Current Climate Change Reports (2020) 6:1–16
https://doi.org/10.1007/s40641-020-00153-z

PROGRESS IN THE SOLUTION SPACE OF CLIMATE ADAPTATION (E GILMORE, SECTION EDITOR)

Migration and Household Adaptation in Climate-Sensitive Hotspots in South Asia

Amina Maharjan[1] · Ricardo Safra de Campos[2] · Chandni Singh[3] · Shouvik Das[4] · Arjun Srinivas[3] · Mohammad Rashed Alam Bhuiyan[5] · Sultan Ishaq[6] · Muhammad Awais Umar[7] · Tanzina Dilshad[8] · Krity Shrestha[9] · Suruchi Bhadwal[10] · Tuhin Ghosh[4] · Natalie Suckall[11] · Katharine Vincent[12]

Published online: 19 February 2020
© The Author(s) 2020

Abstract

Purpose of Review South Asia is highly vulnerable to the impacts of climate change, owing to the high dependency on climate-sensitive livelihoods and recurrent extreme events. Consequently, an increasing number of households are adopting labour migration as a livelihood strategy to diversify incomes, spread risks, and meet aspirations. Under the Collaborative Adaptation Research Initiative in Africa and Asia (CARIAA) initiative, four research consortia have investigated migration patterns and their inherent linkages to adaptation to climate change in climate hotspots. This article synthesizes key findings in regional context of South Asia.

Recent Findings The synthesis suggests that in climate-sensitive hotspots, migration is an important livelihood diversification strategy and a response to various risks, including climate change. Typically, one or more household members, often young men, migrated internally or internationally to work in predominantly informal sectors. Remittances helped spatially diversify household income, spread risks, and insure against external stressors. The outcomes of migration are often influenced by who moves, where to, and what capacities they possess.

Summary Migration was found to help improve household adaptive capacity, albeit in a limited capacity. Migration was mainly used as a *response* to risk and uncertainty, but with potential to have positive adaptation co-benefits.

Keywords Migration · Climate change · Adaptation · South Asia

This article is part of the Topical Collection on *Progress in the Solution Space of Climate Adaptation*

✉ Amina Maharjan
amina.maharjan@icimod.org

Ricardo Safra de Campos
R.Safra-De-Campos@exeter.ac.uk

Chandni Singh
csingh@iihs.ac.in

Shouvik Das
geo.shk@gmail.com

Arjun Srinivas
asrinivas@iihs.ac.in

Mohammad Rashed Alam Bhuiyan
rashedalam@du.ac.bd

Sultan Ishaq
sultan.iq11@gmail.com

Muhammad Awais Umar
awais@sdpi.org

Tanzina Dilshad
tanzina.dilshad@gmail.com

Krity Shrestha
krity.shrestha89@gmail.com

Suruchi Bhadwal
suruchib@teri.res.in

Tuhin Ghosh
tuhin_ghosh@yahoo.com

Natalie Suckall
N.R.Suckall@soton.ac.uk

Katharine Vincent
katharine@kulima.com

Extended author information available on the last page of the article

Introduction

The contemporary human world is becoming more mobile. This movement of people, goods, services, and information has reshaped our understanding of both spatial and temporal dimensions of socioeconomic processes [4]. The impacts of climate change including coastal flooding, erratic rainfall, drought, riverbank erosion, and storm surges, combined with other non-climatic drivers such as land use change, socioeconomic shifts, and changes to gender norms, are likely to alter the patterns of human migration further with a knock on effect on immediate adaptation decisions at the household level [75].

Although climate change brings about a set of challenges at the global level, in certain regions, its impact is likely to be more severe because of higher exposure to climatic risks [58, 16, 28], deeper pre-existing structural vulnerabilities [97], and comparatively lower adaptive capacity [48, 77]. The Intergovernmental Panel on Climate Change (IPCC) has identified such regions as climate change hotspots, defined as locations where impacts of climate change are well pronounced and well documented [98]. For this paper, we expand this definition to climate hotspots as "geographical area[s] where a strong climate signal is combined with a large concentration of vulnerable, poor or marginalized people" ([97]:784).

South Asia is home to several hotspots that are highly vulnerable to the effects of climate change [29, 53]. High dependency on climate-sensitive livelihoods, such as fisheries and agriculture, makes people living in coastal, river basin, and semi-arid regions particularly vulnerable to the impacts of climate variability and change [97]. South Asia experiences recurrent natural hazards such as glacial lake outburst floods, storm surges, droughts, cyclones, and heavy precipitation, which is exacerbated by current and future climate change [16, 47, 100]. As the livelihoods of people deteriorate, they are displaced or are faced with an important decision: to migrate (either the whole household or some of its members) or adapt in situ.

South Asia is a socioeconomic and culturally heterogeneous region but there are important similarities among the countries in terms of population density, development level, poverty, and exclusion [51]. Population movement has been a constant part of life in South Asia primarily as a strategy to diversify and/or supplement income sources beyond ecosystem-based forms of livelihood, but historically, migration in the region has been predominantly associated with labour moves of semi-skilled and unskilled individuals to both international and domestic destinations [39]. Migration trends and patterns in South Asia are diverse but internal migration outweighs international moves. Internal migration as a share of total population is as high as 37% in India, 10% in Bangladesh, 14% in Nepal, and 2% in Pakistan [83]. Although lower than internal migration, international moves from this region are significant. For example, India, Bangladesh, and Pakistan are among top ten emigration countries in the world and Nepal is the third largest recipient of remittance as a share of GDP [106].

Although population movement in South Asia has historically been strongly associated with labour mobility [30, 80], recent studies suggest that growing levels of rural to urban migration in the region have been attributed to the impacts of droughts, floods and irregular precipitation on agricultural production and other ecosystem-based livelihoods [13, 26, 42, 102]. Migration is often leveraged as a critical livelihood diversification strategy by households in areas facing severe climate change impacts [2, 85]. Recent studies have sought to project climate-driven migration in South Asia using a suite of modelling techniques [77]. However, this study seeks to add to the growing body of empirical evidence [17, 23, 54, 55] by examining the composition, direction, and duration of migration at regional level; the drivers and barriers to migration, and how they interact; and the linkages between migration and adaptation at household level [99]. The synthesis of migration patterns presented here draws on empirical findings from the Collaborative Adaptation Research Initiative in Africa and Asia (CARIAA) programme, which aimed to investigate adaptation responses in three climate-sensitive hotspots (deltas, semi-arid regions, and snowpack- or glacier-fed river basins). As part of the programme's objectives, four CARIAA consortia employed a range of quantitative and qualitative methodological approaches to investigate the relationship between migration and adaptation in South Asia.[1]

Drawing on novel empirical datasets, the research synthesized in this paper contributes to the body of empirical knowledge examining the relationship between migration and adaptation in South Asia in the context of climate change. It also provides insights into how the implementation of a suite of research methods is the key to understanding complex characteristics of migration in climate-sensitive areas of Bangladesh, India, Nepal, and Pakistan. The article is organised as follows: the "Conceptual Links Between Climate Change, Migration and Adaptation" section reviews the links between migration and environmental change and provides a brief literature review on previous research examining the relationship between migration and adaptation. The "Methodology" section introduces the study areas, research design, and methodological approach. The "Results" section presents the findings for each study area focusing on the nature of migration in each site and the implications of migration for household adaptation. The "Conclusion" section

[1] The four consortia were the Himalayan Adaptation, Water and Resilience (HI-AWARE) Research on Glacier and Snowpack Dependent River Basins for Improving Livelihoods; Adaptation at Scale in Semi-Arid Regions (ASSAR); Pathways to Resilience in Semi-Arid Economies (PRISE); and Deltas, Vulnerability and Climate Change: Migration and Adaptation (DECCMA).

summarises the results, provide brief policy recommendations, and present future directions for research.

Conceptual Links Between Climate Change, Migration and Adaptation

Migration is a key livelihood strategy that occurs across spatiotemporal scales and can range from temporary moves to permanent relocation [41]. Individuals and households respond differently to the various drivers associated with migration depending on socioeconomic and cultural characteristics, demographic composition, and their contextual setting [14]. Several types of migration—such as seasonal, circular and permanent movement—are recognised as strategies to diversify livelihoods in response to external shocks including international and national market adjustments in transition economies, development, conflict and the effects of climate change, and other environmental hazards in ecosystem-based economies [31, 33, 105]. Early research framed migration decisions as driven by aims to maximise individual profit and minimise loss of household income associated with crop failure, volatility of markets, or economic recession [88]. Recent studies have nuanced this model to demonstrate that migration decisions are a complex interplay of household capabilities (i.e. composition, education levels, social networks), assets, personal aspirations, and external factors such as increased climate variability, livelihood opportunities, and access to towns and cities [22, 26, 72, 85, 94].

Contemporary migration trends in South Asia continue to suggest prevalence of migration driven by economic factors. However, the pervasive effects of climate change could lead to significant incremental or non-linear changes in migration outcomes depending on the context [60, 61]. For example, direct impact brought about by rapid onset hazards such as cyclones and floods or indirect impacts associated with slow onset events including drought and changes in annual monsoon regime [26, 102].

Research on migration associated with environmental drivers has investigated the relationship between population movement and the degree of exposure to and impact of hazards on livelihoods, teasing out the way migration decisions and outcomes vary between households and communities [37, 43, 59]. Underpinning this empirical work is substantial progress in conceptualising the relationship between climate change and migration beyond direct causal factors such as rapid onset disasters causing displacement. In effect, migration associated with cumulative environmental changes over time is a multi-faceted phenomenon that is harder to isolate. Slow onset events are likely to take place alongside economic, social, and political changes [66]. As a result, it is difficult to single out climate change as the main driver of migration. This assessment corroborates the notion that environmental factors alone do not destabilise human security [6]. Limited economic development, the range of government support to communities, capacity to access credit and markets, social cohesion, and political instability are equally important in migration decision-making processes [19, 21].

As the impacts of climate change become more widely recognised, researchers are increasingly examining how migration can contribute to climate change adaptation [3, 85, 99], independent of the reasons for migration. In the context of climate change, adaptation is defined as the process of adjustment to actual or expected climate and its effects, which seeks to minimise harm or exploit beneficial opportunities [48]. Adaptation can be either autonomous or planned. Autonomous adaptation is defined as 'natural or spontaneous adjustments in the face of a changing climate' [20], whereas planned adaptation requires conscious intervention [32]. The IPCC's Fifth Assessment Report makes a strong case for the capacity of migration outcomes to reduce vulnerability for populations exposed to extreme events and longer term climate change [6].

Migration is often characterised as an effective adaptation strategy (e.g. by spreading risk and diversifying incomes) [35, 93, 104]. On the other hand, it has been described as a *failure* to adapt where populations being unable to respond to risk migrate as a last option [6]. Between these two extremes of the migration for adaptation debate are ideas of how migration drivers and outcomes are differentiated and it can denote adaptation in certain situations and for certain people while signifying a failure to adapt for others [18, 85, 87, 103]. In fragile environments, migration is a common response to vulnerability to slow and rapid onset events [68, 104]. Gemenne and Blocher [35] suggested that migration can affect adaptation through three distinct vantage points, namely for the migrants themselves, for the community of origin, and for the community of destination and the combined communities of origin and destination. Our study focuses on the migrants' vantage point, examining the characteristics of migrants as well as social and cultural factors determining who migrates .

Migration can contribute to household adaptation mostly through remittances—by improving existing resource bases of individuals and households, spreading risk, and diversifying income sources to reduce vulnerabilities [35, 93, 104]. Emerging empirical and theoretical research suggests that the roles of remittances, skill acquisition, and transfer are particularly important in household adaptation [7, 66, 82]. In vulnerable areas, migration and the resulting remittances can build the adaptive capacities of the households, particularly when adaption measures incur investments [69]. Furthermore, studies suggest that migration has the potential to enhance household ability to absorb shocks [36, 96].

Contrastingly, migration has also been framed as a failure to adapt or a maladaptive response [49]. Migration may trigger increased risk for those who move, those who are unable to

move, and also for migrant destination areas [103]. The negative consequences of migration for poorer households fighting to cope with a range of economic and material challenges in the wake of environmental and climatic risks can be severe [63]. The erosion of important assets (i.e. human capital) could prove detrimental in the medium or longer term, reducing overall adaptive capacity, especially to households dependent on ecosystem-based livelihoods [36, 85]. Furthermore, in extreme cases, migration can manifest as a failure to adapt or is employed as a last-resort response after other coping strategies have failed [73, 76].

Figure 1 illustrates how climatic drivers (both slow and rapid onset, e.g. floods, rainfall variability) interact with non-climatic drivers (e.g. existing poverty, conflict, development deficits) to influence household migration decisions. These decisions to move or stay have implications on household adaptive capacity through remittances, changes in human and social capital, etc., accruing to influence household adaptation. When households are exposed to climate change impacts, they assess the constraints and opportunities created by sending one or more members to work outside the village (thereby increased or reduced vulnerability), stay and adapt in situ (reduced vulnerability), and stay without adapting (increased vulnerability). These decisions are capital endowment of the household. For migrant households, the capacity to adapt is then dependent on the remittances (both financial and social) received and the ability to overcome loss of labour and social capital. For non-migrant households, the capacity to adapt is dependent on their financial, human, and social capitals.

In the literature, there remain gaps around the implications of migration for adaptation, especially in climate hotspots. Studies have typically modelled climate change and migration patterns to estimate 'climate migrants' (e.g. [77]) or ascertain climatic drivers of migration (e.g. [26]). In this paper, we add to this literature empirically by providing a bottom-up assessment of migration patterns and decision-making [24]. In doing so, we also contribute conceptually to understanding the implications of migration for climate change adaptation at the origin.

Methodology

Study Areas

The study areas are located in environmentally vulnerable regions, characterised by high resource competition and degradation, and a history of exposure to extreme events. The effects of climate change are expected to be higher in the study sites as compared with global average [24]. The study areas in Bangladesh, India, Nepal, and Pakistan were selected according to three criteria: (1) each individual site was located in a country that had been regularly affected by extreme events and was also vulnerable to future climate change [28, 53]; (2) each represented a different climate hotspot where migration is an important livelihood strategy for the households—we chose deltas, river basins, and semi-arid environments experiencing multiple stressors ([71, 91]); and (3) in the case of deltas, sampled locations were selected among migration-sending areas with a well-documented history of rural to urban population movements [92].

The illustrative map (Fig. 2) provides the location and main environmental stressors in the study areas. HI-AWARE study sites covered mountain-based hotspots, i.e. four glacier- and snowmelt-dependent river basins in India, Pakistan, and Nepal, covering the Indus, Upper Ganga, Gandaki, and Teesta river basins. Within the river basin, the study sites were

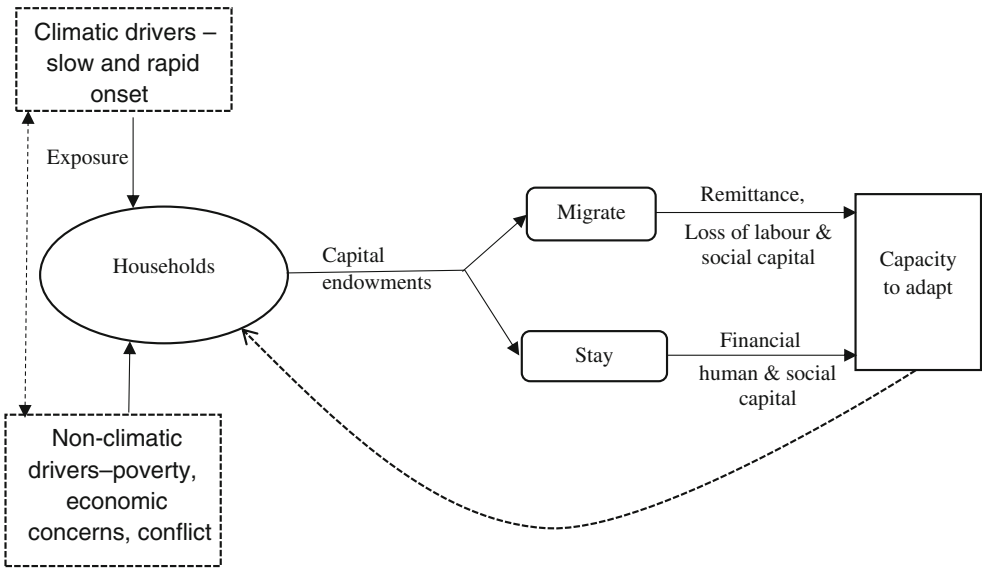

Fig. 1 A conceptual framework of migration for adaptation under climate change impacts

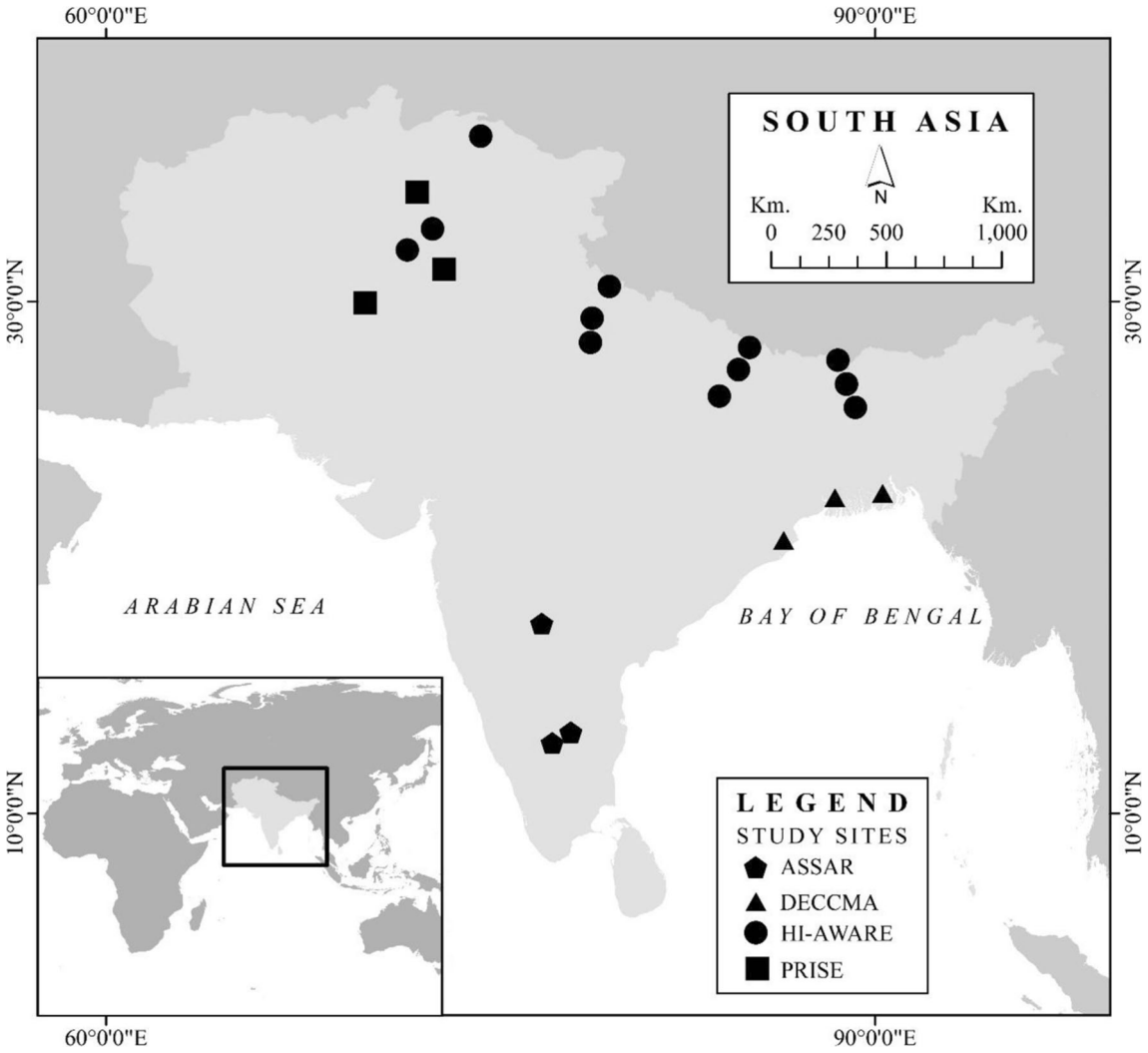

Fig. 2 Location of study hotspots and sites. ASSAR, Adaptation at Scale in Semi-Arid Regions (semi-arid plateau); DECCMA, Deltas, Vulnerability and Climate Change: Migration and Adaptation (deltas); HI-AWARE, Himalayan Adaptation, Water and Resilience (river basins); PRISE, Pathways to Resilience in Semi-Arid Economies (semi-arid plains)

selected to represent up-mid-down-stream areas. DECCMA study sites included deltaic hotspots in the Ganges–Brahmaputra–Meghna (GBM) delta in Bangladesh and India, and the Mahanadi delta in India. It is important to note that the Indian portion of the GBM delta is known as the Indian Bengal delta (IBD) and the area located within Bangladesh is known as the Bangladesh GBM delta. In the Mahanadi delta, the study sites were distributed in five districts. In the IBD, study locations were North 24 Parganas and South 24 Parganas, both districts of West Bengal. Lastly, in the Bangladesh GBM, the sites were spread across 14 districts. PRISE study sites in Pakistan were spread across three districts (D.G. Khan and Faisalabad districts of the Punjab province and Mardan district of the Khyber Pakhtunkhwa (KP) province) and denoted migration in semi-arid plains. In ASSAR, migration was studied along a rural–urban continuum in Karnataka state, south India, denoting semi-arid plateaus as climate hotspots. Migration patterns from 17 villages in Kalaburgi and Kolar districts, 16 peri-urban villages located in the larger Bengaluru Metropolitan Region (BMR), and 31 settlements in Bangalore city were studied.

Data Collection

Primary data across all four study areas were collected during January 2016–September 2017 through a suite of methodological approaches including cross-sectional household surveys that enabled quantifiable and comparable data collection and qualitative life history interviews [24]. The rationale for site selection and sampling approach varied across the four research consortia; however, each consortium focused on capturing the migration profile of household members and the relationship between migration and climate change adaptation. Migration was no only defined as a period of absence

of one or more household members for at least 3 months in the year before the survey but also include migration events of longer duration (> 6 months). A household was classified as migrant household if it had at least one migrant member. The surveys included socioeconomic and demographic indicators as well as comprehensive sections on climate change and its impact, migration drivers, and decision-making and adaptation. In total, 9440 households including migrant and non-migrant households were surveyed across all research areas (2725 households in semi-arid plateaus, 600 in semi-arid plains, 1987 in river basins, and 4115 households in deltas).

In deltas, fifty locations in each study area were selected followed a two-stage cluster sampling design. The first stage of stratification created multi-hazard maps which divided the study areas into five hazard zones (very low, low, medium, high, very high) based on normalizing the hazard score and dividing into quintiles. Each cluster of households in the study area was assigned one of five hazard categories based on the modal risk category. For each multi-hazard zone, the number of clusters was selected proportional to the number of clusters in that zone. Once clusters had been selected, a household listing allowed randomized sampling.

In semi-arid plateaus, within the chosen districts, blocks were chosen purposively based on repeated scoping visits, secondary data analysis to ascertain migration patterns, land use change, and livelihood shifts. Within each block, households were selected using stratified random sampling and questionnaires conducted with household heads. The quantitative surveys were supplemented with detailed village-level settlement histories, gender differentiated Focus Group Discussions (two/settlement), and life history interviews (see [86] for details).

In the river basins, the study area consists of four river basins: the Indus, Upper Ganga, Gandaki, and Teesta. To ensure the representation of different altitudes in the study area, study sites from up-, mid-, and down-stream areas of all rivers basins were included in this study. The study follows a stratified sampling design. In each stratum, districts, study settlements within districts, and households were selected randomly. Similarly, in semi-arid plains, a stratified random sampling technique was used to collect data from rural areas of three semi-arid districts of Pakistan. The whole sample was stratified into four livelihood categories of households; small-landholders (with less than 12.5 acres of land), large landholders (with more than 12.5 acres of land), and non-farm households. To cover the qualitative aspect, 12 gender sensitive focus group discussions (FGDs) were also conducted.

Questionnaires for each site were designed independently to address the context-specific research questions in each area. However, all four surveys derive and generate knowledge based on people's understandings and perceptions of changing climatic conditions as the starting point, and locate migration within a broader array of adaptation responses. The quantitative nature of each survey instrument allowed us to compare answers to questions that were similar across all four hotspots. However, there are two important limitation of our study—(i) sample size, despite being large, is not representative; therefore, the interpretation of findings beyond the study sites should be done with caution, and (ii) all four surveys were one time cross-sectional questionnaires and do not capture temporal dynamics of migration. However, the questions framed in the questionnaire comparing the present situation with past situations and the qualitative inquiries have managed to capture some longitudinal trends.

Results

Migration and Remittance Profile

Who Migrates?

Across the four hotspots, most migrants were married young men of 21–30 years with secondary or higher education levels (Table 1). This is consistent with migration literature suggesting that older men are less inclined to migrate and educated younger men with limited access to resources and input into household decision processes are more likely to do so [11, 43, 75, 77]. The gender balance in outflows from the study hotspots suggested that household migration remained male dominated. Previous studies have established that gender is an important form of social differentiation that influences migration in developing countries [15]. Migration requires sociocultural acceptance, and economic and physical capacities that are not equally available to women [10, 50]. However, there is diversity in female migration across the study hotpots and sites within the hotspots, with some sites reporting higher proportion than others. For instance, the mountain areas in the Gandaki and Teesta river basins, the Kendrapara and Bhadrak districts of Mahanadi deltas in India, and the Barisal and Khulna divisions of the GBM deltas in Bangladesh reported higher female migration rates. The reason for higher female migration in high mountain areas was the sociocultural acceptance of migration by women, coupled with a comparatively higher education attainment. Many respondents reported better job opportunities and opportunity to pursue further education as the major reason for migration of women. Social norms in high mountain areas are more liberal as compared with stringent patriarchal system followed in the plains. Furthermore, in high mountains, environmental conditions necessitate multi-local livelihoods with established familial and friendship networks in destinations. This social norm makes the acceptance of women's mobility easier. In deltas, destruction of local livelihoods and existential threat from a number of extreme climate events was reported as the major driver for women to migrate. The study areas

Table 1 Profile of migrants in the study hotspots (in percentage)

Features	Semi-arid plateau	Semi-arid plains	Deltas
Sex			
Male	73.6	91.7	83.9
Female	26.4	8.3	16.0
Formal education			
Illiterate	34.1	10.1	6.5
1–6 years of school	17.2	10.7	10.8
7–9 years of school	8.7	15.4	13.8
10 years of school and above	47.9	63.8	68.7
Age group			
20 years and below	4.0	22.4	22.4
21–30 years	43.0	46.4	39.4
31–40 years	23.9	21.3	23.5
41–50 years	16.4	6.4	10.8
50+ years	12.4	3.6	3.6
Marital status			
Single	26.7	48.6	43.5
Married	73.3	50.8	55.1
Separated	-	0.3	0.3
Widowed	-	0.3	1.0

In river basins (HI-AWARE) household surveys, intra-household data were not collected

experienced significant losses and increased household vulnerability from cyclones Sidr 2007, Aila 2009 and Phailin 2014.

Where Do People Migrate and the Role of Remittances

Consistent with national statistics and other studies [36, 41, 77, 104], migration was predominantly internal across the four study hotspots. The prevalent types of movements were daily commuting from peri-urban to urban areas, seasonal/circular migration (< 6 months/year) and long-term migration (> 6 months). International migration was high in certain study sites such as the Gandaki river basin (Nepal), GBM delta in Bangladesh, and Faisalabad district in the semi-arid plains of Pakistan. Among international migrations, the most popular destinations were the oil-rich Gulf countries and Malaysia. This finding is consistent with that of Siddiqui et al. [83]'s assessment in the Hindu Kush Himalayan region. Most migrants worked in informal sectors, usually hired as daily wage labourers in industries such as construction or small-scale retail and hospitality.

Migration affected both origin and destination areas through remittances—financial and social. Remittances, it is argued, can provide flexibility in livelihood options, supply capital for investment, and spread risk [89]. Across our four study hotspots, 80% of migrant households reported receiving remittances (slightly lower in deltas, where 66% of respondents reported receiving remittances). Certain regional differences were observed in deltas. For example, only 48% of households reported receiving remittances in the Mahanadi delta in India against 85% in GBM in Bangladesh. This lower remittance transfer in deltas was associated with a short duration of migration. For example, 82% of migrants in Mahanadi delta moved for less than 6 months, and carried remittance in cash and kind in person. Overall, the average annual remittances from internal migration (USD 543) were much lower than those recorded for international migration (USD 1703) in the study sites.

Remittances have the potential to enable rural households to overcome credit and risk constraints by the spatial diversification of labour and income [90]. Moreover, if invested in modern agricultural technologies, tools and livestock, subsistence farmers can increase their productivity and complete the transition from familial to commercial production, which is instrumental in the diversification of rural economies [9, 62]. It is the capacity to mobilise new resources that can enhance household resilience against the pervasive effects of climate change. However, our empirical evidence suggested that across the four study hotspots, remittances were scantly employed to enhance asset base or invest in income-generating activities locally. For example, in the deltas and semi-arid plains, 89% of surveyed households used remittance income to help pay for food, health, education, debt repayment, and household appliances. Consistent with other studies [34, 56], our empirical evidence suggested that remittances acted as a financial buffer against economic losses, thus

representing reactive (albeit powerful) coping mechanisms during hardships. In the river basins, 17% of households reported using remittances to meet household food and non-food needs during hardship brought about by extreme environmental events.

In addition to financial remittances, migration brought social remittances such as new ideas, knowledge, skills and technologies from destination to origin areas for development in the areas of origin [9, 57]. Empirical evidence across all four study hotspots supported this theory. In deltas, 75% of surveyed households reported benefits from new ideas and knowledge to build adaptive capacities at origin. Similarly, 29% of migrant households in semi-arid plains reported learning new knowledge and skills compared to 20% of non-migrant households. The difference was statistically significant at 5% level of significance. Similarly, labour migrants from semi-arid regions and deltas acquired new skills such as masonry, carpentry, and catering at their destination. As a result, migrants were able to diversify their livelihoods upon returning to place of origin. In the Upper Ganga areas migrants had introduced mobile apps to the communities. These apps provided weather-related information, allowing daily agricultural activities to be planned.

Why Do People Migrate?

Consistent with previous findings on motivations for migration [36, 41, 77, 104], the main driver of migration as reported by migrants across the four study hotspots was economic, often associated with better employment opportunities elsewhere. When asked 'What was the primary reason for migrating?' 55% of respondents in semi-arid plateau, 82% in semi-arid plains, 48% in deltas, and 44% in river basins reported economic reason as the primary reason. Other important reasons reported were to pursue higher education, meet family obligations, diversify from unprofitable agriculture, earn better wages, overcome landlessness, and moving for marriage. These responses revealed that unequal development, leading to lack of economic opportunities and access to basic services, was a major driver for people to move from rural areas to urban areas.

Only 6% of the respondents in deltas and 12% in semi-arid plains cited environmental causes such as drought, flood, cyclones, increased temperature, and erratic rainfall as their main motivation for migration. This result highlighted that, in most cases, households did not identify migration of a household member as being related to the environment. It illustrated, rather, that decisions to migrate were multi-causal, in which economic reasons were the primary motivation. Consistent with previous findings [1, 101], environmental drivers had weak attribution in the migration decisions in the study sites. The discrete research designs employed in this study had certain limitations which inhibited the capture of environmental attributes to migration. As previous studies suggest, it is difficult to measure the relative significance of environmental factors vis-á-vis other drivers in labour migration [14]. This was particularly true in cases where empirical evidence was collected via cross-sectional surveys in sending areas. Direct causal signals are stronger in displacement or permanent relocation following sudden-onset environmental hazards. However, recently emerging literature with methodology to capture household's perceptions regarding climate change and household migration decision paves new ways to investigate this linkage [54, 55].

Barriers to Migration

Across the four study hotspots, migration was not always available to households exposed to environmental stressors. The proportion of households that reported migration of one or more members was only 29% in the river basins, 41% in semi-arid plains, 39% in semi-arid plateaus, and 24% in deltas. There were several barriers to migration. Sociocultural norms, household composition, and intra-household work sharing norms made migration a highly gendered process, typically curtailing women migrating [46]. In the study hotspots, lack of financial capital and social network in destination were the most prevalent barriers. In case of Pakistan (Indus river basin and semi-arid plains), having sufficient male adults in the household to send for migration was reported as another important barrier. Lack of access to safe accommodation in destination areas and constant preoccupation about maintaining family commitments in places of origin were reported as significant constraints preventing women migration during the focus group discussion in Bangladesh deltas. Marital status was also highlighted by respondents, with married women enjoying more autonomy to migrate compared with single women.

The barriers discussed above have limited migration as a response to climate change in the study areas. Many surveyed respondents mentioned the desire to diversify their income sources by adding migration into their livelihood portfolio. In the semi-arid plains and deltas, for example, the proportion of immobile households was 59% and 35%, respectively.

Migration for Household Adaptation

There is a growing body of literature on climate change adaptation and its effect on reducing vulnerability to climate change impacts at household levels [27, 70]. Research endeavours in measuring adaptation have focused heavily on assessing the vulnerability or adaptive capacity through various indices [38, 45]. But linking migration to adaptation outcomes is complex with changes over temporal and spatial dimensions being critical [35, 64, 104]. The research analysis conducted by the four CARIAA consortia employed a suite of

analytical tools to examine this relationship in the study hotspots. HI-AWARE examines the adaptation behaviour of the households, DECCMA analyses the differences in adaptation measures of households, PRISE assesses the difference in livelihood resilience of the households, and ASSAR examines changes in the material and subjective well-being of migrant households. Each analytical tool offers a different lens in the migration and household adaptation interlinkages. While the different analytical tools employed make it challenging to compare the results directly across the hotspots, we report the key findings on the implications of migration for household adaptation and attempt to synthesize them. In each section, we briefly describe data and analysis techniques employed in each study hotspot followed by key findings. We highlight that in this synthesis report, we present findings derived from both quantitative and qualitative data and analytical techniques.

River Basins

In the river basins, we examined the adaptation behaviour of households to climate change impacts separated by migration status (migrant and non-migrant households) of the household in four crucial livelihoods sectors—agriculture, livestock, water, and forest. Households were classified as adaptors or non-adaptors—adaptors were households that had reported undertaking at least one measure to reduce the negative impacts of climate change in the particular sector in the year prior to the data collection. A household was categorised as migrant if it had at least one member involved in labour migration for at least 3 months in the year prior to the data collection. The statistical relationship between adaption behaviour and migration status was tested using Pearson chi-square test of independence in the four livelihood sectors. Test results showed that in agriculture sector, migration played a statistically significant role in adaption behaviour of households (Table 2). In other sectors, the differences were statistically not significant. For majority of the households in the study sites, agriculture was a major economic sector and households depended on farm production to meet their food security. This probably explains the reason for migrant households' investment on adaptation measures in agriculture sector. The most commonly used adaptation measures in agriculture were introduction of new crop varieties, use of pesticide/insecticides, adjustment of timing, improved irrigation, shifting to non-farm activities, etc.

Although more than 90% of households perceived changes in climate as compared with situations a decade before, less than one-third of the households reported undertaking adaptation measures to reduce the negative impacts of such changes. Overall, higher proportion of households reported undertaking at least one adaptation measure in agriculture and water sector and least in forest sector. Consistent with findings of Hussain et al. [44] in the Koshi river basin, most of the adaptation measures undertaken by households were autonomous rather than planned. This illustrates the importance of identifying and verifying the autonomous local adaptation practices; however, they might be unable to manage new risks and extreme changes in future [65].

Deltas

The analytical approach in deltas was two-pronged, examining (1) who were migrating as an adaptation response to climate change (assessed through exposure to floods, droughts, sea level rise, erosion, and salinity), and whether or not they deemed that to be a successful adaptation; and (2) differences in adaptation measures adopted by migrant and non-migrant households using Chi-square tests to see if there were statistically significant differences.

Migration was an adaptation response in all three deltas: by 28% of households in Bangladesh; 53.3% in the Indian Bengal delta; and 23% in the Mahanadi. Interestingly, though, migration was not among the top three strategies considered successful adaptations in any of the deltas. Temporary mobility associated with production-related moves was also captured in the survey by way of people reporting work outside the village. Such an adaptation response was mentioned widely by between 51 and 71% of respondents across the three deltas.

Table 3 shows results for the most prevalent adaptation responses. The statistically significant differences between migrant and non-migrant households relate to the use of adaptations that were finance-related. In terms of increasing income to the household, more migrant households took loans in the Indian Bengal, Mahanadi, and the Bangladesh portion of the GBM deltas. This may have been because remittances could act as a guarantee for such loans. Migrant households

Table 2 Household reporting adaptation to climate change by migration status

Sector	Non-migrant households	Migrant households	*p* values for Pearson Chi^2 test
Agriculture	28	32	0.033**
Livestock	16	15	0.630
Forest	7	8	0.454
Water	36	34	0.346

**Significant levels at 5% levels for chi-square test

Table 3 Most prevalent adaptation responses for migrant and non-migrant households

Adaptation	Non-migrant household (%)			Migrant household (%)			*p* value		
	IBD	MD	BD	IBD	MD	BD	IBD	MD	BD
Taking out a loan	47.2	43.5	70.2	63.6	51.0	72.5	0.001***	0.020*	0.375
Modifications to the house	39.9	33.2	60.3	51.7	41.3	62.6	0.001***	0.008**	0.423
Work outside the village	8.2	16.0	5.0	61.0	51.6	71.6	0.001***	0.001***	0.001***

*** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$

also adapted by modifying their homes: for example, by constructing more permanent structures that better withstood flooding and cyclones. This was an important adaptation in deltas, and qualitative interviews in the Indian Bengal delta indicated that this was one of the primary priorities of households.

In Bangladesh, however, it is important to note that there was only a marginal (statistically insignificant) difference between migrant and non-migrant households in terms of taking out loans. This was likely to have been because of widespread household access to microfinance. Bangladesh has been a pioneer in microfinance operations since 1980 [52]. Work outside the village was the only adaptation response that recorded statistically significant differences across the three deltas. Although the survey did not capture the type of mobility associated with that answer, there was a wide range of temporary moves including daily, weekly, and circular trips. In practice, that underpins the livelihoods of people worldwide, and this is particularly the case for smallholder and subsistence farmers living in marginal environmental conditions. Such movements occur for a wide range of reasons including labour and economic motivations.

In contrast, there was no statistically significant difference between migrant and non-migrant households in the use of livelihood-based adaptations, for example diversifying crops; planting climate-tolerant crops; increasing use of irrigation; or using new farming and fishing equipment in the Indian Bengal, Mahanadi, and Bangladesh deltas.

Semi-arid Plains

The approach in the semi-arid plains sought to understand the relationship between migration and resilience by using a livelihood resilience index. The study defines livelihood resilience as 'the capacity of all people across generations to sustain and improve their livelihood opportunities and wellbeing despite environmental, economic, social and political disturbances' [95]. The resilience index was constructed following the method developed by Cutter et al. [25]. Livelihood resilience index is composed of three components: adaptive, absorptive, and anticipatory capacity. Following Bahadur et al. [8], adaptive capacity is defined as the ability of social system to adapt to multiple, long-term, and future climate change risks, and also to learn and adjust after a disaster, Similarly, anticipatory capacity as the ability of social systems to anticipate and reduce the impact of climate variability extremes through preparedness and planning capacities, and absorptive capacity as the ability of social systems to absorb and cope with the impacts of climate variability and extremes. Each component is further divided into sub-components (see Bahadur et al. [8] for detail). Indicators defining the three types of capacities were selected through a careful literature review and customised to match the local context of the study areas.

We found that overall migrant households were more resilient than non-migrant households and they scored better than non-migrant households in all the three components (Fig. 3). They had greater adaptability to shocks as a result of higher and more diversified income sources, better housing, and a higher employment rate. Migrant households also had higher levels of subjective well-being, as they were more comfortable in coping with stressors, more at ease in making life decisions and were exposed to a wider range of opportunities to learn new skills and improve their livelihoods. They were also more adept at planning for the future, more informed about climate change impacts, and had higher capacities to anticipate and deal with shocks such as climate extremes and food insecurity [78].

Semi-arid Plateau

In the semi-arid plateau sites, in addition to the household surveys, life history interviews ($n = 37$ across rural, peri-urban, and urban sites) were used to examine temporal vulnerability and changes in the material and subjective well-being of migrant households across the rural–urban continuum [84, 85]. These life histories were supplemented by historical timelines to reconstruct local ecological, socioeconomic, and politico-institutional changes, and consequent livelihood dynamics. The in-depth life histories analysed 'family trajectories of accumulation or impoverishment over time and of particular matrices of vulnerability' ([67]: 489) and thus

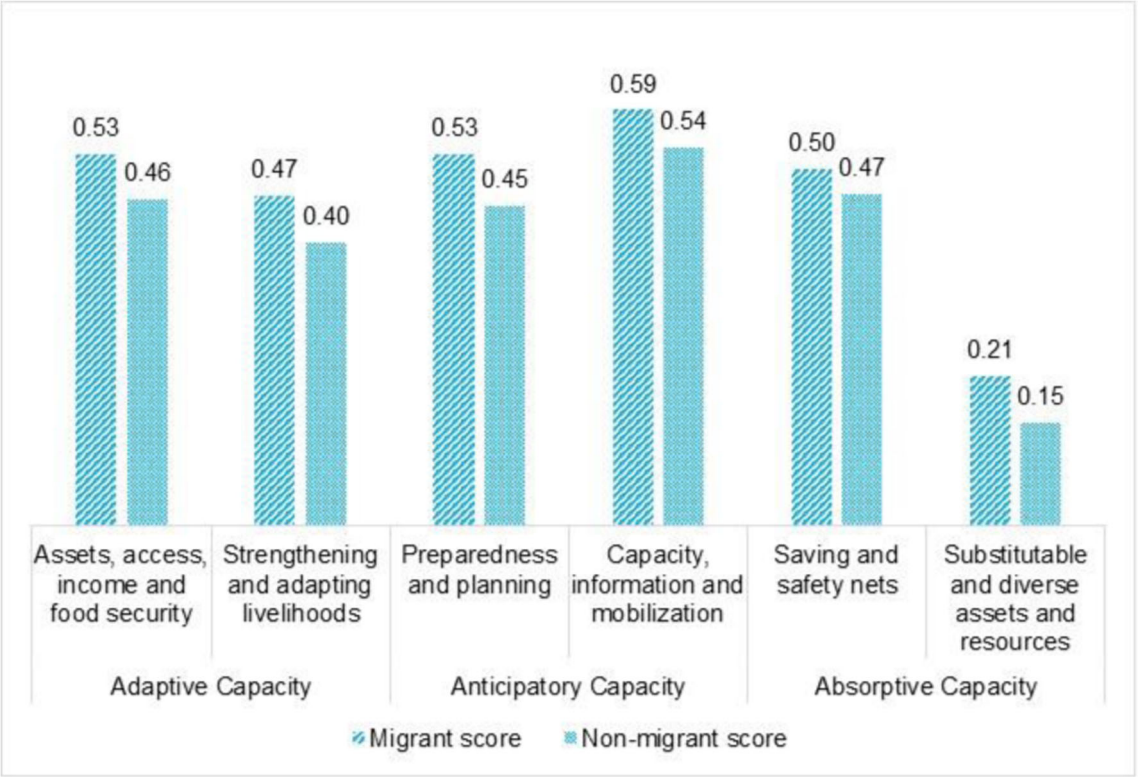

Fig. 3 Resilience index scores by household migration status in semi-arid regions of Pakistan

constructed an understanding around temporal vulnerability and how households followed '(household) trajectories towards vulnerability or resilience' ([79]: 3). These narratives also allowed a nuanced inquiry into how personal and family aspirations, asset constraints, and needs interacted with social norms, agency, and larger-scale institutional and economic changes to shape livelihood choices [86].

Migrant life histories demonstrated that permanent migration, especially accompanied by accumulation of education, skills, and social capital can, over a period of time, be a positive adaptive response, expressed through increased incomes, better living facilities, improved access to services, and lower exposure to extreme events as compared with where they moved from [85]. However, we also found instances where permanent migration was also detrimental, especially when there was inadequate employment or poor living conditions associated with tenure insecurity in destination areas, entering into unsafe livelihoods, or living in flood-prone areas in the cities they moved to [63]. Critically, the life histories demonstrated that the outcomes of migration decisions change over time with some houses improving their assets and capabilities and hence adaptive capacities while others (typically those with poor social networks, low assets, and belonging to marginalized social groups) remaining trapped in cycles of coping. Furthermore, migration outcomes were differentiated within the household, with men and women within migrating household reporting differential impacts on well-being. In keeping with previous research (e.g. [12]), women reported higher work burdens and reduced time for leisure once they moved. However, there were also examples contradicting perceptions of gendered migration: in peri-urban areas, women reported migration improving subjective well-being and adaptive capacities through improved incomes, more autonomy, and changing intra-household gender relations [74].

Discussion

To test the implications of migration for adaptation, this study assessed the role of financial remittances as an indicator of enhanced resilience and well-being. Literature on migration and development is rich with insights about how remittances support households facing environmental shocks [5, 81]. Our findings suggest that migration enhanced household adaptation (e.g. in river basins) and livelihood resilience (e.g. in semi-arid plains), thus fulfilling the potential to be a strategy to move households from a position of vulnerability to enhanced resilience (e.g. in semi-arid plateau). Remittances were an important factor in assessing migration outcomes for climate change adaptation. When mainly used by households to meet basic needs, such as food and non-food consumption, remittances support coping with climate stressors, suggesting that migration is a shot-term response strategy. On the other hand, when remittances are used to build household assets,

leading to long-term sustainability, migration can be a pathway to successful adaptation to the adverse effects of climate-related hazards [104].

In general, across the four hotspots examined in this study, financial remittances were small and mostly used to meet household food consumption, with limited investment or increase in asset base. However, our findings from the deltas and semi-arid plains showed that migration can contribute to an overall increase in household income (e.g. access to loan, using remittance as a guarantee). The additional increased income (both loan and remittances) was then used to enhance household resilience, for example through improvements in house infrastructure. Thus, we suggest that, at present, migration represents a form of response to climate change rather than a long-term adaptation strategy. This is also reflected in the self-assessment of migration as an adaptation strategy by the delta households themselves.

When seen through the lens of well-being (material and subjective) as done in the semi-arid plateaus, migration was found to improve material well-being (e.g. through higher incomes) but dampen subjective well-being (e.g. lower social capital in destination areas, feelings of alienation and insecurity, lesser leisure, especially for women) [75, 85–87]. These findings demonstrate that while remittances help migrating households and can have adaptation co-benefits, moving entails other intangible costs which can in certain conditions increase vulnerability and at other times improve adaptive capacity.

By employing different methodological approaches to assess migration and adaptation linkages, we were able to unpack the complex ways in which migration influence household adaptation in climate hotspots. Overall, our study findings provides a strong evidence that irrespective of reason for migration, labour migration can positively contribute to the household adaptation to climate change impacts. Migration can contribute positively to household adaptation capacity, provided there is policy support to improve the overall outcomes of migration and more planned adaptation locally (Fig. 4). Migration outcomes can be improved by building the human capital of migrants (skills, health, education), reducing cost of migration and remittance transfer, and improving safety nets for migrants at destination [40].

While there may be economic benefits of migration in terms of remittances, we cannot overlook their social costs in terms of the splitting up of families. Permanent relocation or temporary migration, such as household members working outside the village, typically occurred to generate more income. This meant that migrant households increased their financial capital, which could be substituted for other forms of capital (such as physical capital in the case of modifications to the house) which enabled better adaptation. However, interviews with migrants and migrant households across the study hotspots highlighted the negative effects of splitting up families (e.g. marriage breakdown and poor performance of children in school). As most migrants were men, there was an increase in the responsibility and labour burden for women left behind. Women were de facto responsible for all household and field work, but with limited capacities to undertake these new roles. This represents an important research dimension for future consideration, with important implications for adaptation policy and planning.

Conclusion

Analysing novel large empirical datasets in climate hotspots across Nepal, India, Bangladesh, and Pakistan, this paper contributes to the empirical evidence on migration and climate change adaptation. The study argues that migration is an important livelihood strategy as a response to various stressors, including climatic risks such as higher rainfall variability, cyclones, storm surges, and drought, and non-climatic factors

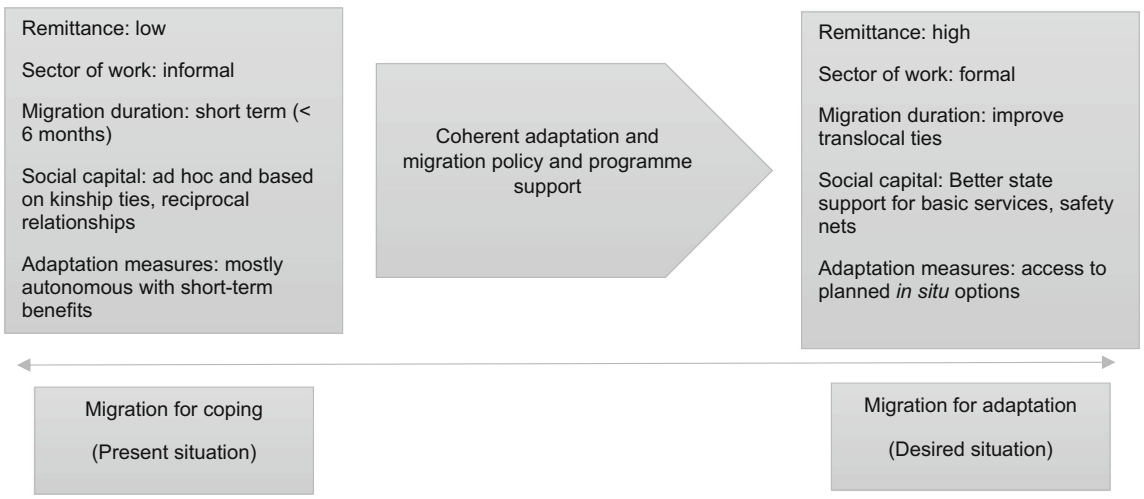

Fig. 4 Migration pathway from coping to adaptation strategy

such as changing aspirations, economic recessions, and regional underdevelopment. Households with available resources send one or more members (often young men) for labour migration, to diversify livelihoods. In return, migrants send home remittances that help to spatially diversify household income and improve access to credit. This helps spread risks and self-insure against the effects of climate change and other non-climatic risks. However, migration is not a strategy that is available to everyone because of various barriers such as sociocultural norms and financial capacities ("Barriers to migration" section). This inhibits the migration capacity of women and historically marginalised households (e.g. on the basis of caste, ethnicity).

Our findings suggest that households in vulnerable areas use migration as a strategy to cope with the adverse effects of climate change and non-climatic risks. However, it is important to stress that migration entails risks for individuals and households. Without achieving positive outcomes that increase the resilience of households or effectively increasing vulnerability of the migrant at destination migration can be an erosive adaptation strategy. Thus, we argue that there is a need for policy and institutional coherence and collaboration to account for the contributions of migration in adapting to climate change. It is important for institutions responsible for the design and implementation of policies addressing climate change and migration issues to have a comprehensive understanding of how migration and adaptation interact, and ultimately to develop migration as a successful adaptation strategy. Lastly, the burden of adapting to the adverse effects of climate change should not lie on the shoulders of migrants. Governments should take the responsibility for building the adaptive capacity of people, and migration could be one of the options.

We identified two important issues that could be addressed by future research: (1) this study did not capture migration of entire households from the origin areas, and (2) involuntary permanently displaced individuals and households, as well as planned relocation initiatives directly attributed to extreme rapid onset climatic events were also not considered. These are important categories of population movements with implications for both material and subjective well-being of individuals and households which deserve careful consideration by both researchers and practitioners.

Compliance with Ethical Standards

Conflict of Interest On behalf of all authors, the corresponding author states that there is no conflict of interest.

Human and Animal Rights and Informed Consent This article does not contain any studies with human or animal subjects performed by any of the authors.

Open Access This article is licensed under a Creative Commons Attribution 4.0 International License, which permits use, sharing, adaptation, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons licence, and indicate if changes were made. The images or other third party material in this article are included in the article's Creative Commons licence, unless indicated otherwise in a credit line to the material. If material is not included in the article's Creative Commons licence and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder. To view a copy of this licence, visit http://creativecommons.org/licenses/by/4.0/.

References

1. Abu M, Codjoe SNA, Sward J. Climate change and internal migration intentions in the forest-savannah transition zone of Ghana. Popul Environ. 2014;35:341–64. https://doi.org/10.1007/s11111-013-0191-y.
2. Adger W, Arnell N, Black R, Dercon S, Geddes A, Thomas D. Focus on environmental risks and migration: causes and consequences. Environ Res Lett. 2015;10:60201. https://doi.org/10.1088/1748-9326/10/6/060201.
3. Adger WN, Barnett J, Brown K, Marshall N, O'Brien K. Cultural dimensions of climate change impacts and adaptation. Nat Clim Chang. 2013;3:112–7. https://doi.org/10.1038/nclimate1666.
4. Adger WN, Eakin H, Winkels A. Nested and teleconnected vulnerabilities to environmental change. Front Ecol Environ. 2009;7:150–7. https://doi.org/10.1890/070148.
5. Adger WN, Huq S, Brown K, Conway D, Hulme M, Adger N. Adaptation to climate change: setting the agenda for development policy and research. Prog Dev Stud. 2002;3(3):179–95.
6. Adger WN, Pulhin JM, Barnett J, Dabelko GD, Hovelsrud GK, Levy M, et al. Human security. In: Climate change 2014: impacts, adaptation, and vulnerability. Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge: Cambridge University Press; 2014. p. 755–91.
7. Afifi T, Milan A, Etzold B, Schraven B, Rademacher-Schulz C, Sakdapolrak P, et al. Human mobility in response to rainfall variability: opportunities for migration as a successful adaptation strategy in eight case studies. Migr Dev. 2016;5:254–74. https://doi.org/10.1080/21632324.2015.1022974.
8. Bahadur AV, Peters K, Wilkinson E, Pichon F, Gray K, Tanner T. The 3As: tracking resilience across BRACED. London: Overseas Development Institute (ODI), 2015. https://www.odi.org/publications/9840-3as-tracking-resilience-acrossbraced.
9. Barnett J, Webber M. Accommodating migration to promote adaptation to climate change. Policy Brief prepared for the Secretariat of the Swedish Commission on Climate Change and Development and the World Bank World Development Report 2010: Development and Climate Change, 2009. 10.1596/1813-9450-5270.
10. Belay A, Recha JW, Woldeamanuel T, Morton JF. Smallholder farmers' adaptation to climate change and determinants of their adaptation decisions in the Central Rift Valley of Ethiopia. Agri Food Secur. 2017;6:1–13. https://doi.org/10.1186/s40066-017-0100-1.
11. Bernard A, Bell M, Charles-Edwards E. Life-course transitions and the age profile of internal migration. Popul Dev Rev. 2014;40:213–39. https://doi.org/10.1111/j.1728-4457.2014.00671.x.

12. Bhagat R. Migration, gender and right to the city. Econ Polit Wkly. 2017;LII:35–40.
13. Bhatta GD, Aggarwal PK, Poudel S, Belgrave DA. Climate-induced migration in South Asia: migration decisions and the gender dimensions of adverse climatic events. J Rural Com Dev. 2016:10(4).
14. Black R, Adger WN, Arnell NW, Dercon S, Geddes A, Thomas D. The effect of environmental change on human migration. Glob Environ Chang. 2011;20:S3–S11. https://doi.org/10.1016/j.gloenvcha.2011.10.001.
15. Boyle P, Halfacree K. Migration and gender in the developed world. Abingdon: Routledge; 2002.
16. Byers E, Gidden E, Leclêre D, Balkovic J, Burek P, Ebi K, et al. Global exposure and vulnerability to multi-sector development and climate change hotspots. Environ Res Lett. 2018;13:055012. https://doi.org/10.1088/1748-9326/aabf45.
17. Call MA, Gray C, Yunus M, Emch M. Disruption, not displacement: environmental variability and temporary migration in Bangladesh. Glob Environ Chang. 2017;46:157–65.
18. Campbell R, Leviston Z, Horwitz P, Dandy J, Drake D. Leaving home: place attachment and decisions to move in the face of environmental change. Reg Environ Chang. 2019;19:15–620. https://doi.org/10.1007/s10113-019-01463-1.
19. Carr ER. Placing the environment in migration: environment, economy, and power in Ghana's Central Environ and Planning A 2005:37: 925–946. doi: https://doi.org/10.1068/a3754.
20. Carter TR, Parry ML, Harasawa H, Nishioka S. IPCC technical guidelines for assessing climate change impacts and adaptations. London: Department of Geography, University College London; 1994.
21. Castles S. Migration and community formation under conditions of globalization. Int Migr Rev. 2002;36:1143–68. https://doi.org/10.1111/j.1747-7379.2002.tb00121.x.
22. Chapagain B, Gentle P. Withdrawing from agrarian livelihoods: environmental migration in Nepal. J Mt Sci. 2015;12(1):1–13. https://doi.org/10.1007/s11629-014-3017-1.
23. Chen J, Mueller V. Coastal climate change, soil salinity and human migration in Bangladesh. Nat Clim Chang. 2018;8(11):981–5.
24. Conway D, Nicholls RJ, Brown S, Tebboth MGL, Adger NW, Ahmad B, et al. The need for bottom-up assessments of climate risks and adaptation in climate-sensitive regions. Nat Clim Chang. 2019;9:503–11. https://doi.org/10.1038/s41558-019-0502-0.
25. Cutter S, Burton C, Emrich C, 2010. Disaster resilience indicators for benchmarking baseline conditions. J. of Homeland Security and Emergency Management 2010:51:7(1). http://dx.doi.org/10.2202/1547-7355.1732
26. Dallmann I, Millock K. Climate variability and inter-state migration in India. CESifo Econ Stud. 2017;63(4):560–94.
27. Deressa TT, Hassan RM, Ringler C, Alemu T, Yesuf M. Determinants of farmers' choice of adaptation methods to climate change in the Nile basin of Ethiopia. Glob Environ Chang. 2009;19:248–55.
28. de Sherbinin A. Climate change hotspots mapping: what have we learned? Clim Chang. 2014;123:23–37. https://doi.org/10.1007/s10584-013-0900-7.
29. De Souza K, Kituyi E, Harvey B, Leone M, Murali KS, Ford JD. Vulnerability to climate change in three hot spots in Africa and Asia: key issues for policy-relevant adaptation and resilience-building research. Reg Environ Chang. 2015;15:747–53. https://doi.org/10.1007/s10113-015-0755-8.
30. Deshingkar P, Farrington J. Rural labour markets and migration in South Asia: evidences from India and Bangladesh. In: Background paper for the World Development Report 2008. London: Overseas Development Institute; 2006.
31. Ellis F. The determinants of rural livelihood diversification in developing countries. J Agric Econ. 2000;51:289–302. https://doi.org/10.1111/j.1477-9552.2000.tb01229.x.
32. Fankhauser S, Smith JB, Tol RSJ. Weathering climate change: some simple rules to guide adaptation decisions. Ecol Econ. 1999;30:67–78.
33. Fidrmuc J. Migration and regional adjustment to asymmetric shocks in transition economies. J Comp Econ. 2004;32(2):230–47.
34. Foresight. Migration and global environmental change: final project report. London: The Government Office for Science; 2011.
35. Gemenne F, Blocher J. How can migration serve adaptation to climate change? Challenges to fleshing out a policy ideal. Geogr J. 2017;183:336–47. https://doi.org/10.1111/geoj.12205.
36. Gioli G, Khan T, Bisht S, Scheffran J. Migration as an adaptation strategy and its gendered implications: a case study from the Upper Indus Basin. Mt Res Dev. 2014;34:255–65. https://doi.org/10.1659/MRD-JOURNAL-D-13-00089.1.
37. Gray CL, Mueller V. Natural disasters and population mobility in Bangladesh. Proc Natl Acad Sci. 2012;109:6000–5. https://doi.org/10.1073/pnas.1115944109.
38. Hahn MB, Riederer AM, Foster SO. The livelihood vulnerability index: a pragmatic approach to assessing risks from climate variability and change – a case study in Mozambique. Glob Environ Chang. 2009;19:74–88.
39. Haque MS. Migration trends and patterns in South Asia and management approaches and initiatives. Asia-Pac Popul J. 2005;20(3):39.
40. Harkins B, Lindgren D, Suravoranon T. Risks and rewards: outcomes of labour migration in South-East Asia. Internatonal Labour Organization and International Organization for Migration, Thailand, 2017.
41. Hugo G. Environmental concerns and international migration. Int Migr Rev. 1996;30:105–31 https://doi.org/10.1177/019791839603000110.
42. Hugo G, Bardsley DK. Migration and environmental change in Asia. In: Piguet E, Laczko F, editors. People on the move in a changing climate: the regional impact of environmental change on migration. Dordrecht: Springer; 2014. https://doi.org/10.1007/978-94-007-6985-4.
43. Hunter LM, Luna JK, Norton RM. Environmental dimensions of migration. Annu Rev Sociol. 2015;41:377–97. https://doi.org/10.1146/annurev-soc-073014-112223.
44. Hussain A, Rasul G, Mahapatra B, Wahid S, Tuladhar S. Climate change-induced hazards and local adaptations in agriculture: a study from Koshi River Basin, Nepal. Nat Hazard. 2018;91:1365–83. https://doi.org/10.1007/s11069-018-3187-1.
45. Iglesias A, Quiroga S, Diz A. Looking into the future of agriculture in a changing climate. Eur Rev Agric Econ. 2011;38(3):427–47.
46. IOM. Gender and labour migration in Asia. International Organization for Migration, Geneva, Switzerland, IOM publications, 2009. https://publications.iom.int/books/gender-and-labour-migration-asia.
47. IOM. Assessing the climate change environmental degradation and migration nexus in South Asia. International Organization for Migration (IOM) Bangladesh, IOM publication, 2016. https://publications.iom.int/books/assessing-climate-change-environmental-degradation-and-migration-nexus-south-asia.
48. IPCC. Climate change 2014: synthesis report. In: Pachauri RK, Meyer LA, editors. Contribution of working groups I, II and III to the fifth assessment report of the Intergovernmental Panel on Climate Change. Geneva: IPCC; 2014.
49. Jacobson C, Crevello S, Chea C, Jarihani B. When is migration a maladaptive response to climate change? Reg Environ Chang. 2019;19:101–12. https://doi.org/10.1007/s10113-018-1387-6.

50. Jost C, Kyazze F, Naab J, Neelormi S, Kinyangi J, Zougmore R, et al. Understanding gender dimensions of agriculture and climate change in smallholder farming communities. Clim Dev. 2016;8(2):133–44. https://doi.org/10.1080/17565529.2015.1050978.
51. Khadria B. Migration in South and South-West Asia. Geneva: Global Commission on International Migration; 2005.
52. Khandker SR. Microfinance and poverty: evidence using panel data from Bangladesh. World Bank Econ Rev. 2005;19(2):263–86.
53. Krishnan R, Shrestha AB, Ren G, Rajbhandari R, Saeed S, Sanjay J, et al. Unravelling climate change in the Hindu Kush Himalaya: rapid warming in the mountains and increasing extremes. In: Wester P, Mishra A, Mukherji A, Shrestha AB, editors. The Hindu Kush Himalaya assessment—mountains, climate change, sustainability and people. Cham: Springer Nature Switzerland AG; 2019.
54. Koubi V, Spilker G, Schaffer L, Böhmelt T. The role of environmental perceptions in migration decision-making: evidence from both migrants and non-migrants in five developing countries. Popul Environ. 2016a;38(2):134–63. https://doi.org/10.1007/s11111-016-0258-7.
55. Koubi V, Spilker G, Schaffer L, Bernauer T. Environmental stressors and migration: evidence from Vietnam. World Dev. 2016b;79:197–210.
56. Le De L, Gaillard JC, Friesen W. Remittances and disaster: a review. Int J Disaster Risk Reduct. 2013;4:34–43. https://doi.org/10.1016/j.ijdrr.2013.03.007.
57. Levitt P, Lamba-Nieves D. Social remittances revisited. J Ethn Migr Stud. 2011;37(1):1–22.
58. Mani M, Bandyopadhyay S, Chonabayashi S, Markandya A, Mosier T. South Asia's Hotspots—The Impact of Temperature and Precipitation Changes on Living Standards. The World Bank: Washington, DC, USA, 2018, ISBN 9781464811555.
59. Martin M, Billah M, Siddiqui T, Abrar C, Black R, Kniveton D. Climate-related migration in rural Bangladesh: a behavioural model. Popul Environ. 2014;36:85–110. https://doi.org/10.1007/s11111-014-0207-2.
60. McLeman R. Thresholds in climate migration. Popul Environ. 2018;39(4):319–38.
61. McLeman R, Smit B. Migration as an adaptation to climate change. Clim Chang. 2006;76:31–53. https://doi.org/10.1007/s10584-005-9000-7.
62. Mendola M. Migration and technological change in rural households: complements or substitutes? J Dev Econ. 2008;85:150–75. https://doi.org/10.1016/j.jdeveco.2006.07.003.
63. Michael K, Deshpande T, Ziervogel G. Examining vulnerability in a dynamic urban setting: the case of Bangalore's interstate migrant waste pickers. Clim Dev. 2018;11(8):1–12. https://doi.org/10.1080/17565529.2018.1531745.
64. Milan A, Gioli G, Afifi T. Migration and global environmental change: methodological lessons from mountain areas of the global south. Earth Syst Dynam. 2015;6:375. https://doi.org/10.5194/esd-6-375-2015.
65. Mishra A, Appadurai AN, Choudhury D, Regmi BR, Kelkar U, Alam M, et al. Adaptation to climate change: stronger action urgently needed. In: Wester P, Mishra A, Mukherji A, Shrestha AB, editors. The Hindu Kush Himalaya assessment—mountains, climate change, sustainability and people. Cham: Springer Nature Switzerland AG; 2019.
66. Mortreux C, Barnett J. Climate change, migration and adaptation in Funafuti, Tuvalu. Glob Environ Chang. 2009;19:105–12. https://doi.org/10.1016/j.gloenvcha.2008.09.006.
67. Murray C. Livelihoods research: transcending boundaries of time and space. J South Afr Stud. 2002;28(3):489–509 https://doi.org/10.1080/0305707022000006486.
68. Nawrotzki RJ, Riosmena F, Hunter LM. Do rainfall deficits predict US-bound migration from rural Mexico? Evidence from the Mexican census. Popul Res Policy Rev. 2013;32(1):129–58.
69. Ng'ang'a SK, Bulte EH, Giller KE, McIntire JM, Rufino MC. Migration and self-protection against climate change: a case study of Samburu County, Kenya. World Dev. 2016;84:55–68. https://doi.org/10.1016/j.worlddev.2016.04.002.
70. Nhemachena C, Hassan R. Micro-level analysis of farmers' adaptation to climate change in Southern Africa. IFPRI Discussion Paper No. 00714. Washington, D.C.: International Food Policy Research Institute; 2007.
71. Nicholls RJ, Wong PP, Burkett V, Woodroffe CD, Hay J. Climate change and coastal vulnerability assessment: scenarios for integrated assessment. Sustain Sci. 2008;3:9–102. https://doi.org/10.1007/s11625-008-0050-4.
72. Patel A, Giri J. Climate change, migration and women: analysing construction workers in Odisha. Soc Change. 2019;1:97–113. https://doi.org/10.1177/0049085718821756.
73. Penning-Rowsell EC, Sultana P, Thompson PM. The 'last resort'? Population movement in response to climate-related hazards in Bangladesh. Environ Sci Pol. 2013;27:S44–59. https://doi.org/10.1016/j.envsci.2012.03.009.
74. Poonacha P, Rai Chowdhury A, Kaur H. Gendered dimensions of periurban transitions in the Bangalore metropolitan region – implications for adaptive capacities of households. Cape Town: ASSAR Short Report; 2018.
75. Rao N, Singh C, Solomon D, Camfield L, Sidiki R, Angula M, et al. Managing risk, changing aspirations and household dynamics: implications from wellbeing and adaptation in semi-arid Africa and India. World Dev. 2020;125:104667. https://doi.org/10.1016/j.worlddev.2019.104667.
76. Renaud FG, Bogardi J, Dun O, Warner K. Control, adapt or flee: how to face environmental migration? Bonn: United Nations University, Institute for Environment and Human Security; 2007.
77. Rigaud KK, de Sherbinin A, Jones B, Bergmann J, Clement V, Ober K, et al. Groundswell: preparing for internal climate migration. Washington, DC: World Bank; 2018. https://openknowledge.worldbank.org/handle/10986/29461
78. Salik KM, Qaisrani A, Umar MA, Ali SM. Migration futures in Asia and Africa: economic opportunities and distributional effects – the case of Pakistan. Pathways to Resilience in Semi-arid Economies (PRISE) working paper, 2017.
79. Sallu SM, Twyman C, Stringer LC. Resilient or vulnerable livelihoods? Assessing livelihood dynamics and trajectories in rural Botswana. Ecol Soc. 2010;15(4):3 http://www.ecologyandsociety.org/vol15/iss4/art3/.
80. Seddon D. South Asian remittances: implications for development. Contemp South Asia. 2004;13(4):403–20.
81. Scheffran J, Brzoska M, Kominek J, Link PM, Schilling J. Climate change and violent conflict. Science. 2012;336(6083):869–71.
82. Scheffran J, Marmer E, Sow P. Migration as a contribution to resilience and innovation in climate adaptation: social networks and co-development in Northwest Africa. Appl Geogr. 2011;33:119–27. https://doi.org/10.1016/j.apgeog.2011.10.002.
83. Siddique T, Bhagat RB, Banerjee S, Liu C, Sijapati B, Memon R, et al. Migration in the Hindu Kush Himalayan region: drivers, consequences, and governance. In: Wester P, Mishra A, Mukherji A, Shrestha AB, editors. The Hindu Kush Himalaya assessment—mountains, climate change, sustainability and people. Cham: Springer Nature Switzerland AG; 2019.
84. Singh C. Using life histories to understand temporal vulnerability to climate change in highly dynamic contexts. In: SAGE Research Methods Case. Thousand Oaks: SAGE Publications Ltd; 2018. https://doi.org/10.4135/9781526440358.

85. Singh C, Basu R. Moving in and out of vulnerability: interrogating migration as an adaptation strategy along a rural urban continuum in India. Geogr J. 2019. https://doi.org/10.1111/geoj.12328.
86. Singh C, Tebboth M, Spear D, Ansah P, Mensah A. Exploring methodological approaches to assess climate change vulnerability and adaptation: reflections from using life history approaches. Reg Environ Chang. 2019a;19:2667–82. https://doi.org/10.1007/s10113-019-01562-z.
87. Singh C, Solomon D, Bendapudi R, Kuchimanchi B, Iyer S, Bazaz A. What shapes vulnerability and risk management in semi-arid India? Moving towards an agenda of sustainable adaptation. Environ Dev. 2019b;30:35–50. https://doi.org/10.1016/j.envdev.2019.04.007.
88. Stark O, Bloom DE. The new economics of labor migration. Am Econ Rev. 1985;75:173–8.
89. Stark O, Levhari D. On migration and risk in LDCs. Econ Dev Cult Chang. 1982;31:191–6. https://doi.org/10.1086/451312.
90. Stark O. The migration of labour. Cambridge: Basic Blackwell; 1991.
91. Syvitski JP. Deltas at risk. Sustain Sci. 2008;3:23–32. https://doi.org/10.1007/s11625-008-0043-3.
92. Szabo S, Brondizio E, Renaud FG, Hetrick S, Nicholls RJ, Matthews Z, et al. Population dynamics, delta vulnerability and environmental change: comparison of the Mekong, Ganges–Brahmaputra and Amazon delta regions. Sustain Sci. 2016;11:539–54. https://doi.org/10.1007/s11625-016-0372-6.
93. Tacoli C. The links between environmental change and migration: a livelihoods approach. London: International Institute for Environment and Development; 2011.
94. Tacoli C. Crisis or adaptation? Migration and climate change in a context of high mobility. Environ Urban. 2009;21(2):513–25.
95. Tanner T, Lewis D, Wrathall D, Bronen R, Cradock-Henry N, Huq S, Lawless C, Nawrotzki R, Prasad V, Rahman MA, Alaniz R. Livelihood Resilience in the face of Climate Change. Nature Clim Chang 2014:5(1):23-26.
96. Tebboth MGL, Conway D, Adger WN. Mobility endowment and entitlements mediate resilience in rural livelihood systems. Glob Environ Chang. 2019;54:172–83.
97. Tucker J, Daoud M, Oates N, Few R, Conway D, Mtisi S, et al. Social vulnerability in three high-poverty climate change hot spots: what does the climate change literature tell us? Reg Environ Chang. 2015;15(5):783–800. https://doi.org/10.1007/s10113-014-0741-6.
98. UCS. Impacts of global warming: people, health. Climate Hot Map: Global warming effects around the world. Union of Concerned Scientists, United States of America, 2011. http://www.climatehotmap.org/global-warming-effects/.
99. Upadhyay H, Kelman I, Lingaraj GJ, Mishra A, Shreve C, Stojanov R. Conceptualizing and contextualizing research and policy for links between climate change and migration. Int J Clim Chang Strategy Manag. 2015;7:394–417. https://doi.org/10.1108/IJCCSM-05-2014-0058.
100. Vaidya R, Shrestha MS, Nasab N, Gurung DR, Kozo N, Pradhan NS, et al. Disaster risk reduction and building resilience in the Hindu Kush Himalaya. In: Wester P, Mishra A, Mukherji A, Shrestha AB, editors. The Hindu Kush Himalaya assessment—mountains, climate change, sustainability and people. Cham: Springer Nature Switzerland AG; 2019.
101. Van der Geest K. North-South migration in Ghana: what role for the environment? Int Migr. 2011;49:s1. https://doi.org/10.1111/j.1468-2435.2010.00645.x.
102. Viswanathan B, Kavi Kumar KS. Weather, agriculture and rural migration: evidence from state and district level migration in India. Environ Dev Econ. 2015;20:469–92. https://doi.org/10.1017/S1355770X1500008X.
103. Warner K. Migration: climate adaptation or failure to adapt? Findings from a global comparative field study. IOP Conference Series: Earth and Environmental Science 2009:6(56) 562006. https://doi.org/10.1088/1755-1307/6/56/562006.
104. Warner K, Afifi T. Where the rain falls: evidence from 8 countries on how vulnerable households use migration to manage the risk of rainfall variability and food insecurity. Clim Dev. 2014;6:1–17. https://doi.org/10.1080/17565529.2013.835707.
105. Williams NE, Ghimire DJ, Axinn WG, Jennings EA, Pradhan MS. A micro-level event-centered approach to investigating armed conflict and population responses. Demogr. 2012;49(4):1521–46.
106. World Bank. Migration and remittances Factbook 2016 Third edition. Washington, DC: World Bank, 2016. doi:https://doi.org/10.1596/978-1-4648-0319-2.

Publisher's Note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Affiliations

Amina Maharjan[1] · Ricardo Safra de Campos[2] · Chandni Singh[3] · Shouvik Das[4] · Arjun Srinivas[3] · Mohammad Rashed Alam Bhuiyan[5] · Sultan Ishaq[6] · Muhammad Awais Umar[7] · Tanzina Dilshad[8] · Krity Shrestha[9] · Suruchi Bhadwal[10] · Tuhin Ghosh[4] · Natalie Suckall[11] · Katharine Vincent[12]

1 International Centre for Integrated Mountain Development (ICIMOD), Khumaltar, Lalitpur, Nepal

2 Global Systems Institute, University of Exeter, Exeter, UK

3 Indian Institute for Human Settlements (IIHS), Bengaluru, India

4 Jadavpur University, Kolkata, India

5 University of Dhaka, Dhaka, Bangladesh

6 Pakistan Agriculture Research Council (PARK), Islamabad, Pakistan

7 Sustainable Development Policy Institute (SDPI), Islamabad, Pakistan

8 Bangladesh Centre for Advanced Studies (BCAS), Dhaka, Bangladesh

9 Practical Action, Kathmandu, Nepal

10 The Energy Research Institute (TERI), New Delhi, India

11 University of Southampton, Southampton, UK

12 Kulima Integrated Development Solutions (Pty) Ltd, Pietermaritzburg, South Africa