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Perceived environmental risks and insecurity reduce future migration intentions in hazardous migration source areas

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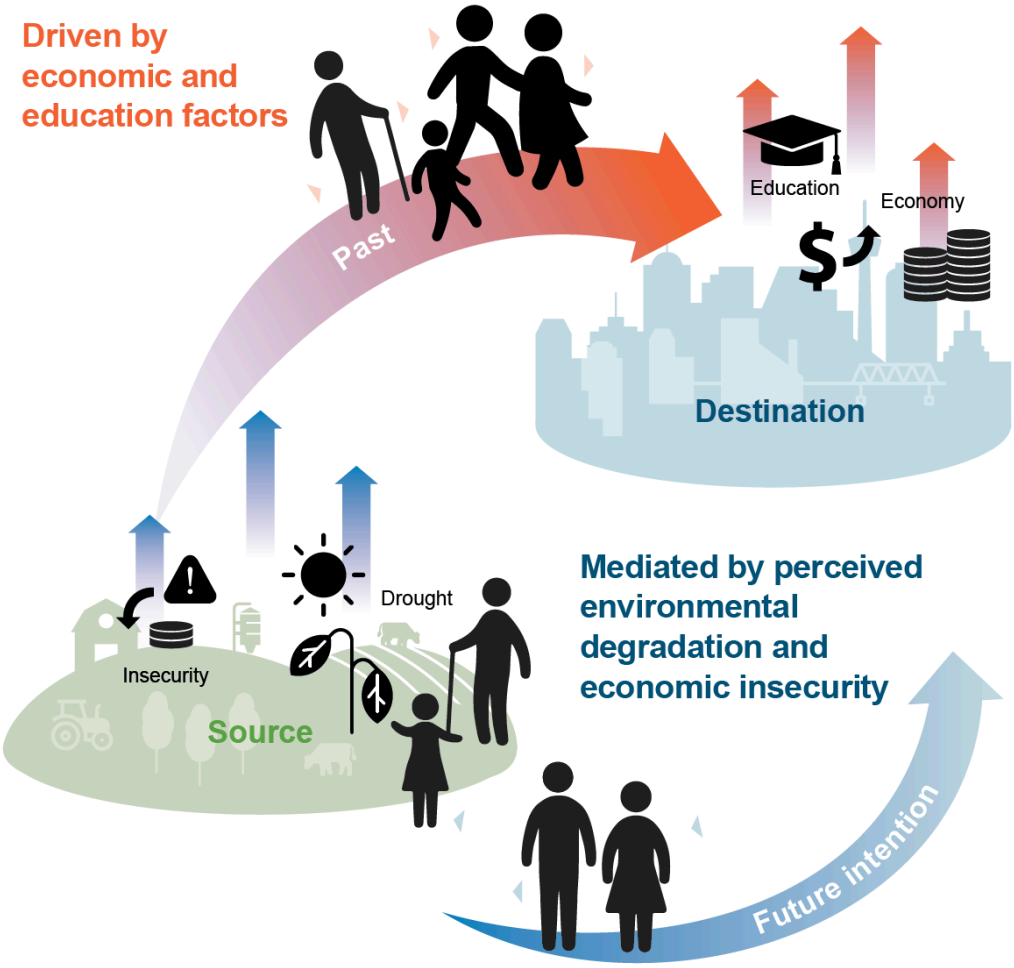
Summary

Environmental change influences population movements at various temporal and spatial scales. Yet individual decisions to migrate involve multiple motivations including perceived environmental risks and economic opportunities. We analyse how perceptions of environmental risks affect migration decisions and future migration intentions. We use cross-sectional household survey data (n=5450) from populations engaged in migration in net out-migration areas in four coastal areas in Ghana, Bangladesh and India to examine ex post migration motivations and ex ante future migration intentions. The data include variables on previous migration, migration intentions, well-being, food insecurity, and perceived long-term environmental degradation. The results show that few households identified environmental risks as the primary driver for past migration decisions. Perceived increased severity of drought and household insecurity both reduce stated future migration intentions. Hence perceptions of environmental risks, including future potential changes, are significant in altering aggregate migration flows from source areas in low-lying coastal regions.

Graphical abstract



Science in Society

The impacts of climate change will affect settlement patterns of the movement of people towards secure and productive localities. Environmental risks translate into actual decisions by individuals and households to move localities. Migration is socially and economically costly, and most evidence shows that it is most likely among households that are economically secure. In this study we show that perceptions of recent environmental change as experienced by rural communities are perceived not to have influenced prior decisions on individuals moving away, but that perceptions of environmental risks affect stated future migration intentions. The results are consistent across low-lying rural coastal areas surveyed in Asia and Africa and show that, for example, households that have experienced drought have a lower probability of future migration. The results indicate that a

changing environment and climate will not necessarily speed up migration flows, but alter them in specific ways.

Highlights

Migrants do not frequently identify environmental risks as primary driver for movement.

Perceived risk of drought and insecurity reduce stated future migration intentions.

Perceptions of environmental risks alter aggregate migration flows in coastal regions.

eTOC blurb

An analysis of perceptions of motivations for prior migration and migration intensions of households in four low-lying coastal areas in Asia and Africa finds that few households identified environmental risks as the primary driver for past migration decisions. Perceived increased severity of drought and household insecurity both reduce stated future migration intentions. Hence perceptions of environmental risks, including future potential changes, are significant in altering aggregate migration flows from source areas in coastal net out-migration regions.

Introduction

Contemporary migration flows globally continue to be dominated by movement from rural to urban areas. It has been widely shown in environment migration studies that these flows are driven at the aggregate level by a mix of social and environmental factors and risks, but remain dominated by future economic and educational opportunities.[1 2 3 4] These same mix of economic, social and environmental factors operate at the individual level and determine when individuals and households make decisions to stay or move to make new lives.[5 6] Escalating future climate and environmental risks may then amplify or create new involuntary migration flows, especially if whole climates shift and alter productivity and habitability.[7] Studies have argued that there are identifiable thresholds in slow onset environmental change and rapid onset disasters that tip populations into migrating rather than staying put.[8 9 10 11] At the individual level, all migration decisions involve implicit perceptions on future risks and opportunities.

What is known about how environmental risks affect migration flows? Some models of migration decision-making incorporate environmental dimensions, for example, as a set of ecosystem services focussing on the productive benefits derived from the environment[12 13], while other models focus on a set of risks that lead people to thresholds of tolerance and eventually to decisions to move locations.[14] At the aggregate level, it has been shown that declines in longer term environmental quality affect the ability of those dependent on them to accumulate resources and capital necessary for migration. Gray[15], for example, shows this relationship: soil quality in Kenya is negatively correlated with migration rates, while van der Geest[16] showed how long-term decline in agricultural productivity led to net out-migration for those areas in Ghana. At the extreme, if environments become effectively uninhabitable, then individual decisions on permanent relocation result in depopulation.[17] Such results have been shown in global modelling as well as single site studies, with the World Bank estimating potentially 143 million internal climate migrants in Ethiopia, Bangladesh and Mexico by 2050.[18] Thus, physical and ecological changes in the environment clearly are

important in potential redistribution of populations. They occur through the process of individual decisions to move.

For any individual or household, however, migration decisions involve multiple social, economic factors and motivations as well as interactions with external risks from environmental degradation or scarcity. Economic, behavioural, and sociological models of migration decision-making therefore all encompass perceptions of the current situation, perceptions of future prospects, and aspirations in potential destinations.[19] All perceptions of the future involve uncertainty and perceptions of environmental quality and variability and hence affect the calculus of migration decision-making. Migration is, in effect, an adaptation strategy for spreading risk, and hence it is also likely driven by perceptions. Numerous studies have shown how farmers and those dependent on resources, such as forestry and fishing, choose their adaptive actions on the basis of perceived risk. Mertz[20] and Deressa et al.[21], for example, document that the adaptive actions of farmers in places with high rainfall variability are shaped by their perceptions of present and of future conditions. Perceptions of risk are constructed in terms of what matters, and may differ from measurement of risk using objective indicators.

This study therefore builds on these areas of knowledge: of how migration decisions are made; on how perceptions affect future intentions; and in the diversity of ways environmental risks can affect decision-making. Here we examine whether past migration decisions are identified as being driven by environmental risks by directly surveying for self-identified motivations. And we examine whether future migration intentions are explained by current perceptions of environmental degradation and household insecurity associated with environmental risks. We do so by focusing on places that are currently areas of net outmigration and also exposed to environmental degradation that residents perceive. The analysis examines whether households that reported perceived levels of exposure to environmental decline and changes in risk differ in migration intentions from those that did not.

We designed the study to examine the extent to which specific elements of perceptions of environment might influence migration intention. We use data collected in places with resource-dependent economies subject to the vagaries of environmental change and risk with high levels of migration: these are predominantly so-called net source areas. We focus on households as the main decision-making unit for migration decisions and delineate a household as engaged in migration where at least one household member has previously moved to another place of residence (see Experimental Procedures).

There are two elements of perceptions of environment. The first is perceptions of household insecurity associated with level of exposure to hazards and impact of weather-related disasters. The second is perceptions of longer term environmental degradation such as perceived increases in erosion of river banks and coasts, salinization, drought and important weather variables.

The analysis spans geographical areas facing similar ranges of environmental stressors: all are low-lying rural coastal regions with natural-resource dominated economies. We conducted a cross-sectional household survey in four deltas in South Asia (Bangladesh and India) and in West Africa (Ghana) between March and October 2016 (Figure 1). These regions are highly populous deltas within low and middle income countries (see Table 1) and all have high population densities than non-delta rural areas in those countries. Such low lying delta regions are typically areas with significant surplus agricultural production and major employment. Yet in all countries it has been

shown that economic growth lags the urban centres, with per capita incomes being significantly lower than national averages (Table 1). As urban areas are major migration destinations, the regions studied here are all areas of net emigration to adjacent urban settlements.[22] [23]

Table 1 here

Figure 1 here

There has been long-standing debate around whether migration intentions ultimately reflect actual migration movements.[24] [25] The use of self-reported future migration intentions has been widely used by demographers, population researchers in studies of local push factors[26] [27] [28] and the general stressors that households face within a location. Koubi et al.[29], for example, examine perceptions of rapid- and sudden-onset hazards and the likelihood of migration among households across five countries and find that perceptions of greater risk reduce likelihood of migration. Expectations of future conditions and opportunities may not be realised, yet it is these perceptions of present and future conditions that are most critical at the time of the migration decision-making.

The paper proceeds by describing the results of analysis for the four low-lying coastal zones in India, Bangladesh and Ghana. The results show that insecurity associated with environmental risks and perceived environmental degradation are important in future stated migration intentions. These results are differentiated across regions and by whether households are engaged in previous migration. We discuss the implications of these results for adapting and anticipating climate change and for the field of migration and environment research.

Results

Self-identified motivations for previous migration decisions

Data on self-identified principal motivations for migration are shown in Figure 2. Of 1668 households engaged in migration across all four study areas, 60 percent reported that the main reason for migration from the study locations was, in effect, better employment and economic opportunities. Education is second most frequently mentioned with 12.5 percent of respondents reporting that the migrant left to pursue formal education or training. Family obligations accounted for 9.5% of the responses, while family reunion was the fourth most cited reason with 7.3 percent. Only a small minority of the respondents (0.6 percent or 16 individuals) reported that the main reason behind the decision to move was associated with environmental reasons, a finding consistent with other studies of motivation.[30] [31] [32] Migration intention results showed a similar pattern: of the 2183 household heads across all four deltas who reported intention to migrate in the future, 78 percent mentioned economic reasons as the main driver while only 1.3 percent suggested environmental concerns. The results in Figure 2 in effect demonstrate that environmental stress may not be the principal driver of migration, even in marginal rural areas prone to natural disasters where local populations are engaged in ecosystem-based livelihoods.

Figure 2 here

Detertminants of future migration intentions

How do perceptions of environmental change affect future migration intentions, both among households engaged in migration and non-engaged households? The survey included direct questions on likely reason for that future migration intention, including perceptions of environmental degradation over the most recent five-year period, and perceived livelihood

insecurity of the household due to environmental risks. Figure 3 focuses on migration intentions and distinguishes among responses for households who have previously engaged in migration (N=725) and not-engaged (N=1458) in migration. Across all four study areas, a negligible percentage of respondents suggested that environmental drivers would be their principal motivation for future migration. However, a high percentage of respondents report that perceived changes in the environment and impact on economic security of their household as the main reason for future migration intentions.

These results suggest that elements of environmental change are important factors in the future intentions of the residents in the four study areas. Almost three quarters of respondents from households in the Mahanadi and Volta delta regions perceived that environmental degradation (from the list that included flooding, drought, salinization and erosion) over the previous five years would be important in future decisions. A lower proportion, about half the households in the Indian and Bangladeshi parts of the Ganges-Brahmaputra delta reported that such environmental dimensions would be the principal reason for future migration . The results are also consistent for perceived livelihood insecurity. In the Volta delta, perceived livelihood insecurity is prevalent among households engaged in migration. In the Bangladesh delta, responses were similar across those who had engaged with migration and those who had not, with households engaged in migration reporting slightly higher perceived livelihood insecurity associated with environmental hazards.

Figure 3 here

Do reported perceived levels of environmental decline affect migration intentions? To answer this question, we employ a binary logistic regression approach. The resulting model has migration intention as the dependent variable, with socio-demographic and the proposed elements of perceptions of environment as explaining the future stated migration intention. We control for household size, age of household head, education attainment of household head, migrant network, and household income, which are known to influence migration. Table 3 reports the odds-ratio resulting from the pooled data with a regional site binary indicator in column (1), and results for each region in columns (2) through (5). Perceptions of degradation of individual elements of the environment, and perceptions of livelihood insecurity are the relevant independent variables.

The model reported in Table 3 examines how households that reported perceived levels of changes in the environment differ in migration intentions from those that did not, controlling for impact on economic security of household and other socio-economic characteristics. As previously mentioned, the dependent variable receives the value of 1 for those households that reported intention to migrate and 0 for those that did not. The model also controls for socio-economic characteristics, as stated above. Because of high spatial correlation between certain environmental variables, problems of multicollinearity could be introduced, which can lead, for example, to difficulties in disentangling variable effects. We conducted the Variance Inflation Factor (VIF) test, which is expected to show values <10 in a non-collinear model, to address any potential multi-collinearity issues. Overall, VIF values in our models were <5. Our additional tolerance tests (all values >.2) suggest that the variables in the models are uncorrelated. Model 2 chi-square is significant indicating that the model fits the data.

The results of the model reveal the importance of people's perceptions of environmental change *vis-à-vis* socio-economic factors in migration intention. The output of the regression analysis shows that perception of drought is negatively associated with intention to migrate: the odds of future intention to migrate for households that perceived changes in drought are 13 percent lower than

the odds for those that did not perceive changes in drought. These results are consistent across regions (shown in columns 2 to 5), albeit not statistically significant in any of them.

Table 3 here

Perceptions about changes in the predictability of monsoon rains in the Bangladesh delta have a positive effect on intention to migration, whilst changes in monsoon and erosion in the Mahanadi delta reduce migrations intentions. The odds ratio of 1.432 suggests that the odds of stating future intention to migrate for households that perceived changes in monsoon onset in the Bangladesh delta are 43 percent higher than for those who did not perceive changes in monsoon. Conversely, the odds ratio of 0.611 associated with the same event in the Mahanadi delta reflect that the odds of future stated intention to migrate are 39 percent lower than for those respondents who did not perceive changes in the monsoon onset.

While past migration in the Mahanadi delta has been associated with the occurrence of cyclones, drought and erosion,[33] significant *in-situ* adaptation responses such as construction of cyclone shelters and saline embankments along with the implementation of irrigation facilities and mangrove rehabilitation programs have had an impact on migration intention of people living in its coastal areas.[34]

Overall, the odds of households with perceived economic insecurity due to environmental variability having future intentions to migrate are 11 percent lower than of those who do not have this perception. This result seems to be dominated by the partial effect of this perception on the intention to migrate in the GBM and Volta Deltas. Household insecurity is not significantly correlated to perceived environmental change (see Table S1). In Table 4 we focus on the relationship between intentions to migrate and perceived insecurity for the pooled data. Table 4 shows no significant correlation between them, with the social determinants of migration such as age and the availability of networks dominating.

Table 4 here

The results in Table 4 show that social determinants such as larger households, households with ecosystem-based livelihoods, and those with migrant networks have odds of reporting future intentions to migrate that are 6, 14, and 90 percent, respectively, higher than those that do not show these characteristics. The odds of reporting future intentions to migrate for households where the household head is older are 1 percent lower than for those whose household head is younger. Several studies have shown that migration is positively related with household size. In other words, people migrate in greater proportions from large households, because labour resources are less scarce in those settings.[35] The result here is consistent with previous findings in both Bangladesh[36] and India.[37] Previous migration history in the household displayed significantly different results across study locations. Strong positive coefficients were recorded for the effect of having migrant networks across all regions. Cities such as Kolkata and Accra, for example, are well-established destination areas for rural migrants in the regions eastern India and Ghana.[38] [39] and migrant networks significantly reduce the social and economic costs of migrating.

Discussion

The analysis here shows how perceptions of environmental change affected previous decisions to migrate, and how they shape intentions for future migration in low lying coastal areas across Asia

and Africa. Virtually no households in this study suggest environmental concerns were their principal reason or motivation for prior migration decisions by household members. Indeed, economic and educational opportunities, new household formation and family relations remain the major motivating factors in future migration intentions in low-lying regions worldwide for all types of migration. We investigate how specific elements of perceived environmental risks affect future migration intentions. In the study localities, elements of longer-term environmental decline such as drought and coastal flooding reduce the likelihood of future migration, as revealed through migration intentions. Household insecurity associated with environmental hazards is not significantly associated with increased future migration intentions. In specific regions, perceptions of changes to monsoon onset and reliability are positively correlated with increased future migration intentions (in Bangladeshi coastal region) and negatively correlated (in the Mahanadi). This result resonates with prior research on how monsoons are perceived radically differently across south Asian rural economies: Stiller-Reeve and colleagues, for example, described this wide variation in when monsoon rains actually occur as well as their significance for livelihoods.[40]

In essence our results point to the complexity and variability of environmental dimensions in future migration intentions across wide geographical areas with similar characteristics in terms of underlying migration dynamics and environmental hazards. In order to benefit from comparability of data, the research design involved collecting categorical data which is necessarily limited in explaining the depth and meaning of the perceptions. The study involved significant pre-testing across language and cultural contexts, leading to the decision to restrict surveys to categorical answers and quantitative assessments. More mixed methods and qualitative insights into what lies behind the perceptions would inevitably bring additional explanatory power to the analysis of future expectations and perceptions of current and past risks.[41 42] Yet the reported patterns of perceptions are illuminating: it has long been argued in migration studies, that migration intentions are a pre-requisite to actual migration flows. Hence future migration intentions are a specific but limited means of eliciting actual future movement.

Despite those methodological caveats, we argue that the study design is robust and the results corroborate previous research on the relationship between household and individual perceptions of sudden- and slow-onset environmental events and migration[43]. Behavioural and network studies and household-bargaining theories of migration all embed perceptions of the future by, for example, integrating all perceptions into net expected utility of moving versus staying put.[44 45] It would therefore be counter-intuitive if perceptions of environmental change on the attractiveness of source and destination areas were not critical to current or future migration intention.

Conclusion

This study shows that a variety of dimensions of environmental affect migration intention. This result confirms similar findings that long-term environmental decline in migration source areas affects migration decisions more than short term variability.[46] This study suggests that perceptions of environmental risks are an effective way to ascertain and integrate dynamic biophysical changes in environment. While there are methodological challenges to measuring perceptions, much interdisciplinary research between social and behavioural sciences emphasizes that experience matters and indeed that perceptions are, in effect, reality when deciding on major lifecourse events. The wider evidence base, for example, shows that knowledge and perceptions of risk are critical to migrants' ability to deal with risks in new areas, adapt to new environments in destination areas, their ability to integrate in conflictual situations[47 48]

The study also shows that socio-economic motivations and socio-demographics remain the principal drivers of migration intention in population source areas in populous delta regions. As Seto[49] and others have argued, the primacy of economic growth and opportunities of cities and urban settlements in low lying regions in Africa and Asia, is driving urbanisation trends through large scale migration flows.[50 51 52] But the detail of the different types of environmental change is important for uncovering the dynamics. Call et al.[53] show that cyclones are less important for circular patterns of migration because they do not disrupt migration as a livelihood strategy. Our data uses future migration intentions rather than observed prior behaviour, but similarly shows that perceptions of recent drought consistently across the regions is significant in dampening future migration, in contrast to shorter term variability such as perceived changes to monsoon rains in Asian delta regions.

This study provides further evidence that indeed migrants are unlikely to self-identify as environmental migrants. It is widely recognised that dominant discourses on a linear relationship between environmental degradation and population loss through outward migration are simplistic and flawed.[54] Much policy discussions assume environmental migrants are an identifiable class of people: yet migrants themselves have very different framing of causes and timescales. While migration is a legitimate and often effective means of adapting to growing environmental risks, the basis on which assistance is regulated or rights can be established requires identification of the environmental dimension of migration motivation.[55] Hence, policy initiatives to strengthen the rights or assistance to so-called environmental migrants are likely to be constrained if they require identifying these populations as a single class.

There is growing evidence that regular migration flows are as likely to be dampened as amplified by a more uncertain natural environment. Environmental change and household insecurity reduces the attractiveness of migration as a feasible adaptation option, as shown by reduced odds ratios for migration intention. If migration intentions are indicative of future actual flows, then this has important implications for population movement in areas subject to current environmental degradation. Continued out-migration from low-lying coastal margins are likely to be affected in somewhat offsetting ways by perceptions of a degrading environmental situation: environmental change reduces the choice and opportunity of populations to engage in their desired movements to urban centres driven by economic imperatives.

Experimental Procedures

Resource Availability

Lead Contact

Further information and requests for resources should be directed to and will be fulfilled by the Lead Contact, Neil Adger n.adger@exeter.ac.uk

Materials Availability

The codes from the statistical analysis performed in Stata 16 are available upon request from the Lead Contact.

Data and Code Availability

The datasets generated during this study and the survey instruments are available at UK Data Service (https://ukdataservice.ac.uk) or, till embargo lifted, upon request from the Lead Contact.

Data Acquisition

The survey data comprises 5450 completed household questionnaires of which 31 percent (N= 1668) were classified as being engaged in migration: households that reported at least one migrant having moved away. The remaining 69 percent were defined as households not engaged in migration. Among all valid responses, 40 percent (N=2183) of respondents reported intention to migrate in the future. For this study, a household is a group of two or more persons living together who make common provision for food or other essentials for living. Households engaged in migration are households that have members that have migrated, either internally or internationally, from their origin area in the previous ten years. This includes individuals who have moved to a new location with the intention of remaining there for at least six months, including permanent and seasonal moves for a range of motivations including employment, education, and family reunion.

The perceptions data comes from interviews with self-defined household heads, a male or female adult giving their individual perceptions of well-being, and reporting on decisions made jointly within the household.[56] The four study sites, the Volta delta in Ghana, the Indian Bengal delta and the Mahanadi delta in India, and the Ganges-Brahmaputra-Meghna delta in Bangladesh (Figure 1) were selected according to three criteria. First, each study site involves a region that has been regularly affected by climatic or environmental-related events and are also vulnerable to future climatic change. Second, given hypothesis on how migration intentions are associated with various perceptions of environment, the study focuses on low-lying coastal environments in different countries experiencing these common stressors.[57] Third, in order to examine if intention to migrate is influenced by perceptions of environmental change, sample locations are all migration source areas with well-documented history of rural to urban population movements.[58] Demographic and environmental characteristics of each study area are shown in Table 1 and the principal variables in the survey in Table S2.

Table S2 here

Fifty locations in each study area were selected using 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 were selected proportional to the number of clusters in that zone. Once clusters had been selected, a household listing allowed randomized sampling. Oversampling for subpopulations was not required due to the prevalence of migration in the research locations. The distribution of the variables for each individual country included in the model is summarized in Table 2.

The design sought to minimize recall bias in responses from household heads by focusing on memorable and significant phenomena within farming economies, without the need to provide exact dates or magnitudes[59] and sought to be consistent in application of questions on intentions to migrate that are, inevitably context-specific. Furthermore, the questionnaire was designed to minimise issues associated with response bias. The order of the questions and response options may influence the likelihood of respondents to select certain sets of answers. To counter this, questions on future migration intentions were not directly associated with perceptions of environmental change. These were placed in a separate section of the survey instrument (avail;able from Lead Contact).

The analysis involved modelling household-level stated future migration intention as a function of the perception variables using a binary logistic regression model to interrogate the data.[60] Migration intentions are measured by the dichotomous answers to the following question: "Do you or other household members intend to migrate in the future?" Migration intention is an aspiration and may or not be carried out.[61] However, studies suggest that intentions provide insight into actual behaviour.[62 63] The theory of reasoned action, for example, assumes that the behavioural intention of an act, in this case migration, is an immediate determinant and reliable predictor of behaviour (following studies by Van Dalen and Henken[64] and others).

In the analysis, the dependent variable receives the value of 1 for those households that reported intention to migrate and 0 for those that did not. The independent variables are: perceived environmental change, household livelihood insecurity, as self-reported in the context of environmental hazards; and a range of socio-demographic variables (Table S2). The main independent variables were coded based on respondents' recollection of environmental changes experienced within the most recent five years; and self-reported impact of environmental hazard on the economic security of the household. We focused on these independent variables because perceptions of environmental impact on economic security of households captures issues such as loss of income, equipment or livestock, bringing about disruptive changes to land use or livelihoods.[65] Respondents were therefore asked about the impact of environmental hazard on the economic insecurity of the household (economic insecurity included damage to crops, livestock, equipment and loss of income). The survey also included a question on perceptions of environment change associated with rainfall, temperature, river and coastal flooding, river and coastal erosion, salinity intrusion, and drought. For each of these events, we asked respondents to answer if over the past five years they had experienced any changes in each of these environmental conditions.

We control for various socio-economic factors that were found to be important drivers of migration decisions in previous empirical research,[66 67] shown in Table S2. More specifically, we use the details informed by household heads as proxies to control for age and formal level of education. Older individuals are typically less likely to migrate and educated people are more likely to do so. To control for migration networks, we asked respondents whether a member of the same household, the extended family or friends have already migrated (given social networks in destination areas increase the likelihood of migration by reducing the costs and risks associated with this process [68 69 70]). Economic factors such as predominant livelihood type and total income of household were also included: households involved in ecosystem-based livelihoods have stronger perceptions of environmental degradation on economic security compared to those involved in different economic activities.[71] Household income was included to control for the impact of wealth on the intention to migrate.

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Author contribution
WNA and RSdC conceived the study, developed the methods, and wrote the original draft. WNA, SC, TA, HA and CM developed the survey and methods. RSdC, MA, SD and MFG conducted the statistical analysis. All authors contributed to the writing of the final version of the manuscript.

Declaration of Interest
The authors declare no competing interests.

Figure and table legends

Figure 1. Location of study areas in Asia and Africa (Panel A) low-lying delta regions with net out-migration and exposure to common hazards in Asia and Africa (Panel A). Indian Bengal Delta and Ganges Brahmaputra Delta, Bangladesh (Panel B), Volta Delta, Ghana (Panel C), and Mahanadi Delta, India (Panel D).

Figure 2. Principal motivation for migration ranked by households engaged in migration. Volta Delta (Panel A) Mahanadi Delta (Panel B), Indian Bengal Delta (Panel C), and Ganges Brahmaputra Delta (Panel D).

Figure 3. Principal motivations for future migration intentions for populations previously engaged or not engaged in migration. Volta Delta (Panel A) Mahanadi Delta (Panel B), Indian Bengal Delta (Panel C), and Ganges Brahmaputra Delta (Panel D). Column 1 in all Panels shows proportion of respondents stating environment as primary motivation for future migration. Column 2 in all Panels shows perceptions of perceived environmental change. Column 3 in all Panels reports perceived livelihood insecurity (N=2183).

Table 1. Geographic and socio-economic characteristics of the four study areas in India, Bangladesh and Ghana

Table 2. Summary statistics of variables of interest across the four study areas (S.D. reports standard deviation)

Table 3. Results of the binary logistic regression model for households that reported future migration intention (N=2183). Standard errors in parenthesis.

Table 4. Relationship between intentions to migrate and household insecurity associated with environmental hazards.

Table 1. Geographic and socio-economic characteristics of the four study areas in India, Bangladesh and Ghana

Features	GBM Delta: Bangladesh and India	Mahanadi Delta, India	Volta Delta, Ghana
Rivers/catchment area (10^3 km^2)	Ganges, Brahmaputra, Meghna (1,730)	Mahanadi, Brahmani and Baitarani (141)	Black Volta, White Volta and Red Volta (398)
Delta area (10^3 km^2)	87300 km^2 (66% in Bangladesh; 33% in West Bengal, India)	5910 km^2	2430 km^2
Annual (and peak) discharge (m^3/s)	35,500 (138,700 - average annual)	1800 (45,000 -- 1 in 50 year event)	900
Sediment input (tonnes/yr)	1 x10^9	29.8 x 10^6	7 x 10^6 since dam construction
Catchment interventions	Construction of Farakka Barrage in 1975 at the apex of the delta resulted in 37% loss in sediment supply in the Hugli River and estuaries.	Hirakud Dam in 1957 Resulting in 67% decline in sediment supply	Akosombo Dam (completed 1965) stopped all upstream influence
Current relative sea-level rise (mm yr^{-1}) 1990-2010	7.0	3.3	3.0
Key current land use issues and hazards	Floods, erosion, low dry season flows, water logging, salinisation, surge	Floods, erosion, low dry season availability, water logging, salinisation, surge	Erosion (especially at Keta), floods, salinisation
Population and population density (2011 census)	56.1 million 1100 people per km^2	8.1 million 625 people per km^2	0.86 million 168 people per km^2
Income per capita (USD per capita 2012 purchasing power parity)	1847	1958	1048
National average income per capita (USD per capita 2012 purchasing power parity)	2981 (Bangladesh) 45674 (India)	4574	4435

Source: Nicholls et al. 2020;[72] Rahman et al., 2020[73]; Pethick and Orford 2013.[74]

Table 2. Summary statistics of variables of interest across the four study areas (S.D. reports standard deviation)

Variables	Volta Delta			Indian Bengal Delta			Bangladesh Delta			Mahanadi Delta		
	N	Mean	S.D.	N	Mean	S.D.	N	Mean	S.D.	N	Mean	S.D.
Intention to migrate	594	0.44	0.50	361	0.28	0.45	913	0.66	0.47	315	0.22	0.42
Perceptions of household's livelihood insecurity	569	0.42	0.49	509	0.39	0.49	791	0.57	0.49	1131	0.80	0.40
Socio-economic variables												
Household Size	-	3.98	2.51	-	4.28	1.72	-	4.95	1.80	-	4.79	2.05
Age of Household Head (Years)	-	47.38	16.96	-	45.75	13.72	-	45.28	14.66	-	51.88	14.54
No Education	383	2.20	0.90	324	2.18	0.88	417	2.12	0.92	220	2.44	0.90
Primary Education	392			499			466			529		
Secondary Education	524			385			411			489		
Higher Education	64			84			88			176		
Main Livelihood of Household Head	851	0.62	0.48	1038	0.80	0.40	1074	0.78	0.42	961	0.68	0.47
Income (US Dollars)	-	101.97	128.60	-	102.68	93.87	-	149.31	180.66	-	131.74	123.75
Family or Friends Migrated	1176	0.86	0.34	528	0.41	0.49	1065	0.77	0.42	508	0.36	0.48
Perceptions of environmental change												
Rainy Season / Monsoon Onset	1269	0.93	0.25	918	0.71	0.45	1129	0.82	0.39	1275	0.90	0.30
Rainfall	1300	0.95	0.21	1155	0.89	0.31	1322	0.96	0.20	1373	0.97	0.17
Temperature	1303	0.96	0.21	1213	0.94	0.24	1366	0.99	0.11	1410	1.00	0.05
River Flooding	684	0.50	0.50	610	0.47	0.50	525	0.38	0.49	1068	0.76	0.43
Coastal Flooding	731	0.54	0.50	367	0.28	0.45	301	0.22	0.41	574	0.41	0.49
Coastal / River Erosion	673	0.49	0.50	478	0.37	0.48	388	0.28	0.45	735	0.52	0.50
Salinization	437	0.32	0.47	414	0.32	0.47	553	0.40	0.49	478	0.34	0.47
Drought	951	0.70	0.46	328	0.25	0.44	639	0.46	0.50	1180	0.83	0.37
Total Observations	1363			1292			1382			1414		

Table 3. Results of the binary logistic regression model for households that reported future migration intention (N=2183). Dependent variable: Intention to migrate. Standard errors in parenthesis.

	(1)	(2)	(3)	(4)	(5)
	Pooled	GBM Delta	Volta Delta	IB Delta	M delta
Monsoon	1.012	1.432**	1.136	0.996	0.611**
	(0.0883)	(0.220)	(0.284)	(0.142)	(0.127)
Rain	1.101	0.963	1.645	0.964	1.110
	(0.151)	(0.287)	(0.526)	(0.201)	(0.435)
Temperature	0.928	1.378	0.748	1.013	0.247
	(0.168)	(0.758)	(0.220)	(0.278)	(0.253)
River Flooding	1.069	0.977	1.034	0.809	1.261
	(0.0792)	(0.135)	(0.155)	(0.147)	(0.206)
Coastal Flooding	0.951	0.774	1.066	0.922	1.002
	(0.0786)	(0.124)	(0.190)	(0.188)	(0.166)
Erosion	1.085	1.092	1.227	1.600**	0.765*
	(0.0887)	(0.171)	(0.210)	(0.349)	(0.118)
Salinization	1.110	0.972	1.413**	0.876	1.148
	(0.0802)	(0.126)	(0.196)	(0.172)	(0.195)
Drought	0.868**	0.892	0.837	0.894	0.818
	(0.0606)	(0.112)	(0.113)	(0.146)	(0.146)
Impact Eco. Insecurity	0.892*	0.742**	0.845	1.317*	1.104
	(0.0580)	(0.0909)	(0.109)	(0.188)	(0.183)
Household Size	1.064***	1.367***	1.027	1.052	0.984
	(0.0158)	(0.0526)	(0.0254)	(0.0414)	(0.0336)
Age	0.985***	0.990**	0.968***	0.994	0.995
	(0.00207)	(0.00415)	(0.00378)	(0.00478)	(0.00481)
Primary Education	1.045	0.971	1.136	0.892	1.179
	(0.0846)	(0.150)	(0.183)	(0.147)	(0.238)
Secondary Education	0.951	0.718**	1.210	0.886	0.982
	(0.0792)	(0.116)	(0.187)	(0.157)	(0.207)
Higher Education	1.036	0.955	1.531	1.238	0.912
	(0.136)	(0.268)	(0.462)	(0.367)	(0.242)
Ecosystem livelihood	1.143*	0.951	1.213	1.589***	0.965
	(0.0804)	(0.139)	(0.161)	(0.280)	(0.137)
Income	1.000	1.002***	1.000	0.999	1.000
	(0.000245)	(0.000632)	(0.000471)	(0.000836)	(0.000556)
Migrant Network	1.901***	1.296	1.590***	1.900***	2.535***
	(0.132)	(0.216)	(0.285)	(0.248)	(0.339)
Volta Delta	0.415***				
	(0.0373)				
GBM Delta	0.238***				
	(0.0219)				
Indian Bengal Delta	0.213***				
	(0.0211)				
Constant	1.578*	0.375	1.080	0.236***	1.434
	(0.420)	(0.257)	(0.508)	(0.110)	(1.615)
Observations	5,451	1,382	1,363	1,292	1,414
-2 Likelihood	6479.528	1648.756	1719.256	1480.259	1436.316
Omnibus test	859.749	121.896	147.732	50.494	63.639
Omnibus test (PValue)	0.000	0.000	0.000	0.000	0.000
Nagelkerke R2	0.197	0.117	0.138	0.055	0.067

Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Table 4. Relationship between intention to migrate and household insecurity associated with environmental hazards.

Variables	Intention
Household Insecurity	0.900
	(0.0583)
Household Size	1.065***
	(0.0158)
Age	0.985***
	(0.00206)
Primary Education	1.042
	(0.0842)
Secondary Education	0.948
	(0.0789)
Higher Education	1.030
	(0.135)
Ecosystem livelihood	1.146*
	(0.0805)
Income	1.000
	(0.000245)
Migrant Network	1.913***
	(0.133)
Volta Delta	0.406***
	(0.0340)
GBM Delta	0.247***
	(0.0220)
Indian Bengal Delta	0.209***
	(0.0193)
Constant	1.622***
	(0.277)
Observations	5,451

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

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