures	Housing and workplace conditions	Ghana	All
Freshwater harvest and storage	Sea/salt water intrusion	Sea level rise	Food and water security	Ghana	Downstream of LVB
Irrigation	Drought/ Erratic/ Unpredictable rainfall	Increasing temperature,	Food security	Ghana	All
Removal of water weeds	Invasion of alien species	Strong winds	Food security, stable financial income, mobility and transport	Ghana	All
Use of warm clothing/ use an umbrella	Heavy rainfall	Heavy rainfall	Housing conditions, mental health, social connections	Ghana	All
Develop off grid energy supply (e.g., solar roofs, micro wind turbine)	Loss of mains power	Extreme weather events	Energy	UK	All
Minimise energy demand at home (e.g., energy efficient electronics) to buffer from climate-induced price spikes/rationing	Increased energy costs	Multiple factors including weather e.g. wind/sun for wind and solar energy	Energy	UK	All
Prepare for extreme events with backups (e.g., battery powered torches/devices)	Loss of mains power	Extreme weather events	Energy	UK	All

Contribute to food aid and food sharing networks	Food shortages	Changing seasonality, increased rainfall, high temperatures	Food and Water Access	UK	All
Create local freshwater store for water capture	Water Shortages	Extreme events	Food and Water Access	UK	All
Grow food with the community (e.g., at community gardens)	Food shortages	Changing seasonality, increased rainfall, high temperatures	Food and Water Access	UK	All
Grow own food (e.g., at private garden, allotments)	Food shortages	Changing seasonality, increased rainfall, high temperatures	Food and Water Access	UK	All
Minimise food waste (at home and when shopping, incl. preserve excess food for future consumption)	Food shortages	Changing seasonality, increased rainfall, high temperatures	Food and Water Access	UK	All
Store non-perishable foods and drinks in house	Food shortages & Extreme events	Changing seasonality, increased rainfall, high temperatures	Food and Water Access	UK	All
Campaign for government to support interventions and communicate to improve uptake of interventions across community	General	General	General	UK	All
Communicate interventions within community, including vulnerable neighbours	General	General	General	UK	All
Engage with local and central government to support the development and implementation of neighbourhood resilience plan	General	General	General	UK	All
Organise / contribute to / attend events and networks to improve general resilience of community (through building social capital).	General	General	General	UK	All
Install flood barriers / sandbags (and alternatives)	Flooding	Increased seasonal / extreme rainfall events	Housing	UK	All
Install shutters (or alternative) to windows to shade rooms during the day	Overheating	High summer temperatures	Housing	UK	All
Insulate housing	Overheating	High summer temperatures	Housing	UK	All
Invest in improved ventilation	Overheating	High summer temperatures	Housing	UK	All
Plant climate change resilient trees on own property to shade south facing walls	Overheating	High summer temperatures	Housing	UK	All

Reduce / remove paving in gardens	Flooding	Increased seasonal / extreme rainfall events	Housing	UK	All
Use fans to cool rooms during high temperatures	Overheating	High summer temperatures	Housing	UK	All
Afforestation: Plant trees in and around the village	Soil erosion, flood, meandering of river	Melting of a glaciers, heavy rain	General	India	All
Use concrete columns for stilt houses	Flood, Inundation, embankment erosion	Melting of glaciers, excess rainfall	House/ living condition	India	Salmora
Identify a safe place for temporary shelter during flood	Flood, Inundation, embankment erosion	Melting of glaciers, excess rainfall	House/ living condition	India	Salmora
Store food and other items of basic need in a safer place	Flood, Inundation, embankment erosion	Melting of glaciers, excess rainfall	Food security and agriculture	India	Salmora
Adopt flood resistant/ climate-resilient agricultural practices	Flood, Inundation, embankment erosion	Melting of glaciers, excess rainfall, change in rainfall pattern	Food security and agriculture	India	Salmora
Explore Income diversification options for women (e.g. Sewing, Weaving, etc.)	Soil erosion, meandering of river	Melting of Himalayan glaciers, excess rainfall	Income/ livelihood	India	Salmora
Educate young generation with training for self-subsistence	Multiple threats like soil erosion, flooding, limited availability of raw materials for boat-making and carpentry	Multiple drivers like excess rainfall, irregular rainfall, melting of Glaciers	Income/ livelihood	India	Salmora
Explore alternative income options (e.g., agriculture, fishing, livestock rearing and high quality banana production, etc.)	Multiple threats like soil erosion, flooding, limited availability of raw materials for boat-making and carpentry	Multiple drivers like heavy rainfall, irregular rainfall, melting of Glaciers	Income/ livelihood	India	Salmora
Develop entrepreneurial skills to market their products	Multiple threats like soil erosion, flooding, limited availability of raw materials for boat-making and carpentry	Multiple drivers like heavy rainfall, irregular rainfall, melting of Glaciers	Income/ livelihood	India	Salmora
Identify alternative options to source soil for pottery	Soil erosion, meandering of river	Melting of glaciers, excess rainfall	Income/ livelihood	India	Salmora
Pre-flood: keep ropes to make boats from banana tree	Flood, Inundation, embankment erosion	Melting of glaciers, excess rainfall	Housing/ living condition	India	Banoria Chapori
Elevate the stilted house further or make another floor	Flood, Inundation, embankment erosion	Melting of glaciers, excess rainfall	Housing/ living condition	India	Banoria Chapori
Learn swimming for survival	Flood, Inundation, embankment erosion	Melting of glaciers, excess rainfall	Housing/ living condition	India	Banoria Chapori
Pre-flood: keep all basic items safely (e.g., food)	Flood, Inundation, embankment erosion	Melting of glaciers, excess rainfall	Food security, agriculture, water	India	Banoria Chapori

During flood: source drinking water from high-lying areas and boil it before drinking	Flood, Inundation, embankment erosion	Melting of glaciers, excess rainfall	Food security, agriculture, water	India	Banoria Chapori
Increase the height of stilted food storage further	Flood, Inundation, embankment erosion	Melting of glaciers, Excess rainfall	Food security, agriculture, water	India	Banoria Chapori
Adopt climate resilient agriculture/ learn scientific approach to farming	Flood, Inundation, extreme weather	Melting of glaciers, Excess rainfall, change in rainfall pattern	Health related	India	Banoria Chapori
Pre-flood: keep all basic medicines ready	Flood, Inundation, disruption to healthcare services	Melting of glaciers, Excess rainfall	Health related	India	Banoria Chapori
Pre flood: store feed for livestock	Flood, Inundation, embankment erosion	Melting of glaciers, Excess rainfall	Livestock rearing	India	Banoria Chapori
Shift livestock to high-lying areas	Flood, Inundation, embankment erosion	Melting of glaciers, Excess rainfall	Livestock rearing	India	Banoria Chapori
Post flood: prepare medicines for livestock	Flood, Inundation, embankment erosion	Melting of glaciers, Excess rainfall	Livestock rearing	India	Banoria Chapori
Learn scientific/ modern ways to livestock rearing	Flood, Inundation, embankment erosion	Melting of glaciers, Excess rainfall	Livestock rearing	India	Banoria Chapori
Gain greater knowledge on nature-dependent resources	General	General	General	India	Banoria Chapori
Gain awareness on various government schemes	General	General	General	India	Banoria Chapori
Gain greater knowledge on how to deal with flood situation	General	General	General	India	Banoria Chapori
Adopt climate resilient farming/ alternative crops based on seasonal changes	Flood, Inundation, reduced agricultural productivity	Melting of glaciers, excess rainfall	Food security, agriculture	India	Kulamua
Reduce the use of chemical fertilizers and urea	reduced agricultural productivity	general	Food security, agriculture	India	Kulamua
Adopt organic farming	reduced agricultural productivity	general	Food security, agriculture	India	Kulamua
Gain awareness on govt schemes related to agriculture and farming practice	reduced agricultural productivity	general	Food security, agriculture	India	Kulamua
Revive livestock rearing	Flood, Inundation, livestock diseases	Melting of glaciers, excess rainfall, extreme weather	Livestock rearing	India	Kulamua
Gain awareness on livestock diseases and prevention	Flood, Inundation, livestock diseases	Melting of glaciers, excess rainfall, extreme weather	Livestock rearing	India	Kulamua
Gain knowledge about alternative livelihood options	Flood, Inundation, reduced agricultural productivity	Melting of glaciers, heavy rain, extreme weather	Income/ livelihood	India	Kulamua

Look for alternative source of income (e.g., fishing, weaving)	Flood, Inundation, reduced agricultural productivity	Melting of glaciers, excess rainfall, extreme weather	Income/ livelihood	India	Kulamua

Table S4: Additional evaluation to the Ghana participants on various aspects of relevance and impact of the project process

Statement	Highly useful		Useful		Adequate		Total	
	Freq	%	Freq	%	Freq	%	Freq	%
Usefulness of methodology for your work	18	82	4	18	0	0	22	100
Usefulness of shared experiences and practices	9	41	12	55	1	5	22	100
Relevance of the recommendations for your work	8	33	15	63	1	4	24	100
Approaches/techniques/concepts	16	70	13	35	4	17	23	100
Strengthened Knowledge on climate	17	81	4	19	0	0	21	100

Table S5: Country case study participant numbers, gender and age ranges

Country	Total participants	Number Males	Gender ratio (M:F)	Age range	Median age
Ghana	24	17	0.708	18-65	c. 37, but exact ages not requested
India	29	19	0.655	26-55	38
UK	24	10	0.417	18-75	55

Box S1: Anonymised example of a personal adaptation plan from a UK participant

EMPOWER | Empowering citizen and community adaptation to systemic risks from climate change

[redacted] **Your personal adaptation plan**

Through your participation in the EMPOWER project, we have identified a range of climate change threats and related interventions. Below is a summary of the plans that you designed during the second workshop, which we hope you will find interesting and helpful. We are grateful to all our participants for their valuable contributions to this project.

General Interventions

1. Engage with local and central government to support the development and implementation of neighbourhood resilience plan (e.g., campaign about insulating homes or for planting / replanting climate resilient trees)

You said: I plan to do it in the future

- Within next six months
- Continuing to engage with a variety of groups that involves these actions

2. Organise / contribute to / attend events and networks to improve general resilience of community (through building social capital)

You said: I already have this intervention in place

- It was something I actively organised myself

3. Communicate interventions within community, including vulnerable neighbours

You said: I already have this intervention in place

- It was something I actively organised myself

4. Campaign for government to support interventions and communicate to improve uptake of interventions across community (incl. improve resilience of UK food production, grow climate-resistant crops, plant hedgerows, improve soil quality, reduce pesticide use, etc.)

You said: I plan to do it in the future

- By this time next year
- To identify suitable vehicles for advancing these approaches/policies

Housing and Workplace Interventions

1. Reduce / remove paving in gardens

You said: I already have this intervention in place

- It was something I actively organised myself

2. Install flood barriers / sandbags (and alternatives)

You said: I do not plan to do this

- I don't consider it to be relevant or important

3. Insulate housing

You said: I plan to do it in the future

- I already have insulation to current required standards...but intend to improve beyond regulatory standards at some point over the next couple of years
- Become clear about whether we are staying put or moving in the medium term

4. Plant climate change resilient trees on own property to shade south facing walls

You said: I already have this intervention in place

- It was something I actively organised myself

5. Install shutters (or alternative) to windows to shade rooms during the day

You said: I already have this intervention in place

- It was something I actively organised myself

6. Invest in improved ventilation

You said: I plan to do it in the future

- Once we've established most appropriate replacement heating method - currently weighing up installation of Air Source Heat pump
- Book a consultation with a company that instals air source heat pumps

7. Use fans to cool rooms during high temperatures

You said: I already have this intervention in place

- It was something I actively organised myself

Food and Water Interventions

1. Grow own food (e.g., at private garden, allotments)

You said: I already have this intervention in place

- It was something I actively organised myself

2. Grow food with the community (e.g., at community gardens)

You said: I plan to do it in the future

- I'm exploring what scope there is for local residents on my lane to club together and buy some land from the farmer, so that we can co-operate on growing food for local consumption
- To work out how best to approach the farmer who is not always receptive to community needs - I have spoken to him in the past about buying a strip of land for arable purposes, and for growing trees, but he was very hostile to the idea

3. Minimise food waste (at home and when shopping, incl. preserve excess food for future consumption)

You said: I already have this intervention in place

- It was something I actively organised myself

4. Store non-perishable foods and drinks in house

You said: I already have this intervention in place

- It was something I actively organised myself

5. Contribute to food aid and food sharing networks

You said: I already have this intervention in place

- It was something I actively organised myself

6. Create local freshwater store for water capture

You said: I already have this intervention in place

- It was something I actively organised myself

Energy Interventions

1. Minimise energy demand at home (e.g., energy efficient electronics) to buffer from climate-induced price spikes/rationing

You said: I already have this intervention in place

- It was something I actively organised myself

2. Prepare for extreme events with backups (e.g., battery powered torches/devices)

You said: I plan to do it in the future

- By this time next year
- Am currently (intermittently when I have spare capacity) researching options

3. Develop off grid energy supply (e.g., solar roofs, micro wind turbine)

You said: I already have this intervention in place

- It was something I actively organised myself

Supplementary Discussion

i) Critical reflections on the effectiveness of EMPOWER pilot process

This study used participatory systems mapping with citizens to identify diverse threat vectors from climate change in case studies from three countries. This Supplementary Discussion concerns the effectiveness of the process. An important caveat to note is that we only evaluated the intentions for interventions and follow up work is needed to assess final implementation, as well as collating further learnings on the practical challenges and successes experienced by participants. At least in terms of self-assessment by participants, the process appears to have been effective, suggesting increased awareness of- and preparedness for- local climate change impacts (Figure 5). For example, testimonials from Ghanaian participants included:

- "I learned about climate change, the causes, effects and possible interventions that I need to adapt and I must be aware about the cost and trade-offs of any of the intervention measures."
- "For me this workshop is important because it has served as platform for awareness for me and my family on climate change."
- "I have more information on how other people are adapting to climate change in the UK and India and these are also applicable to me here in the village. I am better informed now about adaptation measures to climate change."

However, our evaluation suggests there may have been some over-confidence or complacency, particularly in the Ghanian and Indian participants, involving high self-estimates of preparedness for climate change impacts before the workshops, despite later reflection that the workshops increased their sense of preparedness substantially. UK participant self-estimates for preparedness were substantially lower, despite still showing an increase before- versus after- the workshops. This could be related to the perceived impact of indirect risks for UK

participants– such as food and energy insecurity– in a highly interdependent society with lower levels of self-subsistence. It is also made more salient by recent issues such as the Covid-19 pandemic and energy price shocks caused by the Russia-Ukraine war.

As our process is considering planned implementation, it is also important to note how the ultimate implementation of interventions is likely to be affected by various external developments. For example, climate risks may change over time [47] (contingent on GHG emissions and also due to uncertainty in the background evidence provided to participants). Adaptation plans by others (e.g. government putting in place upstream flood defences) may affect the appropriateness of interventions. The economic context may change, for example meaning the nature of participants' work changes, affecting time and money available to implement adaptation plans. Changes in geopolitical context (e.g. trade or conventional military wars) affect food [48] and energy security [49]. Hence, community-based adaptation processes may wish to take an iterative approach where planning is revisited, every few years for example.

ii) Our approach in relation to other participatory approaches, and general limitations in participatory approaches

Our approach differs from other participatory approaches, such as those specifically targeted to informing climate-resilient farming [25] or using scenario building. For example, the Participatory Integrated Climate Services for Agriculture (PISCA) approach [25,50] is targeted specifically at farmers using tools such as Resource Allocation Maps and Seasonal Calendars. Transformative Scenario Planning and other approaches implementing scenarios for climate adaptation (e.g. [26]) use group work with citizens to rank of drivers of change in their community (i.e. social, political, economic, cultural, or technological drivers). The most influential drivers (e.g. top two drivers in [26]) are used to develop alternative future scenarios. Citizens then identify plausible actions they believe will be effective in managing the outcomes of the scenario. Hence, there are similarities, yet our approach using participatory systems mapping helps citizens reflect on the pathways of

a range of different threats to households from climate change (both direct and indirect), facilitated by provision of evidence on some of the possible major impacts. Hence, it helps participants take a systemic (big picture) approach to appraising diverse, context-dependent climate risks, yet in a more systematic way than simply brainstorming from a blank slate. The openly available online tool (PRSM; https://prsm.uk), is useful for doing this remotely but, as we show from the Ghana and India case studies, the process works equally well through in-person facilitation using traditional white-board and sticky notes.

There are some shortfalls of participatory processes that should be borne in mind. One obvious factor is that they are time consuming and costly to undertake [51], and so the potential benefits in terms of enhanced resilience to climate change need to be assessed in light of this when considering upscaling of such processes. Second, participatory processes can be susceptible to advocacy from facilitating researchers[52], and may not always give an equal voice to all stakeholders affected by an issue [12], therefore careful design of the facilitation process is crucial. An additional cautionary point regarding participatory research for citizen-led climate adaptation is that it should not be seen as an alternative to top-down (e.g. state led) climate adaptation processes. Both approaches are essential and there are several external constrains for citizen-led adaptation planning that require facilitation from local and national government [53] (also see main text for discussion on this).

References

1 Harrington, L. J., Frame, D., King, A. D. & Otto, F. E. L. How Uneven Are Changes to Impact-Relevant Climate Hazards in a 1.5 °C World and Beyond? *Geophysical Research Letters* **45**, 6672-6680, doi:https://doi.org/10.1029/2018GL078888 (2018).

2 Behnassi, M. & El Haiba, M. Implications of the Russia–Ukraine war for global food security. *Nature Human Behaviour* **6**, 754-755, doi:10.1038/s41562-022-01391-x (2022).

3 Benton, T. G., Froggatt, A. & Wellesley, L. The Ukraine war and threats to food and energy security: Cascading risks from rising prices and supply disruptions, Research Paper, London: Royal Institute of International Affairs, https://doi.org/10.55317/9781784135225. (2022).

4 Clarkson, G. *et al.* Stimulating small-scale farmer innovation and adaptation with Participatory Integrated Climate Services for Agriculture (PICSA): Lessons from

successful implementation in Africa, Latin America, the Caribbean and South Asia. *Climate Services* **26**, 100298, doi:https://doi.org/10.1016/j.cliser.2022.100298 (2022).
5 Dayamba, D. S. *et al.* Assessment of the use of Participatory Integrated Climate Services for Agriculture (PICSA) approach by farmers to manage climate risk in Mali and Senegal. *Climate Services* **12**, 27-35, doi:https://doi.org/10.1016/j.cliser.2018.07.003 (2018).
6 Schmitt Olabisi, L. *et al.* Scenario Planning for Climate Adaptation in Agricultural Systems. *Agriculture* **10**, 274 (2020).
7 Mansbridge, J. J. Time, Emotion, and Inequality: Three Problems of Participatory Groups. *The Journal of Applied Behavioral Science* **9**, 351-368, doi:10.1177/002188637300900217 (1973).
8 David, M. Problems of participation: The limits of action research. *International Journal of Social Research Methodology* **5**, 11-17, doi:10.1080/13645570110098037 (2002).
9 Nared, J. & Bole, D. *Participatory research and planning in practice*. (Springer Nature, 2020).
10 Kamols, N., Foth, M. & Guaralda, M. Beyond engagement theatre: challenging institutional constraints of participatory planning practice. *Australian Planner* **57**, 23-35, doi:10.1080/07293682.2021.1920993 (2021).