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Climate change as a veiled driver of migration in Bangladesh and Ghana

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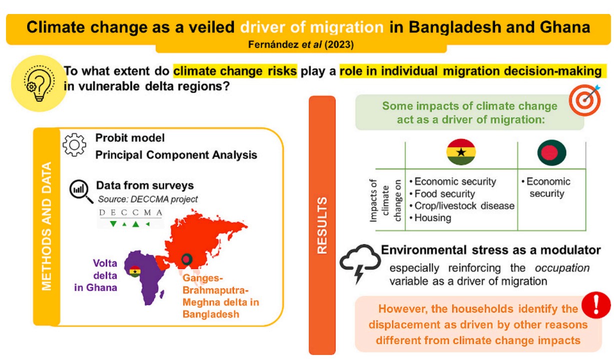
HIGHLIGHTS

- Climate drivers of migration in the deltas of Bangladesh and Ghana are analysed.
- The study is carried out at the micro level using the DECCMA database.
- Households do not identify environmental pressures as the main cause of migration.
- Climate shocks affecting economic security are key drivers of migration in deltas.
- Environmental stress emphasises the occupation variable as a driver of migration.

GRAPHICAL ABSTRACT



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ABSTRACT

People living in deltaic areas in developing countries are especially prone to suffer the effects from natural disasters due to their geographical and economic structure. Climate change is contributing to an increase in the frequency and intensity of extreme events affecting the environmental conditions of deltas, threatening the socioeconomic development of people and, eventually, triggering migration as an adaptation strategy. Climate change will likely contribute to worsening environmental stress in deltas, and understanding the relations between climate change, environmental impacts, socioeconomic conditions, and migration is emerging as a key element for planning climate adaptation. In this study, we use data from migration surveys and econometric techniques to analyse the extent to which environmental impacts affect individual migration decision-making in two delta regions in Bangladesh and Ghana. The results show that, in both deltas, climatic shocks that negatively affect economic security are significant drivers of migration, although the surveyed households do not identify environmental pressures as the root cause of the displacement. Furthermore, environmental impacts affecting

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Delta regions

food security and crop and livestock production are also significant as events inducing people to migrate, but only in Ghana. We also find that suffering from environmental stress can intensify or reduce the effects of socioeconomic drivers. In this sense, adverse climatic shocks may not only have a direct impact on migration but may also condition migration decisions indirectly through the occupation, the education, or the marital status of the person. We conclude that although climate change and related environmental pressures are not perceived as key drivers of migration, they affect migration decisions through indirect channels (e.g., reducing economic security or reinforcing the effect of socioeconomic drivers).

1. Introduction

Climate change is a game-changing phenomenon in all spheres of human life. Large numbers of people migrate involuntarily because of climate pressures that either affect their quality of life, their source of income or both. The definition of environmentally induced migration proposed by the International Organisation for Migration (IOM) (2007) states that "environmental migrants are persons or groups of persons who, for compelling reasons of sudden or progressive changes in the environment that adversely affect their lives or living conditions, are obliged to leave their habitual homes, or choose to do so, either temporarily or permanently, and who move either within their territory or abroad". According to Bilak et al. (2016) an annual average of 21.5 million people had been forcibly displaced by weather-related sudden-onset hazards each year since 2008, and the UNHCR (2022) highlighted that nearly 32 million displacements caused by weather-related hazards in 2022 represent a 41% increase compared to 2008 levels (estimated in close to 23 million that year), of which 98% were caused by weather-related hazards such as floods, storms, wildfires and droughts, according to the IDMC (2023).

Meta-analyses and reviews of the relationship between climate change, environmental change and migration can be found in Hoffmann et al. (2020), Kaczan and Orgill-Meyer (2020), Beine and Jeusette (2021), Piguet et al. (2011), Weerasinghe (2021) and obviously the IPCC (2023). Within those studies, and some others that we refer specifically next, evidence is presented on how climatic events lead to significant changes (water shortage and droughts, land degradation affecting food production and security, see e.g. Hermans and McLeman (2021), on housing, energy and health see e.g. Mazhin et al. (2020); Palinkas (2020); Stoler et al. (2021)) that may lead to migration. In January 2024 a meta-regression analysis of environmental migration literature has appeared (Zhou and Chi, 2024), mainly reflecting that across all the global literature, environmental stressors did not appear as important predictors of (out/in/net) migration, with mixed evidence tending to report a bit more outmigration.

Slow onset impacts of climate change may lead to around 2.8% of the population in Sub-Saharan Africa, South Asia, and Latin America (i.e. >143 million people) moving within their country of origin by 2050 (Rigaud et al., 2018); and, at a worldwide level, Myers (2002) forecast around 200 million environmental refugees in 2050. Despite what these data show, until now, few works in the literature have addressed climatic factors as drivers of migration.

Since the last century, several classifications have tried to explain the different determinants of migration. One of the first is that of Lee (1966), which distinguishes four groups of factors: those linked to the area of origin, those linked to the area of destination, obstacles, and personal factors. Several years later, Yorimitsu (1985) carries out a classification of the major migration determinants consisting of four categories: (1) demographic characteristics of migrants, (2) socioeconomic characteristics of migrants, (3) socioeconomic characteristics of places of origin and destination, and (4) factors accompanied by migration. Afterwards, other literature has distinguished between three types of determinants explaining migrations: root causes, proximate conditions, and intervening factors (Schmeidl, 1997). Root causes include factors such as poverty or population pressures; proximate conditions focus on human rights violations as well as ethical, civil, or military conflicts; and intervening factors refer to migration networks or obstacles to migration. However, it should be noted that this classification is based on a study mainly on refugees and not on a complete analysis of migration or specifically of environmentally induced migration, so there may be other factors that have not been considered.

In this sense, the literature related to migration has tried to distinguish between voluntary and forced migration. Voluntary migrations would be those that occur out of a desire to maximize their welfare, while forced migrations are those that occur in response to some kind of shock, such as wars (Kuhnt, 2019). However, most migrants would be located somewhere in between the two types, neither being forced migrants in their entirety nor voluntary migrants entirely (Erdal and Oeppen, 2018). In this regard, there is a need for more research that analyses the drivers of migrations not only at a theoretical level, showing the hierarchy of determinants, which has not yet been established (Kuhnt, 2019), but also combined with empirically driven research that helps fine-tune the factor or drivers' analyses based on evidence.

In addition to the forced and voluntary migration distinction, it should be made a differentiation between internal and external migration, as internal movements are particularly important in developing countries. Specifically, internal migration in developing countries can lead to positive change in both sending and receiving areas, either reducing poverty rates or fostering economic development (Deshingkar and Grimm, 2004). However, the development benefits of internal migration tend to arise mostly when people move voluntarily, but not when migration is forced by external elements (The World Bank, 2009), so climatic migrations are a problem that must be assessed. The IPCC (2020) defines a climate risk as "the potential for adverse consequences for human or ecological systems, recognizing the diversity of values and objectives associated with such systems". The concept of risk is essential for understanding the increasingly severe, interconnected and often irreversible impacts of climate change on ecosystems, biodiversity, and human systems; and how to best reduce adverse consequences for current and future generations (IPCC, 2022b). Heltberg and Bonch-Osmolovskiy (2011) proposed that a household is vulnerable to any risk associated with climate change if the risk generates a loss of welfare[1] that pushes the household below a certain threshold level. Vulnerability is a function of the nature of the risk, exposure and sensitivity to it, and adaptation capacity. Some of the most exposed regions to climate change risks are the deltas in developing regions of Asia and Africa. Low lying elevation of vast tracts of land makes deltas highly exposed to sea-level rise, among other climate change impacts such as storm surges or salinization (Brown et al., 2018; Jin et al., 2018; Nicholls et al., 2019). In those works, evidence is shown that deltas in India and Bangladesh have some of the highest population densities globally, mainly devoted to agricultural and fishing occupations that strongly depend on the monsoon rainfall conditions with low-income and subsistence livelihoods in many cases (Lazar et al., 2015).

[1] Welfare and Well-being are usually employed as synonyms. However, we refer to well-being as a multidimensional term that refers to a state of health, happiness and/or prosperity; while we employ welfare as a more specific concept that applies to quantifiable well-being, assuming the classical economic assumption that a higher level of utility curve signifies a better condition to the economic agent (Maximo, 2016).

Therefore, the characteristics of these delta regions make them especially vulnerable to the socioeconomic consequences of climate change (Arto et al., 2019; Das et al., 2021). In fact, their socioeconomic vulnerability hinders their adaptation strategies, which are often insufficient to face environmental risks (FAO, 2022; Hossen et al., 2019; Whitehead et al., 2018). Therefore, the well-being of the communities of such deltas is endangered by climate change acting as a risk multiplier that might aggravate other problems in these areas (Ghosh et al., 2019; Hossen et al., 2019), with the rural poor communities being the most affected by climate-change consequences either in India and Bangladesh and sub-Saharan Africa (Barrios et al., 2006; Piguet et al., 2011).

The social environment in such deltas is very dynamic, making mobility a usual practice. Traditionally, economic motivations were the main driver for these migrations. Still, the trends of climate change effects on these regions point to environmental hazards as one crucial driver that should be assessed (Jin et al., 2018; Safra de Campos et al., 2020; Samling et al., 2015). Given this situation, the Deltas, Vulnerability & Climate Change: Migration & Adaptation (DECCMA) project was created to understand how climate-change-driven global and national macro-economic processes impact on migration of men and women in deltas (DECCMA Project, 2022; Nicholls et al., 2019). The project identifies four deltas as especially vulnerable areas to climate change effects: the Bengal delta and the Mahanadi delta in India, the Ganges-Brahmaputra-Meghna (GBM) delta in Bangladesh and the Volta delta in Ghana. We will focus on the Volta delta in Ghana and the Bangladeshi side of the Ganges-Brahmaputra-Meghna (GBM) delta.

In recent years, classifications of migration drivers have begun to include climatic factors. Following the classification of the drivers of migration by Van Hear et al. (2017), climatic stress as a push-driver of involuntary migration may range from a predisposing driver in cases in which mobility is an adaptation strategy to a precipitating determinant when the displacement is forced in cases of life-threatening hazards that accelerates the decision of migrating (The White House, 2021). Environmental and climatic conditions are rarely a unique and direct driver of migration, but they can indirectly influence migration through their impact on other social, economic, political and demographic factors underlying these mobility decisions (Beine and Parsons, 2015; Black et al., 2011). For this reason, migrants usually do not consider their decision as climate-driven, but instead, they perceive economic and social factors as the main cause of their mobility (Adger et al., 2021; Safra de Campos et al., 2020). However, climatic shocks have been proven to be as important as education, gender or marital status in determining internal migration in many countries (Abel et al., 2022).

Based on the above, this paper aims to fill this gap in the literature (as e.g. found in Kuhnt (2019)) by empirically analysing the extent to which environmental change risks play a role in individual migration decision-making in vulnerable delta regions. In this way, we intend to reveal if the subjacent motivation of the migration is related to climate change despite the households do not explicitly identify it as the main reason for the migration (Adger et al., 2021; Safra de Campos et al., 2020).

In addition, this research uses a wide variety of environmental pressure indicators, which enables tracing at the micro level the exposure to different climatic events (floods, droughts, erosion, salinity, storm surges and cyclones) and their effects on each household's welfare and income. Scientific evidence claims that the climate change triggered by the rise in anthropogenic greenhouse gases emissions is increasing the frequency and intensity of these kinds of extreme weather events (IPCC, 2022a; NASA, 2021). The closer antecedent to our proposal is the work of Hoffmann et al. (2019), which studies the motivation of rural-urban migrants who moved from rural areas in the Indian state of Uttarakhand to its capital city. This study considers the land and forest cover changes around the chosen villages as a possible environmental driver of the migrations, which is built at the meso-level using a geographic information system analysis of land cover changes. In our assessment, we work with micro-level climate indicators with a high level of detail, both in the variety of climate events to which the household is exposed, both in the effects of these events on the household's welfare. Moreover, the database used in our study provides indicators of environmental stress both in objective and subjective terms. In this way, our model considers the perception of the household concerning the impacts of climate change phenomena on its lifestyle, which might be a relevant determinant in the migration decision.

Table 1
Relation of the migrant with the household head in those households engaged in migration (percentages of total migrant households).

	Bangladesh	Ghana
Partner	124 (30.69%)	2 (0.47%)
Married child	117 (28.96%)	44 (10.38%)
Unmarried child	106 (26.24%)	205 (48.35%)
Parent	2 (0.49%)	152 (35.85%)
Brother/sister	54 (13.37%)	3 (0.71%)
Brother-in-law/sister-in-law	1 (0.25%)	18 (4.24%)
Other relatives	0	0
Non-relatives	0	0
Don't know	0	0
Total	404 (100%)	424 (100%)

Source: own elaboration with data retrieved from DECCMA 2016 database (Safra de Campos and Adger, 2021).

Therefore, the main contributions of this work are threefold. First, using a representative sample of deltas of Bangladesh and Ghana, this paper analyses the still underexplored climate drivers. Secondly, the attempt to examine the effect of these different drivers on two vulnerable deltas with different characteristics, which allows us to carry out a comparative analysis between the two areas. Finally, this paper tries to clarify whether the motivation for migration is related to climatic factors, even if households do not identify it as such. The role of environmental stress as moderating effect making use of interaction variables with more commonly studied socioeconomic variables results relevant in the final explanatory model.

2. Methods and data

Data is retrieved from quantitative surveys carried out in 2016 as part of the project Deltas, Vulnerability and Climate Change: Migration and Adaptation (Safra de Campos and Adger, 2021). These surveys address different issues such as the circumstances under which the decision to migrate is taken, the conditions under which migration is more or less likely to be a successful adaptation to climate change, or the factors that impede or facilitate successful migration, among others.[2]

To collect the information, the surveys were translated into the main language of the territories and carried out by local people. The regions in which the study was carried out are four delta regions selected as vulnerable to climate change by the DECCMA project (Safra de Campos and Adger, 2021): the largest delta in the world (Ganges-Brahmaputra-Meghna (GBM) in Bangladesh), two medium-sized deltas (Indian Bengal Delta -part of the GBM - and Mahanadi in India), and a small-sized delta (Volta in Ghana). For reasons of data availability in environmental stress and motivation of the migration questions, our analysis has been carried out only for the deltas of Ghana and Bangladesh. Therefore, this allows us to study 2 deltas that have different characteristics and belong to different geographical areas: a very large delta (in Bangladesh) and a relatively small one in Ghana. Analysing vulnerable deltas with different characteristics allows to consider scale, geographic settings, and varying drivers in our analysis. Each delta study area has been delimited according to the five-meter elevation contour line to focus attention on the coastal processes and hazards linked to sea-level rise (Lazar et al., 2015). Thus, our sample size is finally 1328 households for Bangladesh and

[2] For more information on the topics covered in the survey, as well as methodological aspects see: Safra de Campos and Adger, 2021 and DECCMA Project.

Table 2
Description of environmental stress and control variables.

	Meaning
Environmental stress variables	
Housing (HOU)	Binary variable (1-0) with a value of 1 if the individual indicated that flooding, drought, erosion, salinity, storm surges, or cyclone had moderate or high negative impacts on housing; and 0 otherwise.
Ecosecurity (ECO)	Binary variable (1-0) with a value of 1 if the individual indicated that flooding, drought, erosion, salinity, storm surges, or cyclone had moderate or high negative impacts on economic security; and 0 otherwise.
Crop (CRO)	Binary variable (1-0) with a value of 1 if the individual indicated that flooding, drought, erosion, salinity, storm surges, or cyclone had moderate or high negative impacts on crop/livestock disease; and 0 otherwise.
Water (WAT)	Binary variable (1-0) with a value of 1 if the individual indicated that flooding, drought, erosion, salinity, storm surges, or cyclone had moderate or high negative impacts on drinking water; and 0 otherwise.
Foodsecurity (FSE)	Binary variable (1-0) with a value of 1 if the individual indicated that flooding, drought, erosion, salinity, storm surges, or cyclone had moderate or high negative impacts on food security; and 0 otherwise.
Health (HEA)	Binary variable (1-0) with a value of 1 if the individual indicated that flooding, drought, erosion, salinity, storm surges, or cyclone had moderate or high negative impacts on the household's health; and 0 otherwise.
Control variables	
Permanentjob (PJO)	Binary variable (1-0) with a value of 1 if the individual indicated permanent work; and 0 otherwise.
Age (AGE)	Individual's age
Education (EDU)	Binary variable (1-0) with a value of 1 if the individual indicated secondary or higher education, such as university; and 0 otherwise.
Marital (MAR)	Binary variable (1-0) with a value of 1 if the individual stated being currently married; and 0 otherwise.
Gender (GEN)	Binary variable (1-0) with a value of 1 if the individual is a male; and 0 otherwise.
Occupation (OCC)	Categorical variable ranging from 1 to 20 depending on the occupation indicated by the individual. 1: Crop farmer, 2: Livestock farmer, 3: Fish/shrimp farmer, 4: Fishing, 5: Regular salaried employee, 6: Small business owner, 7: Construction worker, 8: Factory worker, 9: Domestic employee, 10: Trader, dressmaker/tailor, 11: Transport worker (i.e. rickshaw puller, taxi driver), 12: Hawker, 13: Guard/gardener, 14: Money lender, 15: Unpaid home carer, 16: Unemployed, 17: Student, 18: Retired, 19: Other, 20: Don't know.

Source: own elaboration.

1300 households for Ghana.[3]

The questionnaires are answered by the person self-identified as household head.[4] In households engaged in migration (with at least one member that has migrated), variables related to individuals' characteristics refer to the migrant's (i.e., age, occupation, marital status, etc.). In households not engaged in migration, the responses refer to the household head. This constitutes a limitation of our model regarding control variables related to the individual's characteristics. Table 1 shows the relationship between the household head and the migrant in those households engaged in migration. In Ghana, the household head has a son/daughter-parent relationship with the migrant, while in Bangladesh the persons staying as the household head is more often the partner or the son/daughter of the migrant, but not the parent.

Environmental stress questions tackle a variety of climatic events such as flood, drought, erosion, and salinization, enquiring both about their magnitude and probability. The questionary does not retrieve information about aspirations and desires among the possible drivers of migration. In consequence, our definition of migration drivers is aligned with that of Van Hear et al. (2017), who define them as structural elements acting as external forces that influence mobility. The migration patterns reported in the questionary are both permanent and temporary, which is relevant as both kinds of responses appear as adaptation strategies in impacted communities (Safra de Campos et al., 2020), and temporary migration should not be ruled out from this kind of analysis (Abel et al., 2022; Bohra-Mishra et al., 2014; Joarder and Miller, 2013).

The empirical strategy consists of two parts: a descriptive analysis of the samples and an econometric analysis. The econometric model used is a probit model that will allow us to analyse the probability of migration and the relative influence of each explanatory variable on this decision. Following Greene (2003), Eqs. (1) and (2) expose the analytical form of the model:

$$y_i^* = x_{i,ENV}^{'}\beta_1 + x_{i,CTRL}^{'}\beta_2 + \varepsilon_i, \varepsilon_i \sim N[0,1] \quad (1)$$

$$y_i = 1 \ if \ y_i^* > 0, 0 \ otherwise \quad (2)$$

where the latent variable y_i^* is defined as the propensity of individuals to migrate, and if it exceeds a certain threshold, the dependent variable y_i will take the value 1 or 0 otherwise. The independent variables are classified into drivers related to environmental stress ($x_{i,ENV}^{'}$) and control variables ($x_{i,CTRL}^{'}$).

Specifically, two different probit models will be used, and, therefore, two dependent variables will be considered. The first one is migration for economic reasons (*migraeco*). This variable takes the value 1 if the individual reports migrating to seek employment, housing problems, debt problems or loss of income, and 0 otherwise. The second variable is migration for social or family reasons (*migrasocifami*), which will take a value of 1 if the migrant reports seeking education, marriage, family obligations, health care or social and/or political problems as the reason for migrating. On the other hand, the vectors x contain the different environmental stress and control variables, the definition of which can be found in Table 2. The gender variable (*GEN*) is not introduced in the analysis for Bangladesh. The reason is that male migration dominates in this country, with 94% of migrants being men. Therefore, it seems clear that gender is significant in migration in Bangladesh, but our aim is to look at further relations that could be distorted by this feature of the sample. In the case of Ghana, 52% of the migrants were men, which implies having a more gender-balanced migration that allows us considering gender as a suitable control variable. Tables A.1 and A.2 in Appendix A show descriptive statistics and correlation matrix respectively. In addition, Variance Inflation Factor tests have been carried out to check the problems of multicollinearity, which satisfy the econometric requirements.

For a deeper analysis, in addition to studying how environment-related drivers influence the decision to migrate, it is interesting to study how environmental factors can affect the other drivers and thus indirectly influence the decision to migrate (Black et al., 2011). To do this, a principal component analysis (PCA) was carried out for the

[3] The survey considered as household a group of people living in the same dwelling and sharing meals and/or expenses.

[4] The survey considered as household head the person who has the most authority and responsibility for household affairs.

independent variables considered as environmental drivers. Principal component analysis is a traditional statistical method (Hotelling, 1933) that converts a set of variables that might be correlated into linearly uncorrelated variables that are called principal components. This method extracts the dominant patterns and displays them in terms of component scores and loadings (Wold et al., 1987). The scores correspond to the transformed values assigned to the variables, while the loadings will be used to obtain the component score by multiplying them by each original standardized variable. To decide on the number of principal components to keep, we will follow Kaiser's rule (Kaiser, 1960). According to this criterion, all components with an eigenvalue greater than unity should be retained. After that, the selected components or factors are normalized by considering the minimum and maximum value of each factor:

$$\frac{factor - minimum}{maximum - minimum} \tag{3}$$

Based on the principal components obtained, an environmental stress variable was generated. It was be interacted with the classical drivers of migration (control variables) and these interactions were included as independent variables in the probit models. This type of variables allows us to know if environmental stress intensifies or reduces the effect of other migration determinants. Therefore, the interactions to see the moderating effect of environmental stress on the control variables—the classical migration drivers—are introduced in Eq. (1), leading to the following expression:

$$y_i^* = x_{i,ENV}^{'}\beta_1 + x_{i,CTRL}^{'}\beta_2 + x_{i,ENVSTRESS}^{'}x_{i,CTRL}^{'}\beta_3 + \varepsilon_i, \varepsilon_i \sim N[0,1] \tag{4}$$

where there is an additional independent variable ($x_{i,ENVSTRESS}^{'}$) that refers to the environmental stress variable generated with the PCA technique.

3. Results and discussion

3.1. Descriptive analysis

This section is devoted to the characterization of the sample in Bangladesh and Ghana, dividing the observations into two groups for each country: one for households involved in migration (with somebody who has migrated) and another one for households not involved in migration (no-one has migrated). In the first case, the responses given by the person answering the survey (the self-designated as household-head) refer to the migrant characteristics, while in the second case the answers refer to the household head characteristics.

Starting with the occupation[5] (*OCC*) by sector (Fig. 1), in Bangladesh, migrants in the sample are mainly occupied as regular salaried employees (37.1%), followed by construction workers (13.8%), factory workers (7.5%) and small business owners (7.3%), while the predominant occupations among non-migrants are small business owners (19.0%), crop farmers (15.2%), regular salaried employees (11.3%) and unpaid home carers (9.1%). Comparing the participation of each occupation among both sub-samples, it makes sense that occupations related to non-mobile assets -such as crop cultivation or owning a small business- have lower participation among the migrants. According to Bernzen et al. (2019), agricultural and self-employment occupations imply a higher reluctance to migrate because these activities require certain investments in the community, which in rural Bangladesh is usually organized around managing assets such as land and local business (Ishtiaque and Ullah, 2013). In addition, it is observed that after migration, individuals occupy jobs with better conditions (regular salaried employees, construction, or factory workers).

In the case of Ghana, there are more similitudes between migrants and non-migrants than in Bangladesh. In both groups, trader, dressmaker/taylor is the occupation with higher participation, accounting for about 25% of the total in both cases, followed by regular salaried employees and crop farmers, which sum up to >24% for both groups, with the difference of crop farmers being more frequent in the non-migrants group in a similar way as in Bangladesh. In Ghana, unemployed people constitute 8% of the migrants in our sample, while their participation among the non-migrants is just 2.3%.

Table 3 displays an additional characterization of the differences between the migrant and non-migrant households in the sample. It shows the results of a *t*-test developed to determine whether the average of the environmental-hazard variables in the model differs or not between these two collectives. Looking at these results, there are clear differences -even under 1% of significance level in most of the cases– between the averages of each variable for households involved and not involved in migration in Ghana, regardless of the motivation behind the displacement. In the case of Bangladesh, the two groups differ significantly concerning the model variables in average terms when looking at socio-familiar migrations (except for the drinking-water variable –*WAT*-). However, when taking just the sub-sample related to economically-motivated migrations and when working with the whole sample without considering the reason for the displacement, just the housing (*HOU*) and crop/livestock disease (*CRO*) variables show a different average for households involved and not involved in migration under a 10% of the significance level.

Focusing now on the features of the migrants in the sample, Figs. 2 and 3 show the characteristics of the destination chosen and the reason behind this election. According to Fig. 2, rural destinations and nearby settlements are more frequent in the sample for Ghana than in the one for Bangladesh, while international migration is notoriously higher among the individuals surveyed in the Asian country. Major cities and district capitals are stronger attractors in our sample for Ghana, but regional capitals have a similar participation of around 12% in both countries. Looking at Fig. 3, the pattern behind the reasons to choose a specific destination is very similar among both samples, with a clear predominance of having family members in the area (>60% of the cases in both countries), followed by having friends there (accounting for a 27% of the responses in both samples). This reinforces the idea of human links behind determinant drivers of some of the decisions behind the migration process (Ackah and Medvedev, 2012; Boas, 2020; Martin et al., 2014).

3.2. Migration drivers: econometric results

Table 4 shows the results of the probit model shown in Eqs. (1) and (2) taking economic and socio-familiar migrations in Bangladesh as dependent variables. Specifically, there are three models for each type of migration, where the variables have been scaled to check the robustness of the results. The first estimation of each model considers only those environmental stress drivers ($x_{i,ENV}^{'}$ in Eq. (1)) that are mainly related to economic losses. The second estimations add the environmental stress drivers ($x_{i,ENV}^{'}$ in Eq. (1)) that are mainly related to health and basic needs. Finally, the third model introduces all the control variables ($x_{i,CTRL}^{'}$ in Eq. (1)).

On the one hand, only climatic shocks that negatively affect houses (*HOU*) could be a driver of economic migration in Bangladesh, although the effect is only significant in the second model. This evidence is intuitive since if the housing has been physically damaged, the need to look for an alternative in other locations is pressing, favouring migration (Myers et al., 2008). On the other hand, climatic shocks that negatively affect the economic security (*ECO*) of households in Bangladesh increase socio-family migration.

In relation to the control variables, we observe that not having a permanent job (*PJO*) disfavours both types of migration. Despite the higher vulnerability to climate events, low-income households might be

[5] Post-migration occupation.

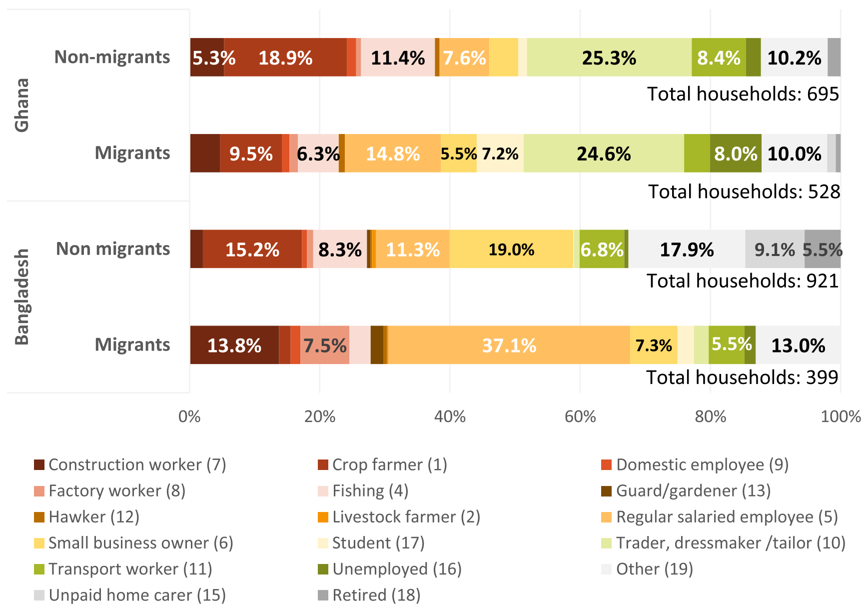

Fig. 1. Occupation of migrants (households involved in migration) and non-migrants (households not-involved in migration) in Ghana and Bangladesh.
Note: the numbers in brackets correspond to the value associated with each occupation in the variable (see Table 2 for variable description).
Source: own elaboration with data retrieved from DECCMA 2016 database (Safra de Campos and Adger, 2021).

Table 3
t-Test to compare migrant and non-migrant sub-samples in average terms of the environmental-hazard variables in the model.

	Bangladesh				Ghana			
	Average migration	Average no migration	t-Test	p-Value	Average migration	Average no migration	t-Test	p-Value
Economic motivation								
Housing (HOU)	0.619	0.568	−1.749	0.04**	0.38	0.291	−3.431	0.0003***
Ecosecurity (ECO)	0.43	0.396	−1.151	0.1249	0.374	0.192	−7.459	0***
Crop (CRO)	0.177	0.142	−1.619	0.05*	0.226	0.103	−6.101	0***
Water (WAT)	0.285	0.3	0.534	0.705	0.189	0.119	−3.547	0.0002***
Foodsecurity (FSE)	0.26	0.266	0.212	0.584	0.289	0.163	−5.501	0***
Health (HEA)	0.226	0.216	−0.405	0.3428	0.129	0.092	−2.186	0.014**
Socio-familiar motivation								
Housing (HOU)	0.649	0.568	−2.352	0.009***	0.471	0.291	−5.456	0***
Ecosecurity (ECO)	0.496	0.396	−2.899	0.0019***	0.411	0.192	−7.281	0***
Crop (CRO)	0.217	0.142	−2.951	0.0016***	0.257	0.103	−6.259	0***
Water (WAT)	0.324	0.3	−0.767	0.2215	0.243	0.119	−4.904	0***
Foodsecurity (FSE)	0.324	0.266	−1.861	0.0315**	0.379	0.163	−7.486	0***
Health (HEA)	0.294	0.216	−2.633	0.0043***	0.171	0.092	−3.559	0.0002***
General								
Housing (HOU)	0.609	0.568	−1.481	0.0694*	0.374	0.291	−3.267	0.0006***
Ecosecurity (ECO)	0.423	0.396	−0.952	0.1705	0.365	0.192	−7.269	0***
Crop (CRO)	0.169	0.142	−1.319	0.0937*	0.215	0.103	−5.715	0***
Water (WAT)	0.288	0.3	0.429	0.6659	0.182	0.119	−3.260	0.0006***
Foodsecurity (FSE)	0.258	0.266	0.313	0.623	0.279	0.163	−5.216	0***
Health (HEA)	0.226	0.216	−0.403	0.3434	0.125	0.092	−1.962	0.025**

*** $p<0.01$, ** $p<0.05$, * $p<0.1$.
Source: own elaboration with data retrieved from DECCMA 2016 database (Safra de Campos and Adger, 2021).

less likely to migrate due to their lack of resources. The costs involved in long-distance migration are often high and out of the budget of poor households (Kartiki, 2011). Age is a key factor in the decision to migrate. In line with the results obtained in the literature (Dustmann and Okatenko, 2014; van Dalen et al., 2005), a negative link is shown with both types of migration: younger individuals are more willing to migrate. In general, it is found that migrants are the sons of the considered household head, either married or unmarried, being also relevant the migration of the couple (see Table 1).

In addition, the variable related to education (*EDU*) is positive and significant in the economic migration model, showing that the higher the level of education, the higher the probability of emigrating for economic reasons. In this sense, people with higher educational attainment have more transferable assets, which enables them to migrate with higher chances of finding an income source in other place (Bernzen et al., 2019). Regarding the marital status (*MAR*), it is a significant variable in both kind of migrations, as our results show that being married decreases the probability of migrating. In the case of economic migration, women who migrate independently are often unmarried, divorced or widowed, as married women are discouraged of migrating

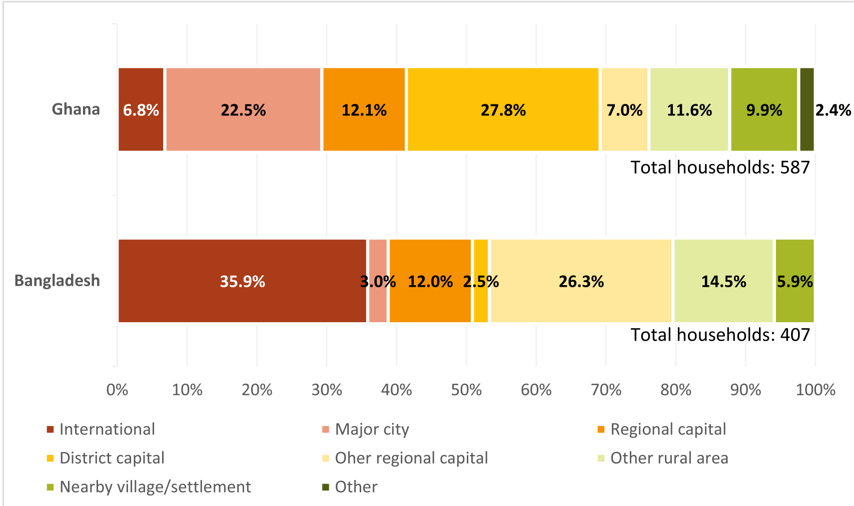

Fig. 2. Destination of the migrants in Ghana and Bangladesh.
Source: own elaboration with data retrieved from DECCMA 2016 database (Safra de Campos and Adger, 2021).

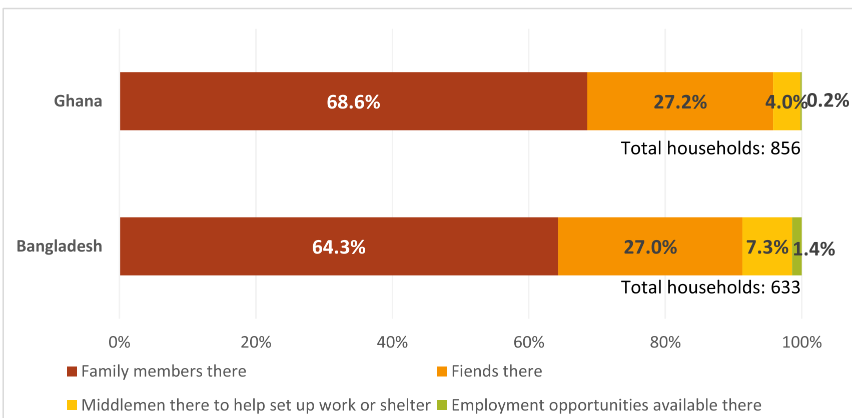

Fig. 3. Reasons to choose destination for migrants in Ghana and Bangladesh.
Source: own elaboration with data retrieved from DECCMA 2016 database (Safra de Campos and Adger, 2021).

on their own by household responsibilities and motherhood (Evertsen and van der Geest, 2020). It is also expected that single men are more prone to reallocate since they are also expected to be the breadwinners and are therefore expected to maintain the same occupational profile (Kanaiaupuni, 2000). Occupation (*OCC*) is the only control variable that is not significant in the two models. The reason might be that its influence on both kind of migration is already covered by other variables such as having a permanent job (*PJO*) or having higher education (*EDU*), whose correlations with occupation are −0.221 and −0.14, respectively (see Table A.2 in Appendix A).

As explained before, the gender variable (*GEN*) is not introduced in the regression. The explanatory analysis shows that the vast majority of the migrants in Bangladesh are men (94% of the migrant in the sample), which implies a strong influence of the gender on the probability to migrate that could mask other effects if introduced in the model.

The results for Ghana are shown in Table 5. Firstly, climatic events affecting the household (*HOU*) seem to increase the likelihood of socio-family migration in Ghana. Losing the home or having it severely damaged creates a problem at the household level, where the family head will consider migrating to maximize the welfare of the family. Regarding food security (*FSE*), this appears to be a key driver of socio-household migration in Ghana, showing that climate events that compromise food security increase the likelihood of socio-household migration. This result is similar to that obtained by Rademacher-Schulz et al. (2014), also for Ghana, where they highlighted that migration is used as a strategy to deal with adverse climatic events that threaten food security.

In addition, the economic security variable (*ECO*) and the variable related to crop and livestock status (*CRO*) are positive and significant in almost all the models. On the one hand, when a climate event strongly or moderately affects household economic security (*ECO*), the probability of migrating increases, similar to what was found for Bangladesh in the case of socio-familiar migration. On the other hand, when crops and livestock are negatively affected by a climate shock (*CRO*), both types of migration are favoured. Climatic events affecting agriculture at a sub-district level are likely to weaken risk-sharing networks and hinder opportunities for employment, increasing the motivation to migrate (Gray et al., 2020).

Regarding control variables, as it was the case for Bangladesh economic migration, educational level (*EDU*) has a positive influence in both kind of migrations in Ghana. In a similar way as in Bangladesh, age has an inverse relationship (i.e. people migrating are relatively young, typically the sons/daughters of the household head, being in this case of Ghana mainly the unmarried ones, and interestingly also in some cases the considered father of the household head). Looking at the gender (*GEN*), being a woman increases the probability of migrating for both

Table 4
Probit model results for economic and socio-family migration in Bangladesh.

	migraeco			migrasocifami		
	(I)	(II)	(III)	(I)	(II)	(III)
Housing (HOU)	0.037	0.054*	0.042	0.036	0.035	0.026
	(0.027)	(0.029)	(0.035)	(0.026)	(0.028)	(0.033)
Ecosecurity (ECO)	0.004	0.014	0.04	0.040	0.041	0.078**
	(0.029)	(0.030)	(0.036)	(0.028)	(0.028)	(0.033)
Crop (CRO)	0.044	0.060	0.038	0.062	0.055	0.018
	(0.040)	(0.042)	(0.050)	(0.038)	(0.039)	(0.041)
Water (WAT)		−0.038	−0.017		−0.039	−0.001
		(0.033)	(0.042)		(0.030)	(0.040)
Foodsecurity (FSE)		−0.035	−0.019		−0.002	−0.012
		(0.034)	(0.046)		(0.032)	(0.041)
Health (HEA)		0.005	0.029		0.053	0.065
		(0.037)	(0.049)		(0.037)	(0.045)
Permanentjob (PJO)			0.163***			0.136***
			(0.033)			(0.030)
Age (AGE)			−0.015***			−0.012***
			(0.001)			(0.001)
Education (EDU)			0.100***			0.013
			(0.032)			(0.029)
Marital (MAR)			−0.262***			−0.249***
			(0.047)			(0.049)
Occupation (OCC)			0.005			0.003
			(0.003)			(0.003)
Observations	1328	1328	1086	1183	1183	949
Pseudo R^2	0.003	0.005	0.2153	0.011	0.013	0.2128
X^2	4.77	8.16	239.12	13.50	16.30	180.16

Marginal effects. Robust standard errors in parentheses.
Source: own elaboration.
*** $p < 0.01$.
** $p < 0.05$.
* $p < 0.1$.

Table 5
Probit model results for economic and socio-family migration in Ghana.

	migraeco			migrasocifami		
	(I)	(II)	(III)	(I)	(II)	(III)
Housing (HOU)	0.033	0.027	0.036	0.102***	0.082**	0.086**
	(0.031)	(0.033)	(0.036)	(0.034)	(0.035)	(0.037)
Ecosecurity (ECO)	0.168***	0.152***	0.191***	0.136***	0.079*	0.066
	(0.037)	(0.041)	(0.046)	(0.043)	(0.047)	(0.050)
Crop (CRO)	0.116**	0.106**	0.111**	0.131***	0.096*	0.117**
	(0.045)	(0.046)	(0.050)	(0.051)	(0.053)	(0.056)
Water (WAT)		0.029	0.029		0.034	0.027
		(0.045)	(0.048)		(0.047)	(0.047)
Foodsecurity (FSE)		0.030	0.035		0.111**	0.140***
		(0.044)	(0.049)		(0.048)	(0.054)
Health (HEA)		−0.011	−0.001		0.014	0.018
		(0.050)	(0.054)		(0.050)	(0.052)
Permanentjob (PJO)			−0.001			0.031
			(0.036)			(0.036)
Age (AGE)			−0.010***			−0.005***
			(0.001)			(0.001)
Education (EDU)			0.117***			0.087***
			(0.032)			(0.032)
Marital (MAR)			0.03			0.033
			(0.032)			(0.030)
Gender (GEN)			−0.174***			−0.176***
			(0.032)			(0.034)
Occupation (OCC)			0.013***			0.012***
			(0.003)			(0.003)
Observations	1300	1300	1168	978	978	899
Pseudo R^2	0.034	0.035	0.1206	0.055	0.062	0.1322
X^2	59.40	60.14	171	63.62	70.48	118.48

Marginal effects. Robust standard errors in parentheses.
Source: own elaboration.
*** $p < 0.01$.
** $p < 0.05$.
* $p < 0.1$.

economic and socio-familiar reasons, which opposes to the case of Bangladesh in which the majority of the migrants in the sample were men. This is aligned with the results exposed by Lattof et al. (2018), which reveal an increased mobility and independence among female migrants in Ghana. Occupation (*OCC*) is significant too in the explanation of both kind of migrations in Ghana, which seems to be connected to the idea of migration as a response to a partial disequilibrium in labour markets. This way of understanding migration matches the results by Molini et al. (2016), which shows that an historical migration pattern linked to the demand of labour in industries such mining or agriculture in specific areas of the country has not changed significantly since the colonial period. Finally, having a permanent job (*PJO*) or being married (*MAR*) does not seem to influence migration decisions in Ghana.

3.3. Migration drivers with environmental stress as moderating effect: econometric results

As mentioned above, a principal component analysis is carried out to deepen the results and then new models are estimated. The initial results of the PCA for Bangladesh and Ghana are presented in Table A3 in Appendix A, while the factor loadings and unique variances are shown in Table A4.

For the case of Bangladesh, Factor 1 itself will be the environmental stress indicator. However, for Ghana the environmental stress indicator will be calculated as the average of Factor 1 and Factor 2. Using this environmental stress variable, we furthermore explore its role as a moderating element on the former control variables. The results are shown in Table 6.

The results for Bangladesh are robust to previous models. For the case of *migraeco* (economic migration), none of the climatic explanatory variables has an influence on the probability of migrating for economic reasons. However, having a permanent job (*PJO*) and a higher educational level (*EDU*) favour economic migration. On the other hand, age and being married (*MAR*) reduce the probability of migrating for economic reasons. The main difference with respect to previous models concerns the occupation variable (*OCC*), which is now significant when explaining economic migration. In addition, it is observed that being subjected to environmental stress positively moderates the occupation driver. Therefore, the occupation itself but also being affected by environmental stress influence the probability of migrating.

In the model regarding socio-family migrations, no significant effects are found with respect to the previous model without interactions.

Table 6
Probit models including environmental stress for Bangladesh and Ghana (model III).

	Bangladesh		Ghana	
	migraeco	migrasocifami	migraeco	migrasocifami
	(III)	(III)	(III)	(III)
Housing (HOU)	0.035	0.025	−0.031	0.084
	(0.047)	(0.042)	(0.052)	(0.052)
Ecosecurity (ECO)	0.037	0.082*	0.115*	0.071
	(0.048)	(0.043)	(0.070)	(0.069)
Crop (CRO)	0.038	0.026	0.048	0.143*
	(0.065)	(0.056)	(0.068)	(0.074)
Water (WAT)	−0.026	0.001	−0.032	0.053
	(0.056)	(0.051)	(0.072)	(0.071)
Foodsecurity (FSE)	−0.047	−0.024	−0.031	0.147*
	(0.058)	(0.052)	(0.071)	(0.077)
Health (HEA)	0.014	0.064	−0.125	−0.022
	(0.063)	(0.058)	(0.082)	(0.078)
Permanentjob (PJO)	0.162***	0.139***	−0.122	−0.104
	(0.033)	(0.030)	(0.082)	(0.097)
Age (AGE)	−0.015***	−0.012***	−0.010***	−0.002
	(0.001)	(0.001)	(0.003)	(0.003)
Education (EDU)	0.101***	0.015	0.007	0.027
	(0.032)	(0.029)	(0.072)	(0.071)
Marital (MAR)	−0.273***	−0.254***	0.143**	0.183***
	(0.047)	(0.050)	(0.070)	(0.062)
Gender (GEN)			−0.180**	−0.198***
			(0.072)	(0.075)
Occupation (OCC)	0.005*	0.003	−0.004	2.62*E*-04
	(0.003)	(0.003)	(0.007)	(0.007)
environstress*Permanentjob (E-PJO)	−0.047	−0.04	0.363	0.37
	(0.032)	(0.028)	(0.231)	(0.236)
environstress*Age (E-AGE)	0.001	4.27E-04	0.003	−0.01
	(0.001)	(0.001)	(0.008)	(0.008)
environstress*Education (E-EDU)	−0.007	0.003	0.361*	0.174
	(0.032)	(0.027)	(0.212)	(0.201)
environstress*Marital (E-MAR)	−0.038	−0.032	−0.377*	−0.507**
	(0.042)	(0.035)	(0.216)	(0.202)
environstress*Gender (E-GEN)			0.021	0.08
			(0.220)	(0.202)
environstress*Occupation (E-OCC)	0.007**	0.005*	0.056***	0.039**
	(0.003)	(0.003)	(0.021)	(0.020)
Observations	1086	949	1168	899
Pseudo R^2	0.222	0.2187	0.1324	0.151
X^2	258.04	186.12	190.87	152.41

Marginal effects. Robust standard errors in parentheses.
Source: own elaboration.
*** $p < 0.01$.
** $p < 0.05$.
* $p < 0.1$.

Climatic factors that affect economic security (*ECO*) have a positive influence on socio-family migrations. In addition, not having a permanent job (*PJO*) would act as a barrier to migration. On the other hand, not-married people (*MAR*) and young people (*AGE*) increase the probability of migrating. In this case, environmental stress would act as a moderator only for the occupation variable. The occupation (*OCU*) itself does not influence the probability of migrating for socio-family reasons, but it does when combined with the moderating effect of environmental stress (*E-OCU*). This is a relevant result as it provides evidence for some occupations being especially vulnerable to climate stress, hence influencing the probability of migrating when considering both aspects.

Concerning Ghana, climatic factors that affect economic security (*ECO*) favour migration for economic reasons, while climatic factors related to crops (*CRO*) and food security (*FSE*) have a positive influence on the probability of migrating for socio-family reasons. Also, some changes are noted.

For economic migration, the education (*EDU*) and occupation (*OCC*) variables are now not significant. However, its interaction with environmental stress is significant. The first of these interactions (*E-EDU*) shows that migrants with higher levels of education and who are affected by environmental stress are more likely to migrate for economic reasons. The education (*EDU*) variable is not significant in this model, but its interaction with environmental stress (*E-EDU*) explains the probability of migrating for economic reasons in a positive way. This means that persons with higher education are more prone to migrate for economic reasons when affected by environmental stress, which may be due to a high awareness about the magnitude of the environmental problem.

The marital status (*MAR*) and its interaction with the environmental stress variable (*E-MAR*) have a significative and negative influence in the probability of migrating both for economic and socio-family reasons. In other words, being married and affected by adverse climatic factors (both at the same time[6]) would reduce the probability of migrating. The logic then is that environmental stress may favour migration, but particularly more for non-married individuals, while being married reduce such movement. In other words, in Bangladesh being married deter migration, but in Ghana this effect is particularly clear when environmental stress is perceived.

About migration for socio-family reasons, different effects are found with respect to migration for economic reasons. The climatic factors that affect the crops (*CRO*) and food security (*FSE*) would be driving migration for socio-family reasons. Looking at the control variables, the marital status (*MAR*) and gender (*GEN*) are the only ones contributing to the probability of migrating for socio-family reasons, the first one in a positive way (being married increases the probability of migrating for these reasons) and the second one in a negative way, which means that being a woman increases the probability of migrating for socio-family reasons. These results are aligned with the idea of migration as a way for women to challenge traditional social roles in rural societies (Guo et al., 2011). Young women in Ghana tend to attribute their migrations to avoid family-imposed practices such as female genital mutilation or forced or arranged marriage, but also to accumulate property for marriage (Anarfi and Kwankye, 2009; Lattof et al., 2018). Regarding the interactions with the environmental stress variables, only the occupation (*E-OCU*) and marital status (*E-MAR*) are modulated by suffering adverse climatic effects, both in the same way as explained in the case of economic migration.

In summary, adverse climatic shocks become drivers of both economic and socio-family migration when they affect certain aspects of individuals, such as their households, economic and food security, or crops and livestock. Moreover, more of these climate drivers are found in Ghana than in Bangladesh. It should be noted that the results show that suffering from environmental stress can intensify or reduce the effect of traditional drivers. In this sense, it appears that adverse climatic shocks may not only have a direct impact on migration but may also condition migration decisions indirectly through the occupation, the education, or the marital status of the person.

3.4. Discussion

The exposed results reveal the significant role of some climate drivers on migration. However, according to the surveys, the explicitly declared reasons for migration are seeking employment, education or family related. But here, when splitting between economic reasons (mostly related to the first reason and others less cited, such as housing or debt problems) and socio familiar reasons (related to the other two reasons, and a few less cited ones as health care), the patterns are better identified. Looking at previous works, Codjoe et al. (2020) found that the main drivers of migration in the Volta Delta were economic (employment opportunities) and education and family reunion, while very few individuals cited direct environmental factors as the main reason for migrating. Economic reasons were also found in the GBM Delta as key affairs in people's perception of drivers of migration (Arto et al., 2019; Nicholls et al., 2019). Safra de Campos et al. (2020) highlighted for this delta the more out-migration of males and especially to cities, and emphasized the role of mobility in diversify households' portfolio of economic activities through access to distant labour markets, to ensure survival or improve standards of living.

Our results acquire further significance when put in context with other research based on surveys. The study by Lee et al. (2015) used the results of a poll that collected responses in 119 countries in 2007–08, which was the largest survey ever conducted on climate change at that time. This work revealed that the second country with the highest proportion of respondents (being aware of it) concerned with climate change was Bangladesh (98%). Those inhabitants at the GBM area that already knew about climate change showed a high concern for climate events and the effects they could entail. The case of Ghana revealed a more intermediate position among the world countries with a relatively low awareness, but, at the same time, those people in Ghana already informed about climate change revealed a relatively medium-high concern about its effects. In light of these results, our findings concerning the misidentification of environmental reasons behind the migration may be showing a low awareness of climate change among the population in the studied deltas, despite the effects of extreme events are already impacting the population and the migration trends.

Abu et al. (2022) developed a binary logistic regression for the Volta Delta, in such case of predictors of future migration intentions as a result of experience of climate-related hazards. Based on the DECCMA project surveys used in this work, one of their main findings was that exposure to drought does not trigger migration intentions, however, exposure to erosion and salinity do. It is clear for us though that such comprehensive surveys have a lot still to offer, to be analysed and exploited as done here, being surveys that are very costly, time-consuming, with few of such details in many contexts and aspects (one just needs to see the comprehensiveness of it, on households' characteristics, their material and subjective wellbeing, migration patterns, adaptation, perception of environmental stress and change, thresholds related to perceptions when circumstances become difficult and economic data).

As hinted in the introduction a meta-regression analysis of environmental migration literature (Zhou and Chi, 2024) has reflected that across all the global literature, environmental stressors have not so often appeared as important predictors of (out/in/net) migration, with mixed evidence tending to report a bit more outmigration. In our analysis, controlling for the most socioeconomic characteristics, we find how environmental stress variables are highly relevant to explain migrations.

[6] The positive value of just the "marital" variable for sociofamiliar reasons is reflecting more the result than the motive of migration. In other words, those (more women than men) that outmigrate for marital reasons (hence marrying just after migration), and hence in the survey are captured already after being married in the destination area.

There is a positive and significant relationship between those having identified environmental stress factors in their origin areas and those migrating. In other words, the motivation for migration is also positively related to climatic factors, even if households do not identify them as such at first (as the explicated main reason).

The role of the interaction of environmental stress with more commonly studied socioeconomic variables results relevant in the final explanatory model, finding e.g. how in Ghana unmarried people tend to migrate more when environmental stress is present. In this regard, the comparative analysis between the two areas also provides some differences as the ones highlighted, indicating the importance of using a general common framework as the one presented, but explicitly surveying, representing, and identifying the characteristics and context of each area, in order to properly understand and explain the results.

4. Summary and conclusions

In this article we have explored the drivers of migration, including usual control variables, but also detailed climate effects, in key deltaic areas of Bangladesh and Ghana where scientific data is clearly illustrating the appearance of different phenomena. This analysis has shown the role of the relatively underexplored climate drivers by using a representative sample of the forementioned deltaic regions. It is confirmed that such effects are not always so perceived or recognized as main drivers of migration, although some of them appear relevantly, which is consistent with previous results (Adger et al., 2021). This happens in both deltas (in Bangladesh only in migration self-reported as for socio-family reasons) with *ecosecurity*: this variable—with which the individual indicates that flooding, drought, erosion, salinity, storm surges, or cyclone has had moderate or high negative impacts on economic security—acts as a driver of migration despite the household does not identify the displacement as driven by environmental causes. Especially for Ghana and for sociofamiliar reasons we also find as cojoint driver the *crop* (the individual indicates that flooding, drought, erosion, salinity, storm surges, or cyclone had moderate or high negative impacts on crop/livestock disease), *foodsecurity* (the same than before, with impacts on food security) and *housing* (on the house).

On the control variables, it was found that individuals tend to migrate relatively young (typically the sons/daughters of the household head, in the case of Ghana mainly the unmarried one, being most common the male migration, most clearly in Bangladesh). In the case of economic migration, higher education tends to point towards higher outmigration (being reinforced with the interaction of environmental stress in Ghana). In Bangladesh, clearly more men migrate, and mostly for economic reasons. In any case, in comparison with most male headed households, the variable does not stand out as most explicative factor. In Ghana, the gender variable affects migration, showing that being a woman increases the probability of migrating both for economic or socio-family reasons. The role of the variable of "permanent job" is not easy to interpret due to the questioning of the migrant at the destination place, where often "stable" job means basically having become a non-returning migrant, while the individual that does not achieve it may have returned and hence not being captured in the sample. The occupation variable explains the probability of migrating in both kind of migrations assessed in Ghana (for economic and socio-family reasons), but it is not significant in the case of Bangladesh. This fact may be related to the migration patterns detected in Ghana, which are historically linked to the demand of specific occupations in certain areas of the country (Molini et al., 2016).

The environmental stress indicators derived from the principal component analysis (PCA), allow exploring the role of the environmental stress as moderating effect making use of interaction variables with more common studied control variables, results relevant in this final outcome. For example, in general, being married deters from migrating, but in the case of Ghana the interaction with environmental stress reinforces this decision. In general, suffering from environmental stress and being young or being non-married tends to increase migration in Ghana.

One of the most interest outcomes of the analysis regards the occupation variable, which is not significant individually when explaining the probability of migrating for economic reasons in Ghana and for socio-family reasons in Ghana and Bangladesh, but has an influence on the probability of migrating (in all the types of migration in the two regions) when it is modulated by the environmental stress, which is an evidence of the higher climatic vulnerability of certain occupations.

In our view this type of analysis may be useful for other areas (especially those considered vulnerable to climate change), where probably the relevance of such factors/drivers on migration have not yet been recognized or made clearly explicit. However, some limitations must be considered. First, climate change is a constantly evolving phenomenon, so the data should be as up-to-date as possible. Our study employs data from 2016 as working with surveys implies assuming certain constraints in the availability of recent data. Nevertheless, analysing structural issues such as perceptions regarding climate change effects requires a medium-long-term perspective. For this reason, the surveys include several questions regarding structural changes evaluated with respect to the past, which are still relevant some years after the data collection process. Second, data collection through surveys in which the basic unit is a household may introduce additional biases. In our case, having households involved and not involved in migration is required to stablish comparisons, but it may introduce additional limitations regarding control variables as the responses related to individuals' characteristics may refer to the migrant or to the household.

CRediT authorship contribution statement

Sara Fernández: Conceptualization, Formal analysis, Methodology, Software, Writing – original draft. **Guadalupe Arce:** Conceptualization, Investigation, Project administration, Writing – original draft. **Ángela García-Alaminos:** Formal analysis, Visualization, Writing – original draft. **Ignacio Cazcarro:** Data curation, Resources, Writing – original draft. **Iñaki Arto:** Resources, Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

The data are available at Mendeley Data (https://doi.org/10.17632/223z53kwnm.1) and the DECCMA project website.

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Appendix A

Table A.1
Descriptive statistics.

	Bangladesh				Ghana			
	Mean	Std. dev.	Min	Max	Mean	Std. dev.	Min	Max
Dependent variables								
migraeco	0.306	0.461	0	1	0.442	0.497	0	1
migrasocifami	0.221	0.415	0	1	0.272	0.445	0	1
Independent variables								
Housing (HOU)	0.580	0.494	0	1	0.329	0.470	0	1
Ecosecurity (ECO)	0.404	0.491	0	1	0.271	0.444	0	1
Crop (CRO)	0.151	0.358	0	1	0.154	0.361	0	1
Water(WAT)	0.296	0.456	0	1	0.146	0.353	0	1
Foodsecurity (FSE)	0.263	0.441	0	1	0.215	0.411	0	1
Health (HEA)	0.219	0.414	0	1	0.105	0.307	0	1
Control variables								
Permanentjob (PJO)	0.545	0.498	0	1	0.709	0.454	0	1
Age (AGE)	40.765	14.282	16	97	38.514	14.348	16	95
Education (EDU)	0.415	0.493	0	1	0.539	0.499	0	1
Marital (MAR)	0.794	0.405	0	1	0.544	0.498	0	1
Gender (GEN)	0.105	0.306	0	1	0.588	0.492	0	1
Occupation (OCC)	9.050	6.109	1	20	8.897	5.587	1	20

Table A.2
Correlation matrix.

	Bangladesh										
	Housing (HOU)	Ecosecurity (ECO)	Crop (CRO)	Water (WAT)	Foodsecurity (FSE)	Health (HEA)	Permanentjob (PJO)	Age (AGE)	Education (EDU)	Marital (MAR)	Occupation (OCC)
Housing (HOU)	1										
Ecosecurity (ECO)	0.316	1									
Crop (CRO)	0.187	0.409	1								
Water (WAT)	0.343	0.252	0.266	1							
Foodsecurity (FSE)	0.379	0.372	0.316	0.438	1						
Health (HEA)	0.327	0.242	0.347	0.474	0.431	1					
Permanentjob (PJO)	−0.024	−0.143	−0.095	−0.110	−0.235	−0.105	1				
Age (AGE)	−0.067	0.028	0.026	0.030	0.010	0.018	0.023	1			
Education (EDU)	−0.124	−0.031	0.009	−0.065	−0.125	−0.072	0.254	−0.141	1		
Marital (MAR)	−0.029	−0.002	−0.039	−0.013	−0.043	−0.014	0.098	0.279	−0.100	1	
Occupation (OCC)	0.109	−0.076	−0.118	0.002	0.019	0.037	−0.221	0.022	−0.140	−0.072	1

	Ghana											
	Housing (HOU)	Ecosecurity (ECO)	Crop (CRO)	Water (WAT)	Foodsecurity (FSE)	Health (HEA)	Permanentjob (PJO)	Age (AGE)	Education (EDU)	Marital (MAR)	Gender (GEN)	Occupation (OCC)
Housing (HOU)	1											
Ecosecurity (ECO)	0.317	1										
Crop (CRO)	0.203	0.530	1									
water (WAT)	0.269	0.310	0.275	1								
Foodsecurity (FSE)	0.313	0.587	0.448	0.382	1							
Health (HEA)	0.343	0.245	0.161	0.352	0.266	1						
Permanentjob (PJO)	−0.060	−0.147	−0.095	−0.086	−0.101	−0.038	1					
Age (AGE)	0.021	0.033	−0.004	−0.003	0.010	0.030	0.069	1				
Education (EDU)	−0.054	−0.007	−0.009	−0.041	−0.009	−0.024	0.032	−0.164	1			
Marital (MAR)	−0.004	0.068	0.023	0.040	0.037	−0.021	0.281	0.122	−0.018	1		
Gender (GEN)	−0.015	0.031	0.004	0.003	0.054	−0.002	0.034	−0.029	0.242	0.104	1	
Occupation (OCC)	−0.035	−0.145	−0.059	−0.030	−0.122	0.020	−0.130	−0.118	0.087	−0.215	−0.164	1

Table A3
Factor derivation from principal component analysis for Bangladesh and Ghana.

	Eigenvalue	Difference	Proportion	Cumulative
Bangladesh				
Factor 1	2.71197	1.79677	0.4520	0.4520
Factor 2	0.91520	0.13759	0.1525	0.6045
Factor 3	0.77761	0.19555	0.1296	0.7341
Factor 4	0.58206	0.05238	0.0970	0.8311
Factor 5	0.52968	0.04620	0.0883	0.9194
Factor 6	0.48348	–	0.0806	1
Ghana				
Factor 1	2.69998	1.66295	0.4500	0.4500
Factor 2	1.03703	0.30233	0.1728	0.6228
Factor 3	0.73470	0.12936	0.1224	0.7453
Factor 4	0.60534	0.07099	0.1009	0.8462
Factor 5	0.53435	0.14574	0.0891	0.9352
Factor 6	0.38861	–	0.0648	1

Source: own elaboration.

Table A4
Factor loadings and unique variances from principal component analysis for Bangladesh and Ghana.

	Bangladesh		Ghana		
	Factor1	Uniqueness	Factor1	Factor2	Uniqueness
Housing	0.6247	0.6098	0.5793	0.4184	0.4894
Ecosecurity	0.6275	0.6063	0.7807	−0.3385	0.2760
Crop	0.6091	0.6290	0.6715	−0.4777	0.3209
Water	0.7008	0.5089	0.6307	0.2802	0.5236
Foodsecurity	0.7462	0.4432	0.7803	−0.2241	0.3410
Health	0.7136	0.4908	0.5453	0.6249	0.3122

Source: own elaboration.

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