WHERE the RAIN FALLS

GLOBAL POLICY REPORT

WHERE THE RAIN FALLS : CLIMATE CHANGE, FOOD AND LIVELIHOOD SECURITY, AND MIGRATION

AN 8-COUNTRY STUDY TO UNDERSTAND RAINFALL, FOOD SECURITY AND HUMAN MOBILITY

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Where the rain falls : climate change, food and livelihood security, and migration

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Executive Summary

The « Where the Rain Falls » (« Rainfalls ») research explores the interrelationships among rainfall variability, food and livelihood security[1], and human mobility in a diverse set of research sites in eight countries in Asia, Africa and Latin America. While climate change affects nearly all aspects of food security – from production and availability, to the stability of food supplies, access to food, and food utilization[2] – the Rainfalls research focused on linkages between shifting rainfall patterns and food production and the stability of food supplies[3] . The central focus of the « Where the Rain Falls » initiative was to explore the circumstances under which households in eight case study sites in Latin America, Africa, and Asia use migration as a risk management strategy when faced with rainfall variability and food and livelihood insecurity. Climate change is likely to worsen the situation in parts of the world that already experience high levels of food insecurity. The consequences of greater variability of rainfall conditions – less predictable seasons, more erratic rainfall, unseasonable events or the loss of transitional seasons – have significant repercussions for food security, the livelihoods of millions of people, and the migration decisions of vulnerable households. In order to make informed decisions about adaptation planning, development, and a transition to a more climate-resilient future, policymakers and development actors need a better understanding of the linkages among changes in the climate, household livelihood and food security profiles, and migration decisions.

This report offers six new contributions to research on climate change and human mobility :

- **Next generation of research methods, utilizing a mix of quantitative and qualitative methods, including a household survey, a variety of Participatory Research Approach (PRA) tools, and expert interviews ;**
- **Empirical evidence from eight detailed cases across three regions, building on earlier empirical work on environmental change and human mobility (EACH-FOR, 2009)[4] ;**
- **Original maps for each of the eight case study sites, providing a visual representation of key data related to rainfall patterns, agriculture, food security, and current migration patterns from the research villages ;**
- **An analytical framework to bring coherence to the evidence generated from eight very diverse research sites in seeking to answer the question of « under what circumstances households use migration as a risk management strategy » ;**
- **Agent-based modelling work to address the question of « under what circumstances rainfall variability might become a significant driver of future migration », with an initial application to the Tanzania research site ;**
- **Policy reflections for governments, multilateral and research institutions, and non-governmental organizations working directly with many of the world's most vulnerable populations.**

Key Findings : Current relationship between rainfall variability, food and livelihood security, and migration

The diverse nature of the eight case studies investigated provided the opportunity to explore the question of « under what circumstances households use migration as a risk management strategy » in a comparative way. From the research an analytical framework emerged that identified important factors contributing to household decision-making at several levels :

- The first level of the framework distinguishes among the eight countries based on relevant macro-level social, economic and demographic indicators. A typology emerged from this analysis of national contexts with different characteristics that impact household livelihood strategies, including migration decisions. This categorization of countries overlaps but does not entirely coincide with a regional typology of country contexts. For example, three of four Asian case studies fall into the category of dynamic countries with medium-to-high poverty and food insecurity, with Thailand representing the exception due to its success over recent decades in poverty reduction.

- At a subnational level, the diversity of the project's specific research sites is described in terms of a range of geographic, meteorological, and agroecological characteristics.
In addition to annual rainfall amounts ranging from 560 mm to 1700 mm, other important characteristics that distinguish the sites relate to: proximity to cities or other centres with significant alternative employment opportunities (e.g., industrial estates) ; elevation; the seasonality of rainfall patterns; and the degree of dependence on rain-fed versus irrigated agriculture.

- Finally, key characteristics at individual and household levels particularly relevant to migration decision-making are also identified, based on primary data gathered through household surveys. These include: household size and composition ; land ownership; asset base ; degree of livelihood diversity ; access to formal and informal institutions ; and education levels. These characteristics reveal the factors that shape current and future migration decisions; and offer insights as to which households may be unable to adapt to changes in rainfall in situ or through migration and the factors that contribute to resilience or vulnerability to rainfall changes in certain types of households.

Field observations

The field research in the eight case study countries found that :

- Rural people in the eight research location overwhelmingly perceive climatic changes happening today in the form of rainfall variability, and these perceptions shape household risk management decisions. The most common changes reported relate to the timing, quality, quantity, and overall predictability of rainfall, including: delayed onset and shorter rainy seasons; reduced number of rainy days per year; increased frequency of heavy rainfall events, and more frequent prolonged dry spells during rainy seasons. In most cases, these perceived changes correlate with an analysis of local meteorological data over the last several decades ;

- The largely agriculture-based households in the research sites overwhelmingly report that rainfall variability negatively affects production and contributes to food and livelihood insecurity. Levels of food insecurity varied significantly across the eight sites depending on such factors as: the total amount and seasonality of rainfall; the degree of agricultural intensification ; the extent of livelihoods diversification; and the access of poor households to the social safety net and other support services ;

- Migration, which was common in the eight research sites, was observed to have the following characteristics: almost entirely within national borders; predominantly male, but with growing participation by women in a number of countries; largely by individual household members (with India as the exception where entire nuclear families moved together); largely driven by livelihood-related needs (household income) in most countries, but with a growing number of migrants seeking improved skill sets (e.g., through education) in countries like Thailand, Vietnam, and Peru; and a mix of rural-rural and rural-urban, with more productive agricultural areas (Ghana, Bangladesh, Tanzania), nearby urban centres (Peru, India), mining areas (Ghana), and industrial estates (Thailand, Vietnam) the most common destinations ;

- Households manage climatic risks like changes in rainfall variability with migration. Migration – seasonal, temporal, and permanent – plays an important part in many families' struggle to deal with rainfall variability and food and livelihood insecurity, and was reported to have increased in recent decades in a number of the research sites. Rainfall was observed to have a more direct relationship with household migration decisions in research sites where the dependence on rain-fed agriculture, often with a single harvest per year, was high and local livelihood diversification options were low. Pressure on rainfall-dependent livelihoods is likely to grow as a driver of long-term mobility in the coming decades if vulnerable households are not assisted in building more climate-resilient livelihoods in situ ;

- Household vulnerability to rainfall variability affects food and livelihood security outcomes and migration choices and patterns. Households with more diverse assets and access to a variety of adaptation, livelihood diversification, or risk management options – through social networks, community or government support programmes, and education – can use migration in ways that enhance resilience. Those households which have the least access to such options – few or no livelihood diversification opportunities, no land, little education – use (usually) internal migration during the hunger season as a survival strategy in an overall setting of erosive coping measures which leave or trap such households at the margins of decent existence.

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Four distinct household profiles : Migration as a risk management strategy

Analysis of the household survey data was used to generate four distinct household profiles in relation to their use of migration in response to rainfall variability and food and livelihood insecurity. The first group – less food secure households with access to a wider range of adaptation options, formal and informal institutions and networks - send young single migrants who send remittances which are used to improve their resilience, such as investing in education, health, and climate-resilient livelihood opportunities and risk diversification. These households use migration as one of a variety of adaptation strategies, moving seasonally or temporally, often to non-agricultural jobs in cities or internationally. The second group – food insecure and land-scarce households with fewer adaptation and livelihood diversification options and lower social capital and access to institutions – use migration to survive, but not flourish. The heads of these households move seasonally in their countries to find work – often as agricultural labour in other rural areas. The third group – households with a sparse range of choices around livelihoods, often landless and food insecure – use migration as a matter of human security in what can be seen as an erosive coping strategy. Heads of household from this group often move during the hunger season to other rural areas in their regions in search of food, or work to buy food for their families. The final group appear to be « trapped populations » that struggle to survive in their areas of origin and cannot easily use migration to adapt to the negative impacts of rainfall stressors.

Potential future relationship between rainfall variability, food and livelihood security, and migration

In order to understand the potential for rainfall to become a significant driver of human mobility in the future, it is important to identify the range of impacts that likely rainfall scenarios may have upon migration flows. Agent-based modelling is a computational social simulation technique that enables the user to model the behaviour of individual decision-making entities as well as their interactions with each other and the environment. Using the Rainfalls case study sites as examples of locations where changes in rainfall might contribute to increased food insecurity and human mobility, a process of future-oriented simulation and analysis provides a valuable opportunity to understand the circumstances under which rainfall variability might become a significant driver of migration in different environments.

The Rainfalls Agent-Based Migration Model (RABMM) represents vulnerability and migration decision-making at two levels of agent analysis: the household and the individual, both of which can be generated from the household survey data collected in each case study location. The RABMM is designed to represent the degree of vulnerability of households to rainfall variability-induced changes in livelihood and food security, and the subsequent impact of these upon the migration of household members.

The research identified a range of impacts that rainfall scenarios of moderate and extreme drying and wetting may have upon migration flows and showed that rainfall changes have the potential to become a significant driver of human mobility in the future. From the initial application of the model to the Tanzania research site the following results were obtained:

- Migration from vulnerable households is sensitive to changes in rainfall patterns. Throughout the majority of the simulation period, the normalized number of migrants modelled as leaving vulnerable households is greatest under Scenario 4 (extreme drying). By contrast, Scenario 3 (extreme wetting) results in the lowest numbers of migrants from vulnerable households. The number of migrants modelled as leaving vulnerable households under Scenarios 1 (drying) and 2 (wetting) both represent a significant increase over the baseline, but less than Scenario 4 ;

- By contrast, « aspirational » migration from households less vulnerable to climatic stressors (« contented households ») shows much less sensitivity to changing assumptions about future rainfall patterns. Both wetting scenarios produce small increases in contented migration, while both drying scenarios show modest decreases.

As the case studies and modelling results indicate, changes in both the mean and variability of local rainfall influence factors like regional labour markets and food production systems. Rainfall variability also affects household vulnerability, depending on household characteristics such as income, assets and family size. Case study and modelling results illustrate the circumstances under which migration decisions occur – showing that both « contented » and « vulnerable » households use migration, but in markedly different ways that either enhance resilience or reinforce a downward spiral of vulnerability to climatic and other stressors.

Reflections for policymakers and practitioners

People in vulnerable communities worldwide are already experiencing impacts associated with extreme weather events and slow-onset climate change[5]. Yet recent estimates indicate that current emissions trends and reduction pledges could lead to a 3.5° C - 6° C[6] warmer world. Fundamentally, addressing the climate crisis requires more than business as usual from national and local governments, in developed and developing countries and by the global community in the areas of food security, the environment, and sustainable development more broadly.

The research findings inform a suite of policy and practice recommendations that, as a collection of actions, can support poor populations to make informed choices about migration, adaptation, and food security that uphold their dignity and safety and enhance their resilience in the face of climate change. The burden of assisting and protecting vulnerable populations cannot be borne by the most affected states and communities alone. The principle of common but differentiated responsibilities – both in terms of minimizing pressure on vulnerable populations and providing adaptation options – must, therefore, underlie policy negotiations and subsequent implementation at all levels.

The longer governments wait to tackle climate change through ambitious mitigation, finance, and adaptation actions, the worse the impacts and the higher the costs – in human and financial terms. Globally, **parties to the UN Framework Convention on Climate Change** must :

- Commit to an equitable approach to reduce greenhouse gas emissions in line with what science says is necessary to keep average global temperature increases below 2° C and potentially below 1.5° C.
- Increase commitments and agree on innovative sources to ensure delivery of adequate, sustainable, predictable, new and additional adaptation finance that promotes transparency, participatory approaches, and accountability.
- Facilitate global and regional coordination through the Adaptation Committee to enable developing countries to access support and undertake national adaptation planning.
- Assess and address loss and damage through the UN Framework Convention and the loss and damage work programme and mechanism in ways that meet the needs of the most vulnerable people.

Climate change, food security, poverty, natural resource management, and human mobility are inextricably linked and cannot each be tackled in isolation. **Global food and nutrition security and sustainable development policymakers must** :

- Reinforce the call to tackle the climate crisis and integrate climate change and gender considerations into global food and nutrition security efforts.
- Craft goals for the post-Millennium Development Goal period that support the right of all people to sustainable development.

Impacts are local, making action at national and local levels vital. **Developed and developing country governments, non-governmental organizations, multilateral institutions and UN agencies** must strive for greater collaboration across sectors, ministries, and national borders. They must also :

- Support, promote, and implement comprehensive, participatory national and local plans in order to anticipate and plan for potential food and livelihood security issues and human mobility related to climatic stressors.
- Address transboundary challenges and opportunities related to adaptation and human mobility.
- Support and promote resilient livelihoods and food security.
- Strengthen and expand disaster risk reduction and links with long-term development.
- Integrate gender considerations.
- Prioritize and engage vulnerable populations.

Climate change presents new, dynamic and significant challenges to already poor and vulnerable populations. They are part of long-term solutions and should be empowered and equipped with better information, resources and livelihood options that take changing rainfall patterns into account. But lasting solutions will take more than local people and communities working to fix the problems : it will take a concerted and purposeful international effort to foster resilience in the face of climatic stressors.

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1- Nature and purpose of this report

1.1 What is known about the influence of environmental change on human mobility ?

Since at least the mid-1980s, scientists have linked environmental change to human mobility[7]. Early debates emerged around future projections and predictions of the number of « environmental migrants »[8]. More recently, both conceptual and empirical work have examined broad relationships between environmental factors and migration in different situations[9]. These studies have identified broad patterns as a point of departure for further, more nuanced work on the interactions of climatic and socio-economic factors[10]. Research since that time has determined that environmental factors do play a role in human mobility[11] and emphasizes that some people who are more exposed to environmental stressors – particularly farmers, herders, pastoralists, fishermen and others who rely on natural resources and the weather for their livelihoods – may be the least able to move very far away, if at all[12]. In the decades ahead, these potentially « limited mobility » populations could face deteriorating habitability of their traditional homelands with fewer options for moving to more favourable places in safety and dignity. The implications of climate change for a wider scope of issues related to population movement in the medium and longer term have driven a quest for better understanding the circumstances under which climatic factors affect human decisions about whether to leave, where to go, when to leave, and when to return.

1.2 Interrelationships of rainfall variability, food and livelihood security, and human mobility

The Rainfalls research derives its information from empirical and participatory research in eight case study countries in Asia, Africa and Latin America. Original primary data informs new maps that show the migration flows within specific regions in the countries of research. In-depth field-based research was conducted at sites in Guatemala, Peru, Ghana, Tanzania, India, Bangladesh, Thailand and Vietnam. The eight Rainfalls case studies present evidence that shows a complex range of interactions and illustrates the interplay among rainfall variability, food and livelihood insecurity, and migration choices (seasonal, temporal, permanent, or none) of households with different characteristics (e.g., wealth, land ownership, access to livelihood diversification options, gender, age, education). The research also shows how those characteristics facilitate or hinder the ability of households to make informed choices about migration.

Based on current interactions of rainfall variability, food and livelihood security and household migration decisions, the Rainfalls research employs agent-based modelling to understand what changes in future rainfall regimes might mean for migration. Taken together, these case studies and the modelling results : (1) demonstrate the complexity and diversity of these relationships and the need to tailor policies and interventions to account for key factors at the national, subnational, community, household, and individual levels; and (2) explore the idea that rainfall variability impacts household migration decisions through negatively influencing household food consumption and incomes, particularly in sites where livelihoods are highly dependent on rain-fed agriculture.

The question of interactions between global (and local) climatic change and human migration is not *whether* environmental drivers are the sole factors causing mobility, but instead *how multiple factors interact* to shape migration choices. A more nuanced understanding of how climatic factors affect migration choices will help shape adaptation investments and policies that help ensure that whatever strategies households use – including migration – *contribute to increased resilience to climate change*[13].

1.3 The value of understanding mobility decisions in the context of a changing climate

The « Where the Rain Falls » (« Rainfalls ») research builds on the findings of research to date on environmental change and migration[14] – it isolates rainfall variability and food insecurity as key drivers in migration and by doing so, allows analysis of household characteristics and answers the research question of « under what circumstances households use migration as a risk management strategy » in response to these two drivers. The Rainfalls research expands insights into how human mobility may develop in the context of a changing climate where rainfall patterns are expected to shift notably in timing (seasonality), quality (extreme events, intensity of rainfall), and distribution (geographically) in coming decades.

Up until now, relatively little has been said in the environmental migration literature about the circumstances surrounding migration decisions and processes, such as the length of stay of migrants in the areas of destination, the characteristics of the migrants and non-migrants, what migrants do upon arrival, which employment they are seeking in the areas of destination, and the factors that enable or constrain migration choices. The Rainfalls research : (1) highlights the characteristics of migrant and non-migrant households and the factors that shape their decisions today (case study results) and in the future (modelling results); and (2) contributes to understanding what kinds of households may be unable to adapt to changes in rainfall regimes in given regions, in situ or through migration, and what factors contribute to resilience or vulnerability to rainfall changes in certain types of households. The Rainfalls research results presented below reveal four household profiles, ranging from those that are able to use migration in ways that increase their resilience to those who have limited adaptation options and struggle to survive in their areas of origin and cannot use migration as a risk management strategy (modelling results); and (2) contributes to understanding what kinds of households may be unable to adapt to changes in rainfall regimes in given regions, in situ or through migration, and what factors contribute to resilience or vulnerability to rainfall changes in certain types of households. The Rainfalls research results presented below reveal four household profiles, ranging from those that are able to use migration in ways that increase their resilience to those who are « stuck » and struggle to survive in their areas of origin and cannot use migration as a risk management strategy.

1.4 New thinking and the contribution of this report

New thinking and practical approaches are needed to address the threats to human security that environmental changes, including climate change, pose for current patterns of human mobility (including migration and displacement) and population distribution in the future. Human mobility is a significant – and in some places growing – response to changes in climate patterns across the world. Yet neither the literature on climate change nor on human mobility fully reflects the circumstances under which mobility is an adaptation option, its impacts, or policy alternatives. Policymakers require better information, empirical data, and analysis of both the challenges and potential solutions associated with population movement in the context of climate change. The « Where the Rainfalls » research responds to this need, and helps to fill the gaps by providing :

- Next generation of research methods: The research approach developed for the Rainfalls project, which has been published to serve as a resource for future research, included a mix of methods (household survey, a variety of Participatory Research Approach (PRA) tools, and expert interviews). In addition, local meteorological data was gathered and compared to local perceptions of changes in rainfall patterns.

- New empirical evidence: Teams of national and international researchers were deployed to eight locations in Guatemala, Peru, Ghana, Tanzania, India, Bangladesh, Thailand, and Vietnam and gathered a large volume of quantitative and qualitative data (n = 1,295 household surveys, and over 2,000 participants in focus group discussions and expert interviews) on historical rainfall patterns, household food security conditions, and human mobility patterns.

- Maps: Original maps have been developed for each of the eight case study sites to provide a visual representation of key data related to rainfall patterns, agriculture, food security, as well as current migration patterns from the research villages.

- Analytical framework: To bring coherence to the evidence generated from eight very diverse research sites in seeking to answer the question of « under what circumstances households use migration as a risk management strategy », an analytical framework is proposed to highlight key considerations at national, site, and household levels.

- Agent-based modelling: Using the data gathered through the field research, the project has begun to develop a Rainfalls Agent-Based Migration Model (RABMM) which offers a picture of potential future household migration decisions under different rainfall variability scenarios. This report presents preliminary results for the research site in Tanzania.

- Policy reflections: Drawing on the findings of the field research, global and national level policy reflections are put forward for consideration by governments, multilateral and research institutions, and non-governmental organizations working directly with many of the world's most vulnerable populations.

1.5 What this report does not do

This report does not do the following :

- **Provide global estimates of the numbers of people that may move or be forced to move in response to rainfall variability in the future.**

- **Indicate specific geographical destinations for migrants in the future.**

- **Draw causal relationships between rainfall variability or other climate change phenomena and human mobility.**

Instead, the report lays out evidence of current relationships between rainfall variability, food and livelihood security, and the circumstances under which households use migration as a risk management strategy for these stressors in different regions of the world. The authors hope that this report will be useful in discussions of where food and livelihood security and migration pressures exist today in relation to rainfall variability, and where they may emerge in the future. The agent-based modelling in the Rainfalls research is intended to present plausible future scenarios that provide decision-makers a basis for focusing their discussions on the role of human mobility in adaptation.

2- Multidisciplinary methods used in the Where the Rain Falls project

Field research was conducted in eight countries (Bangladesh, Ghana, Guatemala, India, Peru, Tanzania, Thailand and Vietnam) in order to address the first objective of the « Where the Rain Falls » project, i.e. « to conceptualize the relationship between changing weather patterns (specifically rainfall and shifting seasons), food security, social inequalities (especially regarding gender) and different forms of human mobility »[15]. The research question associated with this objective is : « Under what circumstances do households use migration as a risk management strategy in response to increasing rainfall variability and food insecurity ? »

In conducting the field research, three complementary methodologies were applied : Participatory Research Approaches (PRA), a household (HH) survey in the research communities, and interviews with various experts in the respective countries. Researchers also undertook literature reviews for each case. The rationale for applying these three methods was to get insights into the research topic and its dynamics from different perspectives and to see whether they complement or contradict one another. The methodologies used in the « Where the Rain Falls » project give value added to the research on environmental and climate change induced migration that has been conducted to date[16]. To the knowledge of the authors, this combination of methods has been used for the first time in a multi-country fieldwork-based project on this research topic.

Although both the participatory research sessions and household survey provide data from the same communities, it was important to collect both qualitative and quantitative data in order to have a comprehensive analysis that not only helps answer the first research question but also serves for developing and applying the agent-based model (ABM). The three methods were pre-tested prior to the field research in order to assure their relevance and suitability in terms of content, length, and applicability in different cultural contexts. Each of the three methods used are presented below[17].

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2.1 Expert interviews

The expert interviews were conducted mainly with government representatives, community leaders, civil society actors, and scientists/academics who possess particular knowledge and information about specific topic areas related to the project's research (migration, rainfall variability, livelihoods/food insecurity, national and local development plans, climate change adaptation, vulnerability, etc.). To the extent permitted by the available time and budget, the interviews were conducted at national, regional/district, and local levels to acquire as much relevant information as possible. The semi-structured interview guide included questions related to each of the three main themes (climate change and rainfall variability, livelihood and food insecurity, and migration). The questions covered not only observations, and the interpretations and analysis of the experts, but were also policy-oriented and gave space for future recommendations from the interviewees.

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2.2 Participatory research approach sessions

The aim of the participatory research exercises was to involve local communities and particular populations in the evaluation of the past and current situations in their respective villages, learn from them how they would like their future to be, and to gather messages to inform local, national, and global policy-making. One important feature of participatory research sessions is that they include open questions that allow both the interviewers and interviewees to go into depth during the sessions without limiting responses to the closed answer format of a survey. Visuals such as flip charts, cards, chalk were tools to facilitate open group discussion. The participatory group sessions helped capture group dynamics and interrelationships among issues. The participatory research sessions were used in the research sites in all eight countries. The group composition of the community participants varied by exercise, with some being homogenous (only men, women, elderly, marginalized, young people, farmers, non-farmers, etc.) and others conducted with mixed groups in order to get the widest possible range of inputs and to isolate or ensure inclusion of the experience of particular social groups. This was particularly important in capturing the views of women, elderly, possibly socially marginalized groups, etc.

The participatory research sessions employed a range of tools, which were tailored to the context, the information needed, and the groups invited to participate.
These included, but were not limited to: transect walks (providing a cross-sectional representation of the different agroecological zones and their comparison against certain parameters of interest to the study); wealth ranking (investigating the perceptions of wealth differences and inequalities in the communities); focus group discussions (bringing various groups of the communities together in open discussions); mobility maps (exploring the movement pattern of the individuals, groups and communities); seasonality calendars (reflecting the perceptions of local people regarding seasonal variations in the research site); livelihood risk rankings (identifying local people's perceptions of the risks they face and how they rank the magnitude of each risk); Venn diagrams (showing the importance and accessibility of crucial institutions and individuals influencing the local communities); and impact diagrams (identifying the impacts of certain activities, interventions or events on the communities and the interrelations among all these factors).

2.3 Household survey

The aim of conducting the household survey was to obtain quantifiable indicators and trends that reflect how different factors affect households in terms of rainfall variability, livelihood/food security and migration, and to make possible a statistical analysis to complement the qualitative outcomes. Multi-country studies of this type on environmental change and migration have largely employed either surveys or focus group discussions to date but not both. The household survey consisted of different sections, each one representing an important aspect of the research, including general household demographic information, economic activities of the household, livelihood-related issues, food security and consumption, migration, coping strategies, rainfall patterns, and household assets and resources. The sections were not isolated from each other thematically, in order to detect the overlap between the different variables and to explore the interrelationships and dynamics among these within households. In contrast to the participatory research results, most of the survey questions were closed and quantifiable. However, there were some open questions in each section to assist in analysis of the survey data and modelling. These open questions helped reveal more detail and context of household responses.

The minimum number of households targeted in each of the eight case studies by the project was 150, covering a total of 3-4 villages in each country research site. Depending on the demographic information available in each case, the researchers used either a simple or stratified random sampling technique[18]. The target respondent was the household head (male or female), and in cases where s/he was not available, the second representative of the household was interviewed provided that they were mature, able to speak to the research topics and were part of the decision-making of the household.

Researchers faced a trade-off in maintaining consistency in the administration and outcomes of the questionnaire across the eight case studies, which represented highly diverse cultural contexts. Pre-testing of the household survey helped researchers determine what areas of the instrument needed slight adjustment for local context: small changes were used as appropriate in the formulation of some questions and also using the measurement units appropriate to each case study. Demographic characteristics (ethnicities, castes, marriage practices, etc.) were considered when modifying the questionnaire for use in each case study.

2.4 Future scenarios of rainfall and migration using agent-based modelling

The first objective of the Rainfalls research was to understand the current relationships among rainfall variability, food and livelihood security, and household migration decisions. This objective was addressed using fieldwork and the methods described above. The second objective of the Rainfalls research involved exploring potential future scenarios to answer the question « Under what scenarios do rainfall variability and food security have the potential to become significant drivers of human mobility in particular regions of the world in the next two to three decades ? » An agent-based modelling approach was employed for this future-oriented research objective. The modelling results are presented in this report for Tanzania. A more detailed description of the modelling approach is presented in the technical annex of this report.

2.5 Research foci, methods and data triangulation

In the conceptual framework for the eight case studies (Figure 1), the most relevant aspects for each household, namely the interaction of rainfall variability, food security, and migration (as a particular part of coping and adaptation strategies) form the centre of interest. They are the basis of the overall livelihood (security) approach used here, shown greyed out in the background. Conceptual extensions were disregarded, and the framework may be additionally determined by other factors, such as economic or political developments or conflicts.

Figure 1 provides an overview of the three major research foci of the Rainfalls project and the sources of information used, as well as how the data were triangulated using the methods described above. In this framework, the livelihood security of the studied households is influenced by rainfall variability (an independent variable influencing livestock and crop production). These factors, plus the factor of land ownership, help shape the food security situation of the household, which is also structured by external processes. In the framework, a notion of « degree of vulnerability » (taking into account the degree of economic diversification, number of household members of working age, financial situation, and others) is used to indicate the range of available coping and adaptation strategies for households. Research findings are based primarily on fieldwork-generated qualitative and quantitative data. Where secondary data has been used, this is indicated by coloured boxes at the edge of the research area boxes. As further shown in this framework, the initial conditions change dynamically due to the interlinkages and interactions of household actions (feedback loops).

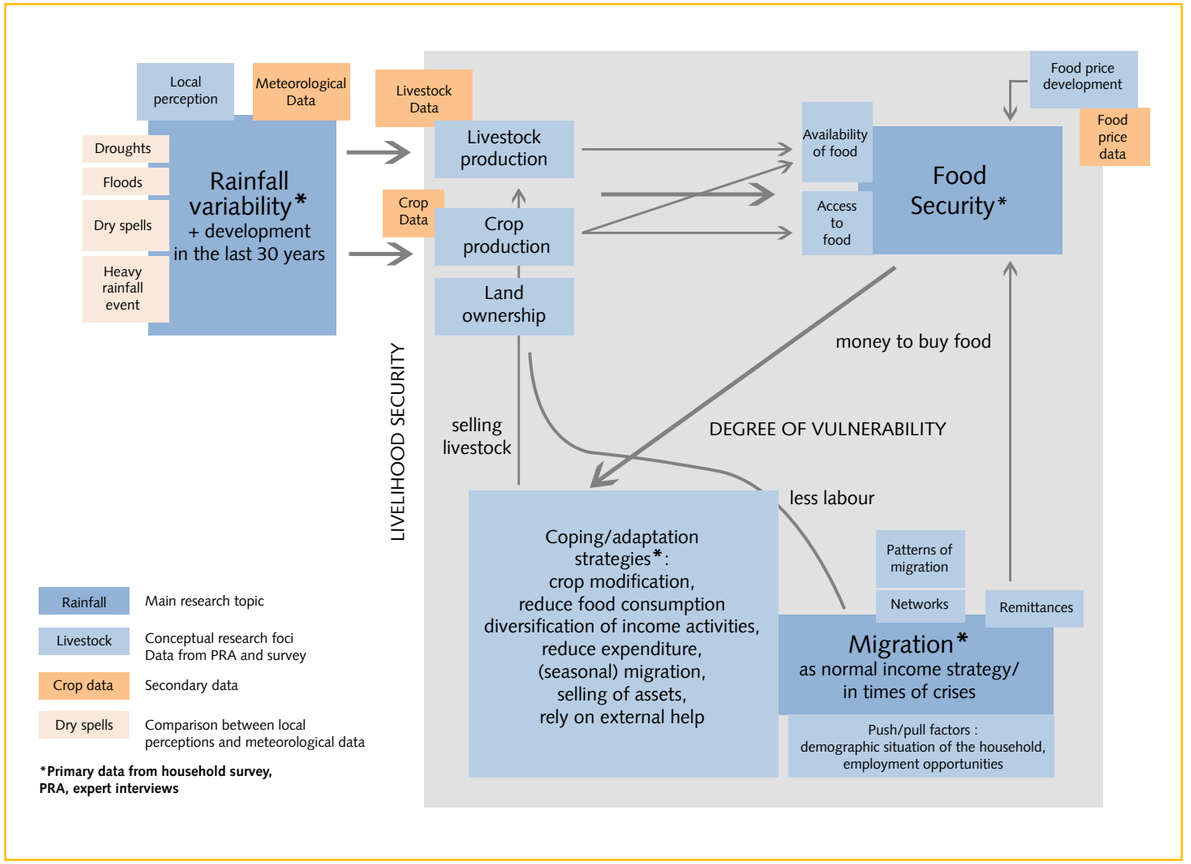

Figure 1 : Research foci, methods, and data sources
Source : Rademacher-Schulz and Rossow, 2012

3- National and research site characteristics

Given the diverse nature of the eight case studies investigated, this section offers a framework to interpret the project's findings and serve as a basis for future research. Criteria for country and site selection are detailed immediately below, followed by the first level of the framework, which distinguishes among the eight countries based on relevant macro-level social, economic and demographic indicators. At a subnational level, the diversity of the project's specific research sites is described in terms of a range of geographic, meteorological, and agroecological characteristics.

3.1 Country and site selection criteria

The eight case study countries and research sites were chosen according to a set of general criteria. Countries represented regional balance, covering three regions: South and Southeast Asia, Sub-Saharan Africa and Latin America. Research sites within the eight countries were « typical » of major ecosystems and livelihoods, with average levels of poverty and food insecurity, and livelihood groups sensitive to rainfall variability. Research sites were also selected to generate a diverse representation of geography and location in a national context (proximity to major or minor economic centres). For practical reasons, research sites were selected based on the availability of reliable rainfall data, geographic accessibility, and CARE presence and established local relationships, the last designed to leverage existing trust with local communities to enable research in a short time frame and subsequent programmatic follow-up.

3.2 National context

The eight countries where research was conducted represent a wide spectrum of macro-level conditions in which households manage livelihood decisions, including migration. In terms of overall economic performance, levels of human development, and food security, Thailand and Peru lead the group of eight research countries (see Table 1)[19]. At the other end of the spectrum, Bangladesh and Tanzania rank lowest for all three indicators. The countries in the middle group – India, Vietnam, Ghana, and Guatemala – range in economic and social development performance and food security. Higher levels of malnutrition in India and Guatemala are notable in this group.

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Additional indicators provide more dynamic insights about the national context in which households' access livelihood options, and how those livelihood options can influence migration decisions in rural households[20]. In countries where there are limited off-farm livelihood diversification options and where population growth rates remain high, rural households may be compelled to use migration as a risk management strategy to cope with food insecurity, more so than households in countries that can provide a wider range of livelihood diversification options in and outside of agriculture. Peru and Thailand emerge from this analysis as countries characterized by dynamic economies in which poverty and food insecurity are relatively low. Vietnam, India, and Bangladesh all fall into a category of countries experiencing economic and demographic transition but with still moderate-to-high levels of poverty and food insecurity. The final category of countries includes Ghana, Tanzania and Guatemala, where poverty and food insecurity levels remain high and where different combinations of low economic growth, high dependence on agriculture, and population growth can be seen to limit the livelihood diversification options of rural households.

	Low poverty and food insecurity	**Medium-high poverty and food insecurity**
More advanced stage of economic and demographic transition	Peru Thailand	Vietnam India Bangladesh
Less advanced stage of economic and demographic transition		Ghana Guatemala Tanzania

Table 1 : Context of 8 case study countries: Poverty, food security, economic and demographic transition at macro level

This categorization of countries overlaps but does not entirely coincide with a regional typology of country contexts. Three of four Asian case studies fall into the category of dynamic countries with medium-to-high poverty and food insecurity, with Thailand representing the exception due to its success over recent decades in poverty reduction. Both Ghana and Tanzania are examples of African success stories in terms of economic growth, but where poverty, food insecurity, and population growth all remain relatively high. The two Latin American case studies fall on opposite ends of the spectrum, with Peru having made great strides in recent decades in both economic growth and poverty reduction, while Guatemala has experienced economic stagnation and continues to suffer from high rates of malnutrition and inequality.

3.3 Research site characteristics

Within the eight countries where the project's research was conducted, there was also considerable diversity in the specific sites selected. An important criterion for site selection was related to the independent variable of the study, namely rainfall. Average annual rainfall across the research sites ranged from 560 mm to 1700 mm (see Table 2). The seasonality of rainfall patterns and dependence on rain-fed agriculture were important considerations, even though in the case of India the communities largely had access to canal irrigation. Characteristics related to other important variables of the research were the sensitivity of local livelihoods to changing rainfall patterns, high levels of poverty and food insecurity, recorded history of migration, and a purported linkage between changing rainfall patterns, food insecurity and human mobility. Elevation (e.g., low and highlands) and the proximity to cities or other centres (e.g., industrial estates) with significant alternative employment opportunities also played a role in site selection.

Research site	Approximate average annual rainfall (mm)	Geography
Northern Bangladesh (Kurigram District)	1,700	Riverine lowland
Vietnam Mekong Delta (Dong Thap Province)	1,500	Delta lowland
Central India (Janjgir District, Chhattisgarh)	1,229	Irrigated lowland
Guatemala Western Highlands (Cabricán Municipality)	1,150	Highland
Northern Ghana (Nadowli District, Upper West Region)	1,036	Savannah woodland
Northern Thailand (Lamphun Province)	1,017	Upland and riverine
Peru Central Andes (Huancayo Province)	800	Highland
Northern Tanzania (Same District, Kilimanjaro Region)	560	Upland and riverine lowland

Table 2: Average annual rainfall in the research sites

The research in Guatemala, Peru and Thailand was conducted in upland sites; while the site in Guatemala was quite remote from major urban centres, the Peru site was distinguished by its proximity to a large and growing secondary city. Lowland sites included Ghana, India, Bangladesh, and Vietnam, while the research villages in Tanzania included sites in both lowland and upland areas. Access to irrigation ranged from almost zero in the sites in Guatemala and Ghana, to 84 per cent in India; nonetheless, most farmers in all three sites were limited to a single annual harvest. Two or more harvests per year were most common in the Bangladesh, Thailand, and Vietnam cases, where higher local rainfall and proximity to rivers result in increased water availability for agriculture. In Tanzania, although the site is semi-arid, the local rainfall pattern is bi-modal; thus two harvests per year are possible when the rains do not fail.

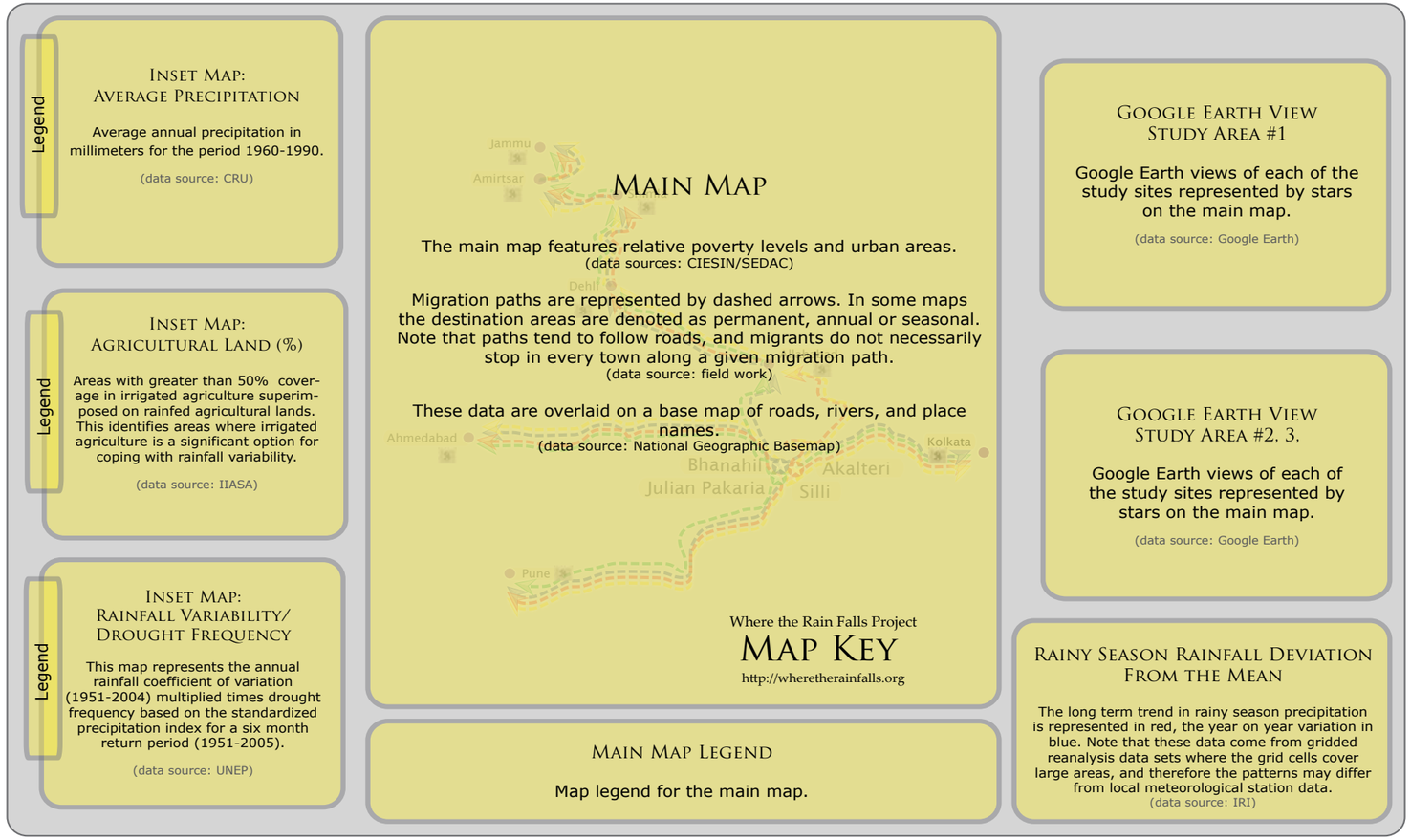
Photo credit : © 2011 Kees van der Geest

4. Case study findings : Migration in the context of rainfall variability, food and livelihood security

This section summarizes findings from the Rainfalls case study reports produced on the basis of the field research in the eight countries covered by the project. These case studies are grouped on the basis of the categories outlined in the analytical framework above, rather than geographically. Each of the summaries also includes a map, the content and purpose of which is described below. The migration patterns discussed below in relation to rainfall variability, food and livelihood security have the following definitions: Seasonal migration in this study is defined as a move of fewer than six months, while temporal migration refers to moves between six months and two years. Permanent migration refers to moves of more than two years.

Key to the maps in this report

Each of the following eight case studies includes a map that provides the location of each research site along with contextual data on rainfall amounts and variability, poverty, and agriculture. The maps also provide depictions of the migration streams reported by respondents during the field research. Complete information on all map elements is provided in the technical annex.



4.1 Thailand : Diverse livelihoods and access to assets and services make migration a matter of choice in Lamphun Province[21]

The Thailand research was conducted in four villages (two ethnic Thai and two ethnic Karen) – Don-Moon, Sandonhom, Maebon-Tai and Huai-Ping – in a typical rural upland setting in Ban Puang subdistrict in Lamphun province in northern Thailand. The villages are located on hilly, forested slopes along small rivers that drain into the Li River. (See location, landscape, average precipitation, agricultural land, drought frequency and migration destinations for the research site in Figure 3 below.) Migration in Thailand over the last 50 years has been part of a wider process of transforming the economy and overcoming previous high levels of food insecurity and poverty. For rural populations in Thailand, migration has been a common strategy to cope with and adapt to the seasonality of agricultural production, land pressure and economic crisis[22]. A combination of investments in more productive agriculture, livelihoods diversification, education, and social safety nets has increased the resilience of households in Lamphun Province to stressors like rainfall variability and food insecurity.

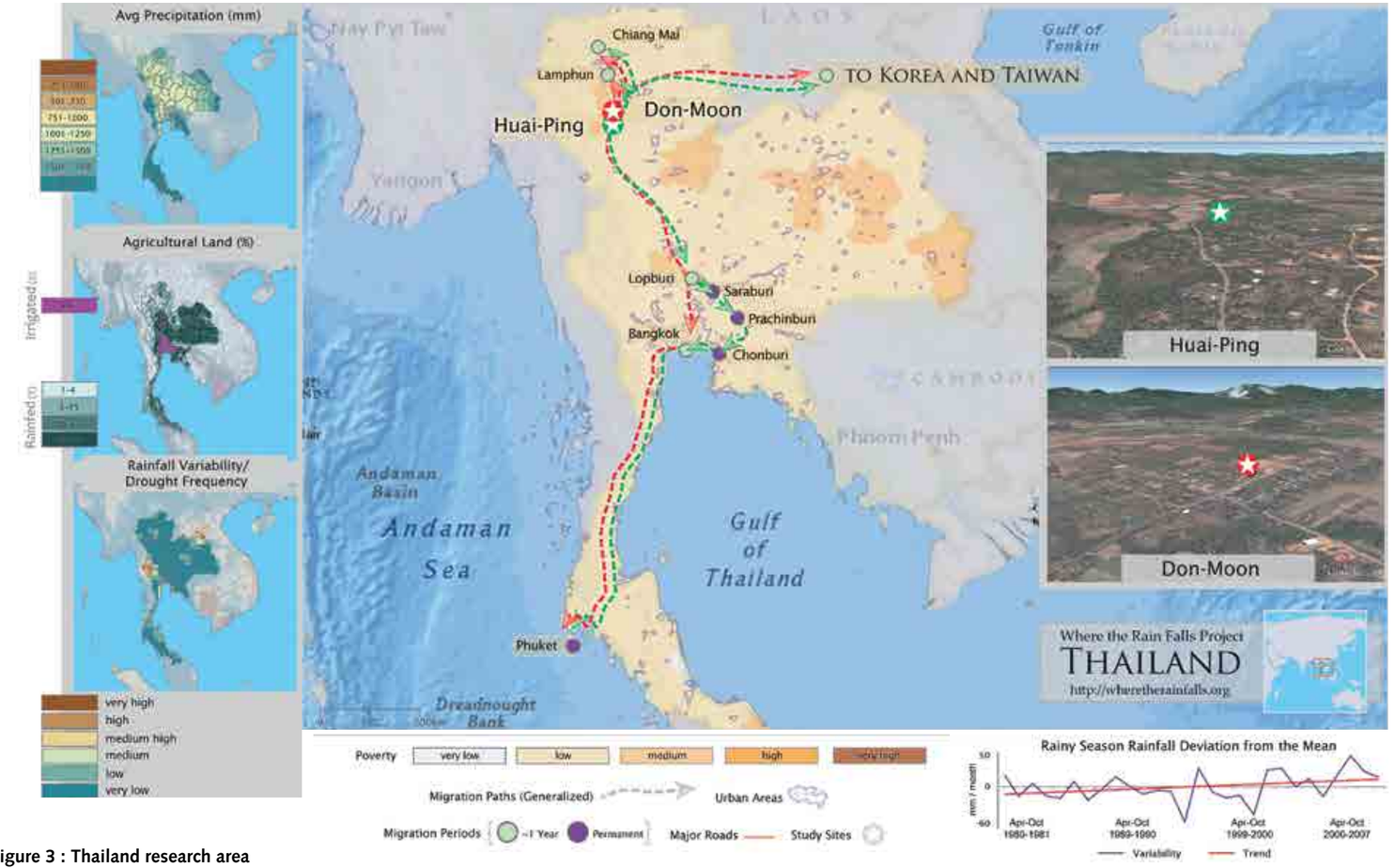


Figure 3 : Thailand research area

Photo credit : © 2011 Phalakorn Paomai

The average total annual **rainfall** in Lamphun Province is 1,017.03 mm. Local meteorological data reveals that total annual rainfall has increased slightly over the last 30 years, with six out of seven peaks above the national mean of 1,200 mm occurring in the last two decades. In late 2011, Thailand suffered one of the most severe flood events in decades. Heavy rains (28 per cent more than normal between January and October) led to severe flooding and damage in Bangkok and central Thailand. Flooding affected 1.6 million hectares, leading to the loss of one quarter of rice production, 730 deaths, and forcing the closure of 9,859 factories employing 666,000 workers. The World Bank estimated the total economic damage and losses at US$45.7 Billion. The exceptional rainfall in 2011 dominated narratives about climatic stress among the villagers in the research area. Participants in the study also noticed changes of weather patterns during the past decade like increased precipitation and higher temperatures during the cold season. Villagers reported being regularly exposed to rainfall-related stress, including dry spells, heavy rainfall, and the occurrence of flash floods. Of households interviewed, 87 per cent stated that heavy rainfall events occurred more frequently in the past 10-20 years.

Poverty and **food insecurity** are primarily rural phenomena in Thailand, with 88 per cent of the country's 5.4 million poor people living in rural areas. Thailand has reduced its national poverty rate from 57 per cent in 1962/63 to 8 per cent in 2009. The poverty rate in the Northern region in 2010 was 10.5 per cent, which is above the national average and much higher than in Bangkok (0.6 per cent). Although food insecurity in general has been greatly reduced, it is still an issue in rural pockets in the Northern and North-eastern regions[23]. In the study area, the two ethnic Thai villages had income more than double, and significantly higher levels of educational attainment, than the two ethnic Karen villages. Across the four villages, only 2.4 per cent of households were found to be landless. Over recent decades, as the percentage of the population in northern Thailand engaged in subsistence agriculture has declined significantly, income from cash crops, along with weaving, remittances, small business/trade, and government social safety net programmes (e.g., elder allowance) have become important elements of a more diversified set of **livelihood options** for people living in the rural areas of Lamphun Province.

Migration is common in the four villages (67 per cent report migration experience by one or more members). While nearly 62 per cent of persons with migration experience were males, women now constitute fully half of current internal (non-international) migrants. Three-quarters of current internal migrants are not married, and 85.5 per cent are temporal migrants who left the village for more than six months without returning. International migration used to be an important livelihood strategy among households in three of the four study villages. Now only 10.7 per cent of current migrants are international (mostly working in Taiwan and South Korea).

According to outcomes of the PRA sessions, the most important migration destinations are currently all internal, with Bangkok accounting for 40 per cent and industrial estates (Lamphun, 25 per cent) and urban centres (Chiang Mai, 20 per cent) accounting for most of the rest. Whereas less than one-quarter of all persons with migration experience cited non-economic reasons for migrating, 38.6 per cent of current internal migration is motivated by education, which shows the changing nature of outmigration from these villages.

Of households surveyed, 51 per cent considered the impact of rainfall-related environmental stress on their livelihoods to be significant. Further, three-quarters of households reported that they suffered from lower income due to declining crop yields and deceasing income from agriculture as a result of the exposure to environmental stress. In spite of clear and significant climatic stress, diversification of risk has spared most households from hunger or erosive coping strategies. A large majority of households in the four villages are food secure, and the severity and frequency of climate stress do not currently exceed a threshold that in the people's point of view necessitates migration for survival purposes. Diversified on- and off-farm (less sensitive to rainfall variability) income generation activities, access to financial resources through community funds, and assistance from the local government all contribute to reducing vulnerability to rainfall-related stress and food insecurity. Despite the negative impact of climatic stress, the majority of households reported that they were able to cope and adapt in situ and used migration as an opportunity to capture even better opportunities.

In Thailand, surveyed households were affected by rainfall stressors, but most had access to assets that allowed them to offset rainfall variability. Migration for such households represented an additional option to further manage environmental and other risks in ways that contribute to household resilience (such as using remittances to finance education that allows livelihood diversification and lowers sensitivity to rainfall variability and food insecurity).

Photo credit : © 2011 Phalakorn Paomai

Figure 4 : Peru research area

4.2 Peru : Livelihood options and migration strategies in Huancayo Province vary by elevation and proximity to urban centres[24]

The research was conducted in three villages – Acopalca, Paccha and Chamisería – in the Shullcas river sub-basin (and its surroundings) of the Mantaro River basin in the Department of Junín in the Peruvian Central Andes. The villages, located in Huancayo Province, are situated at elevations ranging from 2,500-3,500 (Quechua ecological zone) to 4,000-4,800 (Puna ecological zone) metres above sea level. (See location, landscape, average precipitation, agricultural land, drought frequency and migration destinations for the research site in Figure 4.) Mobility patterns in the research area vary considerably by elevation and proximity to the city of Huancayo.

The current annual **rainfall** in the Shullcas sub-basin is approximately 800 mm. Findings from the project's research support the perception of increasingly unpredictable rainfall patterns that, together with frost and intense heatwaves, negatively impact agricultural production. The main reported changes in rainfall patterns in the research area include higher intensity and lower frequency of rainfall events, more heavy rains at unexpected times, and longer dry spells during the rainy season. Floods and droughts affect 37 and 42 per cent of households surveyed, respectively. The research area is also affected by the retreat of the Huayatapallana glacier. Other projected impacts of climate change in Peru include an increased number of frost days, and 10-19 per cent reduction in rainfall[25].

The **poverty** level in the Department of Junín was reported at 32.5 per cent in 2010, with 13.8 per cent extreme poverty; chronic malnutrition in the poorest mountainous areas of Peru can reach nearly 50 per cent. In the study area, more than one third of the population derives its **livelihood** from agriculture, and farmers report declining yields due to « tired » soil. Of the surveyed households, 43.3 per cent were landless, 39.3 per cent small farmers and 8.8 per cent were large farmers. In more isolated locations at higher elevations, the economy is largely dependent on livestock-raising.

At lower elevations, households depend primarily on small-scale agriculture and various types of regular or casual employment in the nearby city of Huancayo. Land tenure arrangements have a significant impact on household livelihood strategies, with land fragmentation a growing problem in lowland agricultural areas. Highland areas do not suffer from land fragmentation because they have retained communal land tenure systems, a risk pooling approach to manage climatic extremes. Despite the important domestic and productive roles they play, women and girls remain largely excluded from decision-making processes at household and community level (and higher), and their access to education also remains less than that afforded to men and boys. Women also bear the brunt of the impacts of environmental change, given that their responsibilities include the collection of water and firewood, in addition to the role they play in livestock-raising and agriculture.

Migration serves as a diversification strategy for livelihood, income generation, risk management and adaptation to climate change. Overall, migrants from the research villages are predominantly adult males and young people, and they engage primarily in temporal, rather than seasonal, migration. Since the majority of migrants are male, women have to shoulder additional work and emotional burdens when men migrate for extended periods of time. Households below the poverty line, including the landless and those with landholdings of 0.5 hectares or less, were twice as likely to migrate in search of non-farming livelihoods as those above the poverty line. With respect to factors affecting migration decisions, rainfall and food security stressors ranked higher than issues related to aspirational migration (such as social networks and the pull of « bright city lights »).

Photo credit : © 2007 Nathan Bolster/CARE

elevations, daily movement of one or more household members back and forth to Huancayo is common for construction, commerce, and other economic activities. These households also engage in seasonal migration to the outer edge of the Amazon basin to harvest coffee. In contrast, those at higher elevations engage in longer-term migration, including going to the United States on three-year contracts as shepherds. Here, migration is a typical risk management strategy because of fewer livelihood options (beyond herding) at higher elevations.

Households surveyed reported increasingly unpredictable rainfall patterns that, together with frost and heatwaves, negatively impact agricultural production. The impact of changing rainfall on food production was severe for 53 per cent of the households responding. Two thirds of households surveyed sustain crop damage and lower crop yields, and 42 per cent experience substantial negative impacts on household income. While variations in rainfall directly impact household food security, the effects are less severe in the research area now than in the past due to lesser dependence on agriculture-based livelihoods and expanded employment opportunities in non-farming activities in urban areas. The population of the nearby city of Huancayo grew by 50 per cent since the 1980s. However, it is important to note that income from farming is often complemented, not substituted, by non-farming income. Rainfall changes affect the ability of households to feed themselves and earn livelihoods. Although Peru has made great strides in reducing levels of poverty and food insecurity, migration remains an important livelihood diversification strategy, particularly for landless and other poor households. To avoid food and livelihood insecurity, half of the households surveyed seek to increase income through other activities (facilitated by migration).

Photo credit : © 2008 Phil Borges/CARE

4.3 Vietnam, Mekong Delta : Landless, low-skilled poor of Hung Thanh Commune have few options, despite a rising economic tide[26]

The research in Vietnam took place in Hung Thanh Commune (Thap Muoi District, Dong Thap Province), which is located about 135 km from the coast and is part of the commercial rice production region of the upper Mekong Delta. (See location, landscape, average precipitation, agricultural land, drought frequency and migration destinations for the research site in Figure 5 below.) This area is flooded annually, with peak flood levels normally occurring in October; at the time of the fieldwork for this research in October to November 2011, Hung Thanh Commune was experiencing the highest flood level in ten years and was inundated except for a small strip of land along the main elevated road. Poor households that are landless and land-scarce are most vulnerable to changes in local climatic conditions and benefit least from the intensification of agriculture underway in the research area. The increased mechanization of agriculture – although beneficial to farmers with larger landholdings – decreases demand for employment of landless agricultural labourers. For this group, outmigration is an increasingly important strategy in response to multiple livelihood threats, including changing rainfall patterns and flood regimes, increased concentration of land ownership, and reduced labour demand due to mechanization.

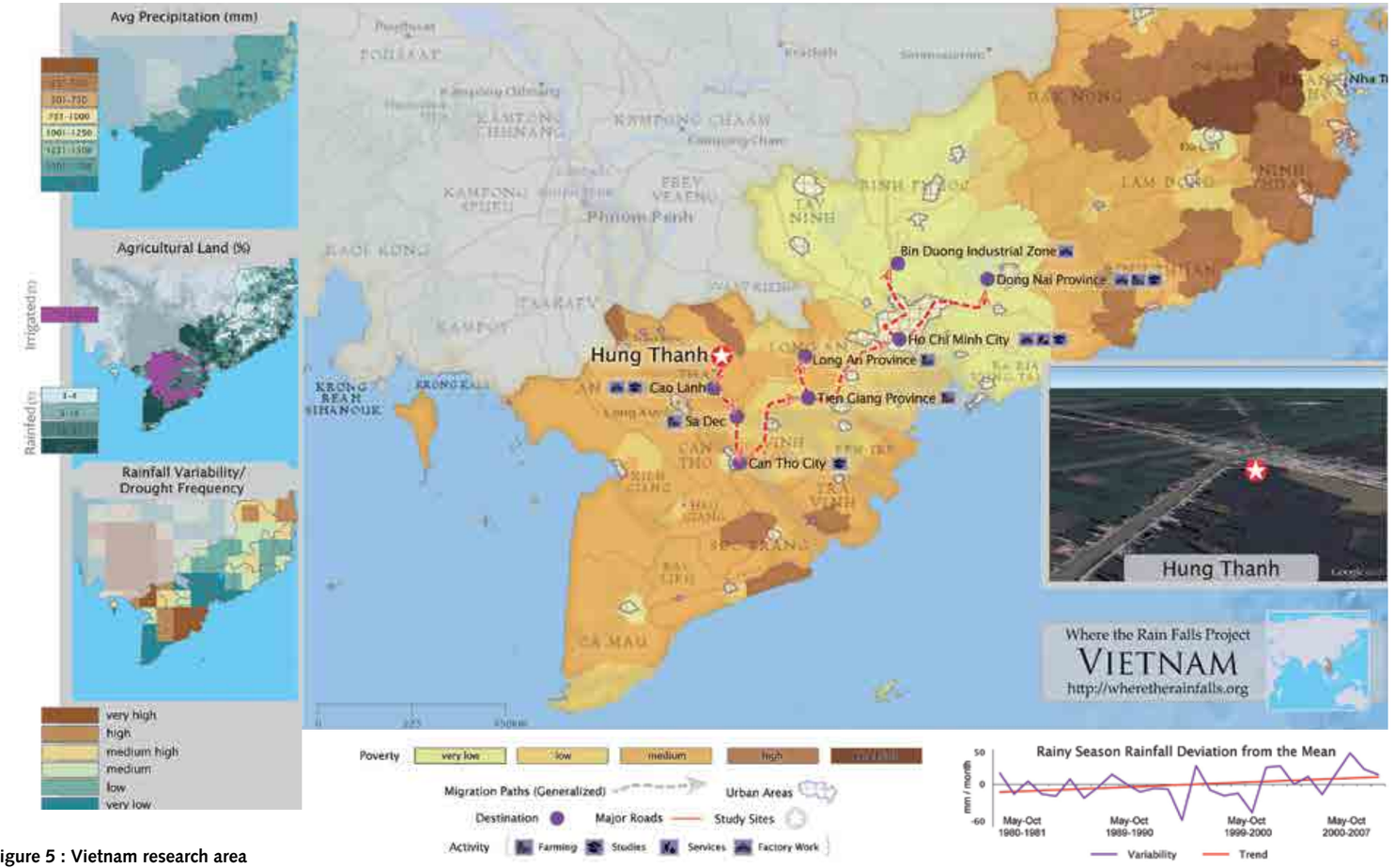


Figure 5 : Vietnam research area

The research revealed several changes in **rainfall** patterns over the past 20-30 years : the total amount of annual rainfall has increased ; the rainy season lasts longer than before ; rainfall has become less predictable; and the occurrence of extreme weather events, such as storms and heavy rainfall, has increased. Despite increasing annual levels of rainfall in the past 20-30 years, flood levels have decreased over the same period, as evidenced by data provided by the Cao Lanh Meteorology and Hydrology Station for the period 1979-2008. This paradox can be attributed to the fact that flood levels depend to a large extent on rainfall patterns and water retention outside the research area, further upstream in the Mekong River basin.

Livelihoods and food security in the research area remain significantly dependent on agriculture, but recent decades have seen some diversification, with remittances, rents, aquaculture, and salaried jobs growing in importance as income sources. Of the household survey respondents who have their own rice farm (62.0 per cent of the total); the vast majority indicated that their yields are negatively affected by changing rainfall patterns and flood regimes. However, the negative impact of changes in rainfall patterns and flood regimes is to some extent offset by positive man-made agricultural changes, including increased use of improved seeds and fertilizers, dyke construction, and mechanization, which have all contributed to higher rice yields and cropping intensity. Landless and land-scarce households, representing 30.7 and 26.0 per cent respectively of the 150 households surveyed, are least able to take advantage of these advances and, in the case of mechanization, are often negatively impacted.

Photo credit : © 2005 Phil Borges/CARE

Photo credit : © 2011 Kees van der Geest

Half the landless households (50.0 per cent) and one out of four land-scarce households (25.6 per cent) faced food shortages in the seven days prior to the survey. They had to cope by borrowing food or money to buy food (83.3 per cent), consuming less expensive food (63.8 per cent), limiting meal size (50.0 per cent), or reducing the adults' food intake in favour of children (36.1 per cent). Among landless households, 41.3 per cent indicated that they had experienced inadequate food intake in the past year, and 52.2 per cent report having had such an experience in the past five to ten years, more than double the average for all households surveyed. Food insecurity reaches its peak in the flood season (September to November), particularly in the case of landless people who work as farm labourers and are often unemployed during this season.

Although official **migration** figures at commune level are lacking, all evidence from the household survey, participatory research sessions and expert interviews indicate that migration has increased sharply in the past ten years. Migration from Hung Thanh Commune is increasingly common because of growing pressure on local livelihoods, increased demand for industrial labour outside the commune, and less strict political restrictions on mobility. More and more men and women from Hung Thanh Commune find work in industrial zones, especially in Ho Chi Minh City. The household survey revealed that in 90 out of 150 households (60.0 per cent), at least one current member had migration experience. Of the 168 migrants identified in the surveyed households, 106 (63.1 per cent) were male. On average, migrants in the research site were 22 years old at the time of their first migration. Seasonal migration mainly occurs during the flood season, when there is less work in the community. Almost half of the migrants move to destinations outside the Mekong Delta region, but still within the southern part of Vietnam (primarily Ho Chi Minh City, Binh Duoung and Dong Nai). People from Hung Thanh Commune who migrate within the province are mainly seasonal migrants who work as farm labourers or in local factories for periods shorter than six months. In addition, as well as the indirect impact of rainfall variability on human mobility, the fieldwork revealed a very direct link between flooding and migration. During the flood season, there is less work in the community, and many young people use this time to engage in seasonal migration. This phenomenon reveals that, for these communities, there is an additional, significant and recurrent factor that shapes and will shape migration decisions.

A majority of questionnaire respondents noted adverse effects of heavy rainfall, shifting seasonality of rainfall and a higher frequency of rainy days on crop yields and non-farm income sources. When survey respondents were asked whether changing rainfall patterns negatively affect their household economy, 89.5 per cent of the respondents answered « yes », 35.9 per cent of whom answered « yes, a lot ». In general, households are more likely to use migration as a risk management strategy if they face difficulties attaining livelihood security locally because they : do not have enough land ; there is not enough demand for farm labour ; or they lack the skills and investment capital for generating a viable non-farm income in situ.

While migration enables these households to manage risk in the short term, the impact on longer-term resilience can be very negative. For landless, low-skilled households, migration can help fill household income gaps if successful, but can also interrupt skill-building and education which are needed for building greater capacity to manage shocks, and flourish economically.

Figure 6 : India research area

4.4 India : Poor households in Janjgir-Champa still must rely on seasonal migration for food security, despite irrigation, industrialization and safety nets[27]

The research undertaken in India covered four villages – Jullan Pakaria, Akalteri, Banahil and Silli – in the Janjgir-Champa district of Chhattisgarh State, where the farmers are heavily dependent on the production of a single annual crop of paddy rice grown during the monsoon season. (See location, landscape, average precipitation, agricultural land, drought frequency and migration destinations for the research site in Figure 6.) Despite the fact that the majority of farmers (84 per cent) in these villages have access to canal irrigation, food insecurity remains high. The irrigation system secures one crop per year. However, there is not sufficient water to allow a second crop season (rabi), so most local farmers appear to have largely abandoned the production of pulses and other crops. This contributes to high levels of seasonal unemployment during the dry season, which often leads to migration as a coping strategy, particularly for smallholder and landless households.

The project's research explored rainfall-related problems (drought, delayed monsoon rains, seasonal shifts, more erratic monsoon rains) facing households in the four research villages and found evidence for changes that negatively impact food security. Although there is no discernible decline in average annual **rainfall**, local data and experts confirm a significant drop in the number of rainy days per year (from 65 to 56) and a one-week delay (from 10 to 17 June) in the onset of the monsoon. Groundwater levels in the area are also reported to have dropped. More than one-third of the interviewed households reported that droughts and dry spells have increased over the past 10-20 years. Around 60 per cent of the interviewed households reported suffering from shorter rainy seasons.

The **livelihoods** of households in the research villages are highly dependent on agriculture. Some of the key challenges of agriculture in Chhattisgarh, and in the study area in particular, according to both experts and focus group participants, are : delayed monsoon/seasons ; single annual harvest/rice monoculture ; recurrent crop diseases; input-intensive unsustainable agriculture ; labour shortage during peak

harvesting seasons; and poor prices for the producer. While all four villages have access to canal irrigation, the quantity of available water and the management of the systems result in insufficient irrigation water for many farmers.

Given the high dependence of local residents on rice monoculture during the monsoon season, it is not surprising that, in the livelihood risk rankings generated by participants in participatory research sessions, rainfall-related risks, such as delayed or erratic rainfall, shifting seasons, flash floods, and the shortage of freshwater for drinking, were categorized as major risks. Another important factor with implications for food security in the research site is rapid population growth, which, coupled with the traditional inheritance system, leads to land fragmentation. This may explain the significant increase observed in survey results of households engaging in day labour now compared to ten years ago. According to focus group participants, people cope with food insecurity by seeking external help from families and institutions, reducing food consumption and expenditures, or trying to increase their income without leaving their villages. Regarding the available safety nets and institutions, the communities listed the village Panchayat (elected institutions of self-government), Anganwadi Centres (creche/pre-school nutrition programme), ration shop (fair price public distribution system), and Post Office as the key institutions impacting their food security. Despite the existence of major national social safety programmes, especially subsidized food rations for below poverty line (BPL) families and the 100-day guaranteed employment scheme (MGNREGA), focus group participants reported that these schemes are not always administered in an equitable and transparent way, resulting in some poor families being excluded from receiving benefits.

Most of the **migration** from the research area is seasonal (around 66 per cent), and the most common pattern is that, after the main harvest takes place in the months of November and December, people migrate from January to May. The majority (88 per cent) are migrants who are seeking better livelihoods and alternative sources of income less sensitive to climate stressors, with educational migrants accounting for only 2 per cent of the total. Migrants from the research villages mainly seek employment in brick making (34 per cent), casual labour in the informal sector (28 per cent), and construction (16 per cent). The main migration destinations are Raipur (Capital of Chhattisgarh), Korba (coal mining area in northern Chhattisgarh), and major cities in the eastern (Kolkata), western (Pune and Ahmedabad), and northern (Allahabad, Chandigarh, Amritsar, Shimla, Jammu, Ladakh, and Delhi) parts of India. This pattern of seasonal migration is facilitated by a well-developed but informal network of mediators and brokers. Although people in the research villages most commonly migrate in families (only 19 per cent are single), the majority of migrants in the research site remain males (62 per cent). While family migration has the positive effect of keeping households intact, migration disrupts the education of school children and reduces the overall exposure to school education, which in turn has long-term negative implications for the future incomes and social mobility of the concerned households. Migration is one of the most important strategies employed by the residents of the research villages to cope with rainfall variations/climatic changes and food insecurity. Even the people who stay and borrow from others might still be forced to resort to migration in order to be able to repay their loans.

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Therefore, migration is often the last resort for resource-poor, landless households, especially when they are unable to access or benefit from livelihood options in situ. Yet, while migration enables them to cope with challenges, it does not increase their resilience or enable them to capture better opportunities. In some cases, migration has negative intergenerational consequences when the need to migrate compromises skill-building and education necessary for improvements in life quality, health, and the ability to attain stable livelihoods. While newly constructed power plants in the area could, in theory, absorb local farmers who seek job opportunities, focus group discussions revealed that these power plants compete with the communities for resources (land, water, fresh air) and have not, to date, offered many job opportunities to residents of the research villages. Instead, the power plants import skilled labour from outside, and local residents are forced to continue to seek better livelihood opportunities elsewhere.

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4.5 Bangladesh : Migration is a key coping strategy for poor households in Kurigram, but one with high social costs[28]

Research was conducted in four villages – Khanpara, Khamar Holokhana, Arazi Khodomtola, and Doalipara – in Kurigram District in northwest Bangladesh. Kurigram experiences high levels of poverty, and 75 per cent of the district's residents depend directly for their livelihoods on agriculture. The Brahmaputra and Dharala rivers traverse Kurigram, and the agricultural livelihoods of its residents are sensitive to droughts, floods, and riverbank erosion. (See location, landscape, average precipitation, agricultural land, drought frequency and migration destinations for the research site in Figure 7 below.)

'Middle class' and 'poor' households, with landholdings relative to their wealth status, are more 'sensitive' to droughts, i.e. rainfall variability, as their livelihoods are dependent on a mix of rain-fed agriculture, supplemented by some access to irrigation. As to the 'poorest', frequently land-scarce or landless households, they are highly vulnerable in all cases due to a mix of factors, including their more limited skill set and smaller asset base to buffer from shocks. Rural migration in search of agricultural employment is used as a coping strategy against food and livelihood insecurity related to climatic (among other) stressors.

The decline in total amount of monsoon rainfall in Kurigram is minimal, yet the **rainfall** variability is increasing. Rainfall data from local weather stations reveal that the total amount of rainfall during the monsoon season (1 June to 30 September) varied over the period from 1979 to 2012 from less than 1,000 mm to more than 2,500 mm in some years. The poor rains during the 2011 monsoon season yielded only 57, 75, and 87 per cent respectively of the long-term average for the months of June, July and August and included 24 consecutive days without rain. The majority of people in the study area identified significant changes in rainfall patterns over the last 10-30 years.

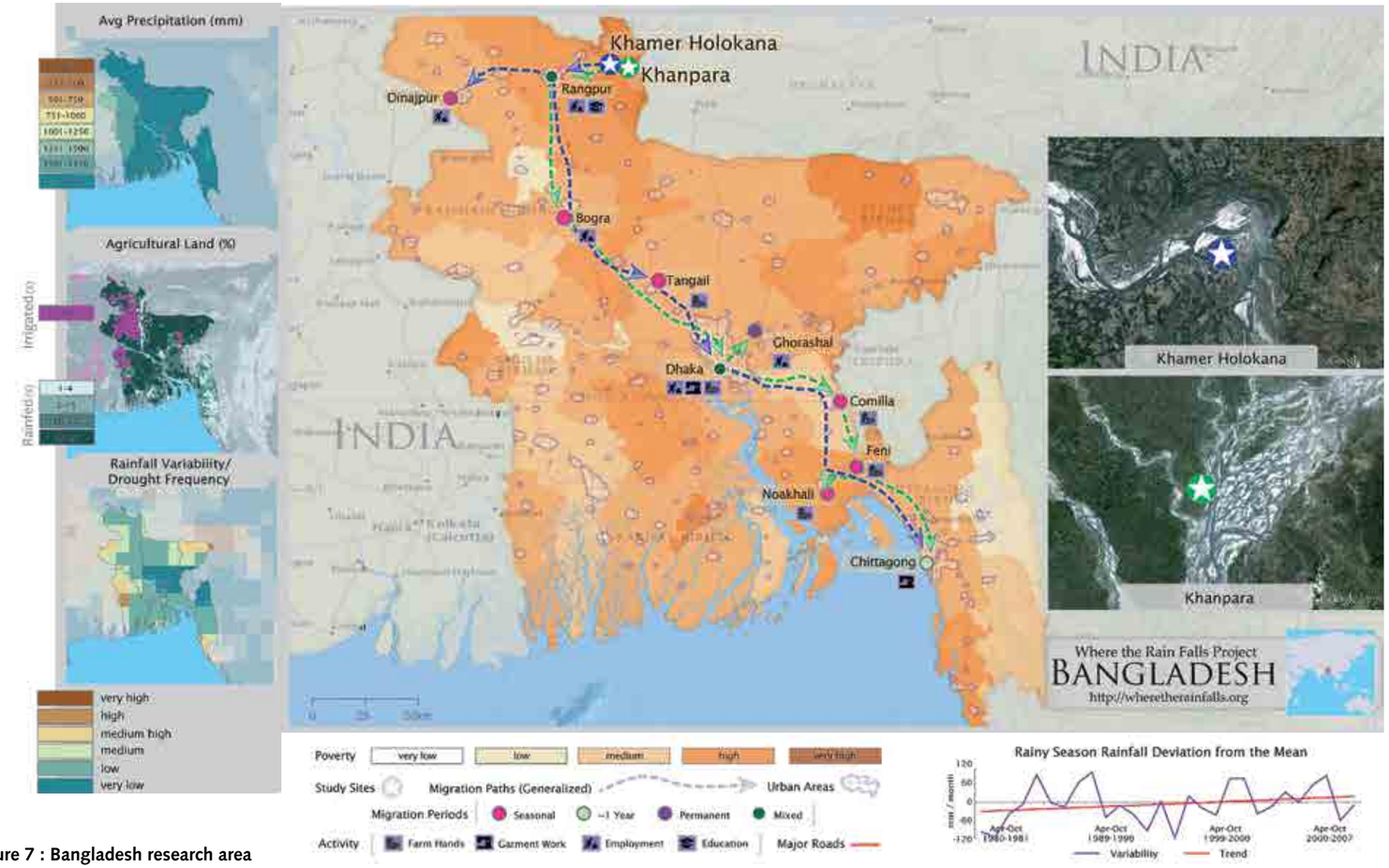

Figure 7 : Bangladesh research area

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This opinion might be influenced by recent experiences, such as a three-week dry spell in the middle of the 2011 monsoon : 96 per cent of survey respondents reported an increase in dry spells and droughts, and 84 per cent reported more frequent extreme weather events. More than 90 per cent of research participants recalled that there used to be six distinct seasons, while there are now only four seasons. Focus group discussions also reported drastic declines in the rainfall episode (during the month of October) known locally as *Kaitan Satao*. The district is also highly exposed to floods, droughts and heavy rains, according to 65, 46 and 38 per cent respectively of survey respondents. While floods can result from locally heavy rain, even normal monsoon rains can result in severe flooding in Kurigram when heavy rains occur upstream in northern India and the Himalayas.

In Kurigram District, local, agriculture-based livelihoods are seasonal and sensitive to changes in rainfall patterns. Rainless periods during the critical aman rice season, described by research participants as unprecedented, gravely affect household **livelihood and food security**. Poverty rates have declined in recent decades, but chronic food insecurity remains a major problem in Kurigram District, particularly during the hunger season (Monga), which reaches its peak in September to October. Although agricultural production in the district has increased, due in large part to the introduction of high yield varieties and increased cropping intensity, poor households are least able to benefit due to the high cost of inputs and limited availability of land. Population growth poses further challenges to the food security of local households.

For example, where the population of Khanpara 30 years ago was around 200, it is now 590, a nearly three-fold increase; the same amount of land previously cultivated by 25 families now must support 118 households.

Migration has been quite common in Kurigram since the mid-1970s and is used by poor, land-scarce farming households as a way to avert seasonal food insecurity. Almost half of the households (43 per cent of all families interviewed) rely on income from migration. The average migrant from the research villages is 37 years old (older than a typical « aspirational » migrant) and has just 3.5 years of schooling. Each migrant has made an average of 22 trips. The most common pattern is seasonal migration (about 80 per cent of cases), with each trip lasting an average of 5.3 months. Ninety eight per cent of the migration movements from the study site are within Bangladesh. The overwhelming majority of migrants from the studied villages in Kurigram move to seek employment as farm labourers in other rural areas, as this does not require more than the farming skills that they already possess. The agricultural regions of Munshiganj and Feni are the two most common destinations for seasonal migrants according to the participants in a focus group discussion in Khanpara. The reason cited by migrants for choosing Munshiganj and Feni as prime (rural) destinations is the high demand for labour there – in particular during the harvesting season – due to increased cropping intensity and local outmigration. Many villagers also temporarily work in the cities of Dhaka or Rangpur due to better wages in the ready-made garments industry or in the informal economy. Although the overwhelming majority of migrants from the research villages are male (97 per cent) and heads of household (89 per cent), women bear much of the social costs of migration. Women who are left behind often assume responsibility for the cultivation of family land and sometimes work as casual labourers to feed the family and repay debts. In addition, adolescent girls and young women also face sexual harassment in the absence of male household members, leading to social stigma and even early marriage, which has long-term negative social and demographic implications.

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In Kurigram, migration is a major 'coping strategy' to address risk and unfavourable economic and environmental conditions, including the local implications of rainfall variability. Of survey respondents, 89 per cent noted that the prevailing weather patterns and rainfall variability affect their household economy. Longer dry spells, were considered by 39 per cent of the households surveyed as a 'very important' reason to migrate, while 36 per cent noted that more frequent droughts can be a 'very important' trigger for migration. Both of these climatic variations have severe impacts on local agricultural production and thus on people's livelihoods. While the richest households are exposed to the impacts of rainfall variability on larger holdings of agricultural land, they are less sensitive because of a larger asset base and multiple income sources. Landless, low-skilled, poor households that rely on rain-fed agriculture for both their livelihoods and food security are most sensitive to rainfall variability. These are the households that most often migrate due to food and livelihood security when rains fail or are unpredictable. Extremely poor, landless households are sensitive to rainfall variability, but often lack the necessary resources to migrate to areas with higher demand for agricultural labour. As a consequence, this « trapped » part of the population remains critically food insecure throughout the year. For households with a migrant, remittances sent from migrants who work permanently in urban areas contribute to a household's food security for those households with the education and skills to capture employment opportunities. Land-scarce, low-skilled households engaged in seasonal migration in agriculture are, however, often not able to break a cycle of food insecurity, indebtedness and temporary labour migration. For them, migration is an erosive coping strategy with worsening human welfare in the long-run.

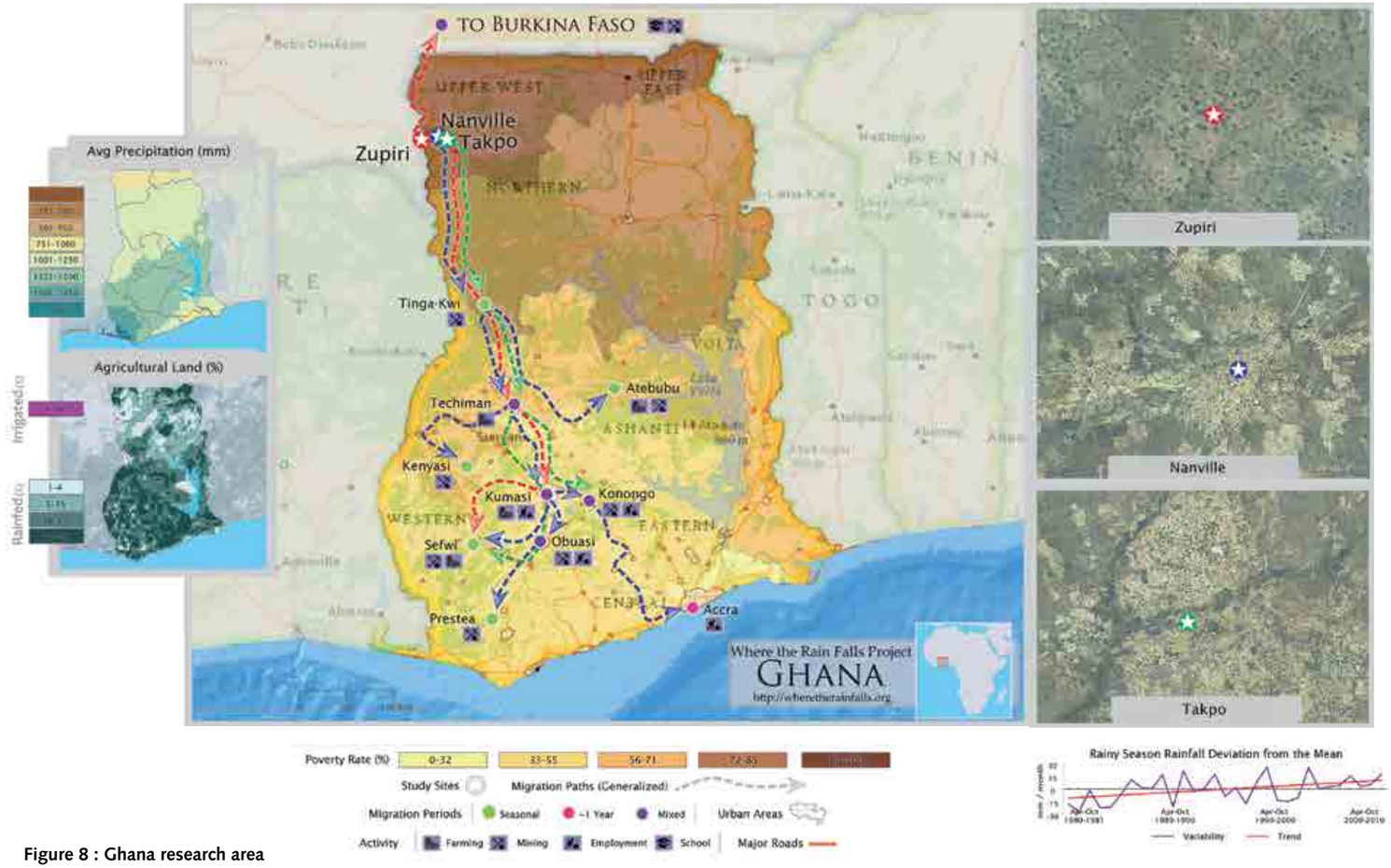

Figure 8 : Ghana research area

4.6 Ghana : High dependence on rain-fed agriculture in Nadowli District contributes to continued reliance on seasonal migration as a coping strategy[29]

The research was conducted in four villages – Mantari, Nanville, Takpo, and Zupiri – located in the Nadowli district in the Upper West Region, the poorest region in Ghana. (See location, landscape, average precipitation, agricultural land, and migration destinations for the research site in Figure 8.) As farmers in these villages have no access to irrigation facilities, their agricultural production is largely confined to a single harvest per year and entirely dependent on rainfall. The high dependence on rainfall and lack of alternative in situ livelihood opportunities for poor households in these villages makes them highly vulnerable to climate change and perpetuates continued reliance on migration – seasonal, temporal, and permanent[30] – as a livelihood strategy and mechanism for coping with food insecurity.

The climate in this region is marked by a wet (May to September/October) and a dry season (rest of the year). The following changes in **rainfall** patterns over the past 20-30 years have been observed in the research villages: an increase in heavy rainfall causing floods; a delay of the rainy season (from April to May); and an increase in the occurrence of dry spells associated with higher temperatures. Results from the household survey document that 92 per cent of the participants perceived changes in rainfall patterns over the period, with 87.3 per cent of interviewees perceiving more droughts over the past 10-30 years and 64.8 per cent reporting more extreme weather events. Villagers' perceptions of an ever more unpredictable climate are largely supported by local meteorological data and expert opinion, which confirm that average temperatures are increasing and that both longer dry spells and heavy rainfall events are increasing in frequency during the planting season. The evidence regarding a delayed onset of the rainy season is more ambiguous, but analysis of meteorological data from different weather stations in northern Ghana shows a delay in the onset of the wet season by more than two weeks for the period between 1961 and 2001[31].

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The **livelihoods and food security** of 85 per cent of the people in this district are based on subsistence agriculture and livestock production, and the degree of economic diversification is very low. The main staple food crops are millet, maize, sorghum and yam, and farmers increasingly cultivate groundnuts as a cash crop to enable them to buy food from local markets to support their families. The food security of households in the research area is undermined by the lack of support provided to smallholder agriculture, including limited access to farm inputs (fertilizer, pesticides) at affordable prices, as well as high post-harvest losses due to pest infestations. The dry season is the time where people engage in trade activities, food processing and seasonal migration. The majority of the household respondents in the research site (98 per cent) mentioned that changing rainfall patterns have a negative effect on crop production, which, in turn, worsens the economic situation of the household. Dry spells and heavy rainfall events during critical stages in the farming season can negatively affect crop production, leading to reduced yields or harvest losses, and ultimately resulting in food shortages.

Negative effects on food crop production, in turn, lead to rising food prices. Of the surveyed households, 37 per cent reported that rising food prices reduced the accessibility of food for their families. Of the respondents of the survey 75 per cent did not have enough food to cover household needs during the lean season prior to the next harvest (May to August), and 69 per cent of them did not have enough money to buy food during the same period. According to 37 per cent of the respondents, animal production has declined as well, reducing thereby the « safety valve » in times of crisis when people sell their livestock to gain income to buy food from the market. In coping with food insecurity, caused to a large extent by rainfall variability, survey respondents mentioned the following coping and/or adaptation strategies, ranked by importance (multiple options possible) : sale of assets (29 per cent) ; reduction of food consumption (21 per cent) ; diversification of household income (14 per cent), which is mainly migration; and modification of crop production, primarily planting other crops, earlier maturing varieties, and increased application of fertilizers (11 per cent).

Due to social and cultural norms in the research site, male **migration** is more common than female migration. Nevertheless, the number of female migrants has increased since the 1980s, and women currently account for 31 per cent of all migrants. The average age of migrants at their first trip is 23 years. Migration is mainly undertaken for economic reasons (83 per cent), and only 9 per cent are educational migrants[32]. Results from the household survey show that 39 per cent are seasonal migrants, followed by 36 per cent permanent migrants, with temporal migrants making up the remaining 25 per cent. The participatory research findings confirm that seasonal migration is the dominant migration type. Interactions in focus group discussions on mobility and seasonal calendars indicated that migrants usually move during the dry season and normally return to assist their households with farm work when the agricultural season at home starts. In cases of acute food shortage, household members may be forced to migrate at uncommon times of the year, such as during the rainy season. The main economic activities of migrants are farming (52 per cent) and mining (14 per cent), and the most important destinations are the Brong Ahafo (38 per cent) and Ashanti (39 per cent) regions. The reason why people leave for Brong Ahafo (the middle belt of the country) is that it has two annual cropping seasons and more fertile lands than the northern part of Ghana. Gold mining areas across the country attract young seasonal migrants who hope to make a fortune in a short period of time. Migration to these regions is now facilitated by both well-established networks that have developed there among migrants from the research area and the availability of regular transportation facilities to those destinations.

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Household members migrate mainly for livelihood and food security reasons, which are directly linked to climatic and environmental factors by virtue of their dependence on rain-fed agriculture. The household survey showed that the most important reasons for migration are : the decline in crop production for own consumption ; shifts in the rainy season ; unemployment ; longer drought periods followed by unreliable harvest ; and increase in drought frequency. The ten most important factors centre exclusively on agriculture (plus livestock rearing) and its link to food security and climate/rainfall variability. As a result, for poor households in the research area, migration to other parts of the country is a common means to diversify household income and receive remittances to purchase food. Migration enables these households to bridge gaps in income but it does not serve to enhance their long-term well-being. Coping can imply negative consequences for these households, such as when heads of household (who have migrated to find food or money to buy food) are not present to support other household members. Better-off households, on the other hand, show a more diversified livelihood portfolio, have more active working members engaged in (seasonal) migration, and in turn are much less vulnerable to the negative impacts of rainfall changes. Their seasonal migration serves more as a means of upward social mobility. Female-headed households are more vulnerable than male-headed households, face a higher degree of food insecurity, have fewer members of working age, possess less land, and engage slightly less in migration than male-headed households.

Figure 9 : Guatemala research area

4.7 Guatemala : Little livelihood diversification and limited migration opportunities leave people of Cabricán with few good options[33]

The project's research was conducted in four villages – El Cerro, Buena Vista, El Durazno, and Quiquibaj – in the municipality of Cabricán in the western highlands of Guatemala. Located at 2,625 metres above sea level, Cabricán is among the poorest municipalities of the country. (See location, landscape, average precipitation, agricultural land, drought frequency and migration destinations for the research site in Figure 9.) The population of these communities is from the indigenous Mam community and depends heavily on rainfall for a single annual harvest.

Cabricán is in a cold weather region with well-defined rainy and dry seasons, and the normal **rainfall** pattern is bimodal, with peaks in June and September. Total annual rainfall, most of which falls between May and October, has fluctuated from as little as 600 mm to more than 1,400 mm over the last 35 years. Over the last four decades, local meteorological data shows a trend of higher total rainfall, with alternating periods of decrease and increase.

One important determinant of rainfall timing and quantity in Guatemala is El Niño, which has increased in both frequency and severity over the last 60 years : three occurrences (all mild) from 1951 to 1970; five (two strong, one very strong) from 1971 to 1990; and six (one very strong) from 1991 to 2010[34]. El Niño has a negative impact on the rainfall, mainly on the Pacific side of Guatemala, and specifically during the months August and September[35]. Respondents to the household survey identified several significant changes in local climate over recent decades : the rainy season has become shorter; rain frequency has decreased and intensity increased; and dry spells are longer. Participants in focus group discussions confirmed these findings, with elderly people stating that, 30 years ago, the rainy season would start in March and end in October/November. Over time, the onset of rains has shifted to as late as May/June, and rains now normally end in October. Of households surveyed, 67 and 65 per cent respectively reported more heavy rains and an increase in severe weather events over the last 10-20 years.

During the last 13 years, Guatemala has been seriously affected by four extreme precipitation events associated with hurricanes and tropical storms : Mitch in 1998; Stan in 2005; Agatha in 2010; and tropical depression 12-E in 2011. All four events resulted in unusually high precipitation and significant storm-related damage in municipalities such as Cabricán in the western highlands.

The project's research confirmed the lack of diversification in local **livelihood systems**, with 66 per cent of households reporting agriculture as their primary economic activity. Farming households in the research villages engage in the *milpa* system of subsistence agriculture (corn in association with various types of beans) with one harvest per year. Of landholdings in Cabricán, 90 per cent are of less than one *manzana* (7,000 square metres), and more than 90 per cent of its population earns less than US$2/day, with the main distinction among households being the better housing conditions of those receiving remittances. **Food insecurity**, which peaks in the months leading up to the harvest in November, is widespread, with 78 per cent of survey respondents reporting having suffered food shortages at least once in the last ten years. Food security in Cabricán is further undermined by poor access to nutritious foods (few products available in local markets) and consumption habits (strong tendency to over-consume maize). Weaving has risen to be the second most important activity, with 22 and 30 per cent of households respectively reporting it as their primary or second most important activity. However, people engaged in weaving are paid only for the amount of labour they provide to the owner of the machinery, who controls both the input supply and marketing of the final product,

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diminishing the potential for this activity to serve as a viable, long-term livelihood diversification strategy.

Human mobility in the research area is a common risk management strategy. Historians date such mobility in Guatemala back to the 1870s, when coffee was developed as an important export crop and the indigenous population of the highlands became the main source of plantation labour. Today, with regard to outmigration from Cabricán, data from the household survey show that it is almost exclusively (97 per cent) motivated by attempts to reduce the variability of household consumption and income related to rain-fed agriculture. Only 25 per cent of households reported having migration experience, possibly an underestimation related to reluctance to admit having a household member abroad. Males make up 77 per cent of migrants, and 80 per cent are either married or in consensual union. In addition to the patriarchal character of Guatemalan society, language presents an additional barrier to outmigration for women in Cabricán, many of whom are mono-lingual in the Mam language.

In addition to the relative isolation of Cabricán in the context of the national economy, migration opportunities (both seasonally in Guatemala and longer-term to the United States) are also decreasing: seventy per cent of households reported aspiring to undertake non-seasonal migration to destinations in the United States (New York, New Jersey, Virginia and Los Angeles) where the villages of Cabricán have developed networks over the years. Yet migration to the United States has also become much more difficult over the last decade due to : more stringent US border enforcement ; declining demand for migrant labour in the US ; the high cost (between 45 and 50 thousand Quetzales or approximately $6,000) and more dangerous conditions of making the trip through Mexico. Households report lower preference for internal migration to destinations such as Quetzaltenango and Guatemala City. In the past, seasonal internal migration, to both the southern coastline and the midlands, was common, but that market for migrant labour has shrunk significantly due to the shift to less labour-intensive crops (sugar cane versus cotton) and since the growers of export crops have developed their own full-time local labour forces.

When survey respondents were asked whether changes in rainfall affect their food production, 68 per cent said « yes, a lot » and 29 per cent said « yes, but only a little ». Research participants in the four villages expressed serious concerns regarding the future prospects for their families and communities. Households reported concerns about the long-term viability of their farming systems and food availability. They also reported limited opportunities for livelihood diversification (such as weaving, where incomes are also decreasing due to excess labour supply). Rainfall-related stressors, food and livelihood insecurity, and difficulty of accessing migration leave local farmers with few apparent viable options to diversify income sources and lift their families out of poverty, whether through in situ adaptation or migration.

Figure 10 : Tanzania research area

4.8 Tanzania : Migration is a common coping strategy for smallholder farmers and livestock keepers struggling for food security in Same district[36]

The project's research in Tanzania was conducted in three villages – Bangalala, Ruvu Mferijini and Vudee – in Same District in the Kilimanjaro Region, which is a semi-arid zone in the Pangani basin of northeastern Tanzania. (See location, landscape, average precipitation, agricultural land, drought frequency and migration destinations for the research site in Figure 10.) Given the high level of dependence on agriculture, and the limited off-farm employment opportunities in the district, inadequate or untimely rainfall often translates into crop failure, food insecurity and migration for poor households with little or no access to good land with access to irrigation water.

Over the past 60 years, total annual **rainfall**, characterized by a bimodal pattern with the « long » (*masika*) rains occurring in March to May and the « short » (*vuli*) rains occurring in September to December, averaged 560 mm/year. The project's research revealed a consistent perception that rainfall patterns in Same District have changed significantly over the past 20 years. The main perceived changes were : (1) increased frequency of prolonged dry spells during the rainy season ; (2) later onset and earlier cessation of rains ; and (3) increased frequency of heavy storms. In addition to changes in the timing and distribution of the two annual rainy seasons, residents also noted higher temperatures and stronger winds as factors that exacerbate local water shortages. An analysis of local rainfall data over the last 30 years provides evidence to support local perceptions of negative changes in rainfall, including : a decline in long season (*masika*) and total annual rainfall ; reduced number of rainy days per year (from 90 to 71) ; and a pattern of early cessation, and thus shorter growing seasons. The data also provides dramatic examples of the unpredictability of rainfall, with several cases of extremely low annual rainfall followed by years of very high rainfall. The evidence supports local perceptions of the changing and very unpredictable nature of rainfall in the research area, where the timing and distribution/intensity of rains can lead to crop failures even in years with « normal » total annual rainfall.

Food and livelihood insecurity is a pervasive problem in Same District and is normally highest during the months from September to January. Focus group discussions in Bangalala, the base village for the field research, revealed that only approximately 5 per cent of households are considered « rich » and able to ensure three meals per day for all household members. By contrast, the middle group (65 per cent of households) could only afford two meals per day, while the poorest 30 per cent often struggled to provide one nutritious meal per day. While the three villages reflect a wide range of agro-climatic conditions in upland and lowland areas of the Pangani basin, their residents share a high degree of dependence on crop and livestock production for their livelihoods. Based on data from the household survey and the participatory research sessions, the top three economic activities – agriculture, livestock, and casual labour – are all very dependent on the natural resource base of the region, and little diversification into off-farm livelihood activities has taken place. Local agriculture, in turn, is highly dependent on rainfall, either directly or via local irrigation systems (including traditional storage structures known as *ndiva*). The average landholding in the area is 1.54 hectares (considered land scarce) and supports six household members. Focus group participants in the three research villages reported utilizing the following short-term coping strategies to deal with food shortages : (1) Changes in household food consumption (fewer meals per day or even going an entire day without eating, elimination of more expensive foods such as fish, eating lighter meals) ; (2) Changes in economic activity (casual labour in the local community, cutting timber, collecting firewood, burning charcoal, and reducing cultivated area) ; (3) Sale of assets (most often livestock, but almost never land) ; and (4) Seeking help from others (government relief, assistance from NGOs, and borrowing money from friends and family).

Given the dearth of alternative local off-farm employment opportunities, **migration** is a very important risk management strategy for households in these villages, where economic migrants out-number educational migrants by a two-to-one ratio. While the majority of migrants are male and young, women now represent one-third of the total. While a slight majority (53.4 per cent) of first trips is seasonal (less than six months) with return, the pattern varies widely across the three villages. Only in Ruvu Mferijini, where there is a significant Masaai population, were seasonal migrants a clear majority (66.3 per cent). Migration from the research villages is overwhelmingly internal, with very few (mostly Masaai herders) moving across international borders (to Kenya). The majority of migrants appear to move to other rural areas with more favourable weather conditions, where they can engage in the farming and livestock-keeping activities with which they are most familiar or find work as casual labourers. The participatory research sessions revealed that most migrate to destinations in Kilimanjaro region and neighbouring parts of northeastern Tanzania, but the results of the household survey also showed that the single most common destination is the capital city Dar es Salaam (32 per cent of the migrants), where they seek work as labourers in markets/retail, construction, and other services. Outmigration from Same District should thus be seen as a mix of rural-rural and rural-urban. Under the conditions that prevail in Same District, changes in rainfall patterns translate directly into impacts on food security, and drought was identified as the major hazard to household livelihoods. More than 80 per cent of household survey respondents reported that rainfall variability negatively affected their food production « a lot ». The results of the household survey also indicate strong linkages between unpredictable and changing weather patterns and the decision to migrate. The top three factors affecting household migration decisions, all directly related to rainfall, were : (1) increased drought frequency ; (2) longer drought periods ; and (3) water shortage. Participants in focus group discussions expressed their concerns about the degradation of the local environment, which they attributed to recurrent droughts, lack of enforcement of laws against logging and other destructive practices in critical watersheds, and continuing population growth. Focus group discussions with youth, who are on the whole freer to move, suggest that they see little future in agriculture and may be more inclined to seek their fortunes in urban areas, despite the hardships encountered there by migrants with limited education and financial resources.

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5- Analysis of current household migration decisions : Household characteristics and sensitivity to rainfall variability and food/livelihood security

This section provides an overview of key characteristics at individual and household levels, based on primary data gathered through household surveys. Building on those characteristics, this section analyses the findings reported from the eight case studies to show current relationships between rainfall-dependent livelihoods and food security and the circumstances under which households currently use migration to manage the risks of impacts on household consumption and income, generating four distinct household profiles.

5.1 Household characteristics in districts sampled

Each research site manifested particular characteristics, but the median values provide a snapshot of the populations across the investigation areas. The median household had 5.6 dependent members, and the household head and dependents, respectively, had 4.7 and 5.9 years of education. Ghana, Guatemala, and India households participating in the Rainfalls survey had the largest average household sizes. Median poverty rates for households surveyed were at 67.7 per cent, using international standards of between 1.25 and 2 US dollars per day.

A median of 52.7 per cent of the households surveyed faced food insecurity in the past year. Tanzania, Bangladesh and Peru manifested households with the highest responses of food insecurity in the last year, but, as the analysis below indicates, the ability to manage food insecurity through options like migration varies significantly among these three.

Table 3 summarizes the households surveyed in districts in eight countries. The last column of the table shows the total number of households surveyed in the Rainfalls research sites – each case surveyed between 130 and 206 households representing (at least 10 per cent of the local (district) population in six of the eight cases). Overall, Rainfalls researchers surveyed 1,295 households and additionally included over 2,000 individual participants in focus group discussions and expert interviews. Of the households surveyed, a median value of 13.3 per cent was headed by females.

Table 3 : Households surveyed in eight case study research sites

	Lamphun Thailand	Huancayo Peru	Chhattisgarh India	Dong Thap Vietnam	Kurigram Bangladesh	Nadowli Ghana	Same Tanzania	Cabricán Guatemala	
Households interviewed (n)	206	150	180	150	150	158	180	136	total = 1310
Approximate % of local population	31,7	29,9	12,8	8,6	2,3	27,2	11,9	18,5	mean = 17,8
Female headed households interviewed (%)	14,6	20,6	7,7	6,6	2,7	12	23	15	mean = 12,8
Female interviewees (%)	14,6	75,3	18,3	44,7	19	20	58,1	63	mean = 39,1
Average age of the interviewees	49,62	42,14	43,58	44,4	45	47,75	47,39	37,04	mean = 44,7
Demographic information of interviewed households									
Household size (Average)	4,31	5,03	6,64	4,3	5,1	7,03	6,08	6,79	mean = 5,6
Dependency ratio (population)*	0,49	0,88	0,70	0,46	0,80	0,93	1,29	1,10	mean = 0,83
Average years of schooling of HH-head	4,16	7,56	5,93	5,2	3,3	2,78	5,16	3,12	mean = 4,7
Average years of schooling of HH-members aged 14+	5,82	8,42	7,48	6,7	4,6	4,02	6,06	3,57	mean = 5,9
Household economy & food security									
Poor - (1.25 - 2.5 US$/cap/day) %	78	82	55	68,6	66	na	na	61,6	mean = 51,4
Households facing food shortages in last year (%)	29,1	82,6	43,9	43	75,3	52,5	84	52,9	mean = 52,9
Holdings of productive land, interviewed households									
Landless households (%)	2,4	43,3	24,4	31	36	6	6,7	2,9	mean = 19,1
Land-scarce HH - Small land holding (%)**	44,6	39,3	36,1	26	48	3,8	24,8	65	mean = 35,9
Medium land holdings (%)***	22,3	8,6	12,8	36,6	13	33	49	24	mean = 24,8
Above average land holdings (%)****	30,6	8,8	26,1	6,6	3	43,6	19,3	6	mean = 17,9
Average land holding size (ha)	2,856	0,54	1,18	2,4	0,5	7,02	1,815	0,54	mean = 2,1 ha
Migration experience of interviewed households									
Households with migrants (%)	67	63,3	41,7	60	43,3	76,6	53,9	23,5	mean = 57
Migrants seeking livelihood diversification (%)	76,00	75,6	87,7	69,6	90	82,8	78,4	97,1	mean = 80,6

* Definition of dependency ratio : Ratio of household members typically not in the labour force (the dependent part - age ranges 0-14 and >64) and those typically in the labour force (the productive part - age range 15-64). It is used to measure the pressure on productive household members.

** Definition of land scarce varies by country : Thailand <=10 Rai or 1.6ha ; Peru 0.1-5.0 ha ; India <= 1 Acres ; Vietnam 0.1–1.0 ha ; Ghana 0.1-1.0 ha;
Bangladesh 0,1 - 0,7 ha ; Tanzania 0.01 to 1.75 acres ; Guatemala <0,44 ha.

*** Definition of medium-sized farm varies by country : Thailand 10.01 to 20 Rai ; India 1.01 - 2 acres ; Ghana <5ha; Tanzania 1.76 to 4 acres ; Guatemala >0.44 and <1 ha

**** Definition of above average-sized farm varies by country : India >=2 acres ; Ghana >5.01ha ; Tanzania >=4.01 acres ; Guatemala >1 ha

Access to land of sufficient quality to support household food consumption and income needs was an important issue in the research areas. Landlessness and land scarcity was manifest in median values of 15.5 and 37.7 per cent of households surveyed respectively, with these households in each site manifesting distinct characteristics relevant to their mobility decisions (discussed below). The average land holding for households across all sites was 1.5 hectares of productive land (excluding grazing land for livestock). Landlessness and land scarcity among sampled households was high in a number of research sites : Bangladesh (84 per cent of households sampled), Peru (82.6 per cent), Guatemala (67.9 per cent), India (60.5 per cent), and Vietnam (57 per cent). Land scarcity was more moderate in Thailand (47 per cent), Tanzania (31.5 per cent), and Ghana (9.8 per cent, but where soil quality was a significant factor in spite of less land scarcity). However, in the latter case of Ghana, land scarcity is not a relevant factor as land ownership rights are held by the community and farmers can easily get access to other community members' lands.

The average household dependency ratio is the highest in the research site of Tanzania (1.29) followed by Guatemala (1.10). This means that in Tanzania, on average, every active household member corresponds to 1.29 inactive (dependent) household members. The two other extremes are the cases of Vietnam (0.49) and Thailand (0.46); for example, in the research site of Thailand, on average, every active household member corresponds to only 0.46 inactive (dependent) household members. Table 4 summarizes migration experience in the households sampled in the respective case studies[37].

Table 4 : Migration experience in the households sampled

Indicators	Lamphun Thailand	Huancayo Peru	Chhattisgarh India	Dong Thap Vietnam	Kurigram Bangladesh	Nadowli Ghana	Same Tanzania	Cabricán Guatemala		
Total number of households	206	150	180	150	150	158	180	136	Total =	1310
HH with migration experience %	67	63	42	60	43	77	49	19	mean =	59,13
Migrant demographic information										
Total number of migrants	224	160	212	168	89	257	204	35	total =	1349
Male %	61	64	62	63	97	69	68	77	mean =	70,06
Female %	39	36	38	37	3	31	32	23	mean =	29,94
Average age of migrants	23,18	24,43	21,1	27,6	37	22,68	24,95	22,8	mean =	25,47
Education level of migrants (average years of schooling)	8,48	8,88	6,1	7,6	3,5	4,06	5,7	4,83	mean =	6,14
Marital status of migrants										
Single %	43	33	19	58	11	40	45	20	mean =	33,68
Married %	50	46	70	39	89	53	47	46	mean =	54,85
Other %	7	21	11	3	0	7	8	34	mean =	11,47
Purpose and termporal aspects of migration choices										
Migration motivated by need to earn livelihood %	76	76	88	70	90	83	40	97	mean =	77,37
Migration motivated to improve skills, education %	18	14	2	18	10	9	20	3	mean =	11,74
Other %	6	10	10	13	0	8	41	0	mean =	10,89
Type of migration										
Seasonal %*	66	67	66	36	80	58	50	17	mean =	54,85
Temporal %**	6	33	28	64	20	37	43	80	mean =	38,91
Permanent %	28	0	6	0	0	5	7	3	mean =	6,24
Migration status										
Current %***	42	46	58	50	84	68	47	NA	mean =	56,25
Returned %****	60	53	42	50	16	32	53	NA	mean =	43,77

*Seasonal migration is defined as yearly recurring migration over periods of less than six months per year.

**Temporal migration is defined as a move from the household of origin during at least six months per year to a place within the country or abroad with the purpose of working, studying, or family reunification, over a distance that forces the concerned person to settle at the destination and stay overnights.

***Current migration means that a person is currently away for the purpose of migration.

****Returned migration is defined as the return of a once-migrated household member who has not migrated again in more than one year.

5.2 Migration as adaptation or failure to adapt? Four rainfall migration profiles

The eight Rainfalls case studies help build understanding about how households use migration to manage risk or to survive when faced with changing rainfall patterns that affect food and livelihood security. Rainfalls research reveals that « contented » households with diverse assets and access to a variety of adaptation, livelihood diversification, or risk management options – through social networks, community or government support programmes, and education – can use migration in ways that enhance resilience. Those « vulnerable » households which have the least access to such options – few or no livelihood diversification opportunities, no land, little education – use migration as a survival strategy in an overall context of erosive coping measures which leave or trap such households at the margins of decent existence.

The Rainfalls research synthesized in this report for policymakers reveals four different profiles of households in relation to how they use migration in the face of rainfall variability, livelihood and food security stressors. Each of the household profiles described below was visible across all eight research sites, but some countries manifested clusters of households with dominant patterns in how they are affected by rainfall stressors. These profiles represent a spectrum with households within a profile being closer to one or the other of the profiles on either side. They are thus are not mutually exclusive and serve as a point of departure for further research to refine key explanatory variables.

Households that use migration to improve their resilience (successful migration)

Across all case studies, these households use migration as one successful risk management or livelihood strategy amongst a wider range of options. The profile of such households was low income or poor, but with adequate access to a variety of livelihood options and assets (social, political, financial) to enable the household to be less sensitive to rainfall stressors. Children in these households typically had 3-5 years more education than parents, with migrants usually in their early 20s, single, aspiring to better livelihood opportunities, and able to send remittances back home. Migration, first and foremost, is an accessible option for those households to enhance livelihood security and resilience for the entire household, including members left behind. Second, migration is an active, positive choice associated with capturing an opportunity that benefits the household. For instance, in these households, migrant remittances facilitate investments in education, health, and assets that enhance the welfare of the household in ways that make it less susceptible to rainfall stressors.

For the next two groups, impacts of migration on households facing rainfall stressors depend on the degree of « success » migrating members have in securing food or resources to obtain food.

Households that use migration to survive, but not flourish

For this group, migration is a way to avoid the worst consequences of rainfall variability and food insecurity, but few or inadequate livelihood diversification or in situ adaptation options available mean that households may be « just getting by ». These families are usually land-poor, and while they may have access to livelihood diversification strategies, these options are often insufficient to ensure food security for the household. Migrants are usually heads of household in their mid-40s. Children in these households have—within a four-month average—the same level of education and skill sets as their parents. These families have less access to social institutions and less access than the previous group to other forms of livelihood diversification or measures to cope with rainfall-related stressors on livelihoods and food security.

While migration for these households is somewhat accessible – they have the assets necessary to migrate – the migration choice is more risky than for contented households. The households in this group can easily slide from « contented » to « vulnerable » if migration proves to be erosive or if rainfall stressors overwhelm the capacity of these households to cope. For these households, migration may perpetuate cycles of debt (migration is an investment), and periodic hunger (if migration is unsuccessful). Migration may not be the first choice if more viable in situ options were available or accessible. Migration for such households is often seasonal or temporary to obtain food directly, or to obtain resources to access food. Migration, therefore, serves as a stop-gap measure, allowing temporary relief from rainfall variability and the impacts of crop failure or decline on the household economy, but it does not transform households or release them from the poverty cycle.

Households that use migration as a last resort and erosive coping strategy

Another profile of households included those for whom migration is an erosive coping strategy (i.e. one that makes them more vulnerable or prevents them from escaping poverty). These households are similar to the previous group : They are landless or land scarce, poor, and have few or no options to diversify livelihoods away from crop and livestock production. Children from these households have the same (low) level of education as their parents. Migrants from these households compete for unskilled labour in the agricultural sector (and sometimes in urban settings). The migrant profile of such households in the Rainfalls research was head of household, mid-40s, married with dependents. These households are also « just getting by », and do not have access to or are unable to capture in situ adaptation or livelihood diversification options. Typical coping measures when faced with rainfall stressors on livelihoods and food availability include reducing food consumption, the quality of food consumed, selling assets, or seeking help from others in the village. As these household may already have limited mobility, focus group discussions indicated that entire villages may face similar challenges and be in a poor position to help each other in times of need (co-variation of risks).

Migration for this type of household can be seasonal (less than six months), temporal (more than six months) or permanent, with the nearest places with more favourable livelihood opportunities as areas of destination. When such migrants leave during the hunger season to find food or resources to access food, household members left behind can be more vulnerable to a variety of environmental as well as social stressors. Migration both is a last resort to avoid the worst consequences of food insecurity and may require actions – such as attempting to access credit to pay for migration expenses – that leave the household deeper in poverty. Furthermore, for these populations, repeated environmental shocks and stressors – and repeated migration –erode their livelihoods, food security, and asset base enough to make migration inaccessible. This pattern can be seen in small numbers in all the cases but is more pronounced in countries that generally face larger challenges with poverty and food insecurity and low livelihood diversification options for climate-sensitive sectors.

Households that cannot use migration and are struggling to survive in their areas of origin

The final profile of households includes those that have been described as « trapped populations » in the literature : households that do not possess the assets necessary to migrate, even to cope with food insecurity, or who cannot access migration options. These are often landless or land-scarce households in very poor areas. Characteristics of these households (or individual members within the household) include : female-headed households who may have multiple burdens of needing to care for agricultural land and care for young children or elderly, households where – often – a main breadwinner has already left the household in search of other livelihood options, households with few able-bodied workers in relation to dependents like children, elderly, or disabled persons. These households face acute food production and consumption shortfalls when rainfall varies, and they report having too little to eat at multiple times in a given year. These households tend to have few or no diversification options, and limited migration options. For trapped households or populations, repeated environmental shocks and stressors can continue to erode their asset base and increase their food and livelihood insecurity. In Guatemala, remote, food-insecure communities face a situation where they have few good options – high sensitivity to rainfall, few local options to diversify risks or livelihoods, and migration options that are too expensive (to a major city, or international), too risky, or to places with similar challenges.

6- Migration in the context of future rainfall variability, food and livelihood insecurity

In order to understand the potential for rainfall to become a significant driver of human mobility in the future, it is important to identify the range of impacts that likely scenarios may have upon migration flows. By investigating the impact of rainfall variability on household- and community-level factors such as food and livelihood security, the influence of such variability on the decisions made by individual migrants can be further understood. Using the *Rainfalls* case study sites as examples of locations where changes in rainfall might contribute to increased food insecurity and human mobility, a process of future-oriented simulation and analysis provides a valuable opportunity to understand the circumstances under which rainfall variability might become a significant driver of migration.

6.1 Agent-Based Modelling

Agent-based modelling is a computational social simulation technique that enables the user to model the behaviour of individual decision-making entities (such as individuals and/or households), as well as their interactions with each other and the environment. This modelling approach provides an opportunity to combine different levels of analysis in order to understand the overall behaviour of the phenomenon of interest. An Agent-Based Model (ABM) is made up of numerous individual and potentially heterogeneous units (agents) which are capable of making autonomous, often goal-oriented decisions and may have the capacity to learn, adapt and modify their behaviour based on perceived changes in their environment. The behaviour and interaction of agents is governed by user-defined rules parameterised on the basis of existing knowledge or data. By characterising an ABM using available data and assessing the capacity of the model to replicate the real-world phenomenon, such a model may be effectively used as either a predictive tool or a means to offer insights that would have been otherwise unattainable.

The following sections describe both the conceptual framework behind the Rainfalls ABM and the initial results gained from modelling work focused on Same District, Tanzania. The following description of both the conceptual framework and Tanzania model results represent the preliminary findings of the agent-based modelling approach undertaken by Rainfalls. While further information on the development and parameterisation of the model is provided as a Technical Annex, subsequent publications will provide more in-depth investigation into the modelling approach and its application to other case study locations.

Photo credit : © 2012 Lars Johansson

6.2 Rainfalls Agent-Based Migration Model

The Rainfalls Agent-Based Migration Model (RABMM) is designed to represent the degree of vulnerability of households to rainfall variability-induced changes in livelihood and food security, and the subsequent impact of these upon the migration of household members. Behind the computational workings of RABMM lies a conceptual framework (Figure 11) intended to represent the complex relationships between the multi-level factors that contribute to household food and livelihood insecurity and migration. Within the framework, boxes indicate components included in the model at one or more level of analysis (external, structural/institutional, household and individual), while arrows indicate the primary direction of influence of one component over another. Bold elements highlight the principal components of the vulnerability assessment and migration decision-making processes being modelled. Non-bold items indicate secondary factors seen to contribute to these processes.

The household-level vulnerability assessment shown at the centre of the conceptual framework is affected by the influence of an external change in local rainfall variability and mean upon a broad range of structural/institutional factors affecting food and livelihood security, including the general state of regional labour markets and food production. The vulnerability assessment is further affected by household-level attributes and characteristics, including income, assets and family size. Whether or not a household identifies itself as vulnerable (with an imminent need to change their situation) or contented (where existing coping strategies are proving adequate) it undertakes a migration decision-making process. Affected by individual-level factors such as age, gender and marital status, as well as household-level factors such as the number of economically active members and land ownership, the migration decision may result in both vulnerable and contented forms of migration. These are indicative of migration under more need-driven and opportunity-seeking circumstances respectively. As in a real-world system, the behaviour of one agent affects the later actions of others through such interaction and feedback effects as the impact of migration on the social network, household income and the local labour market.

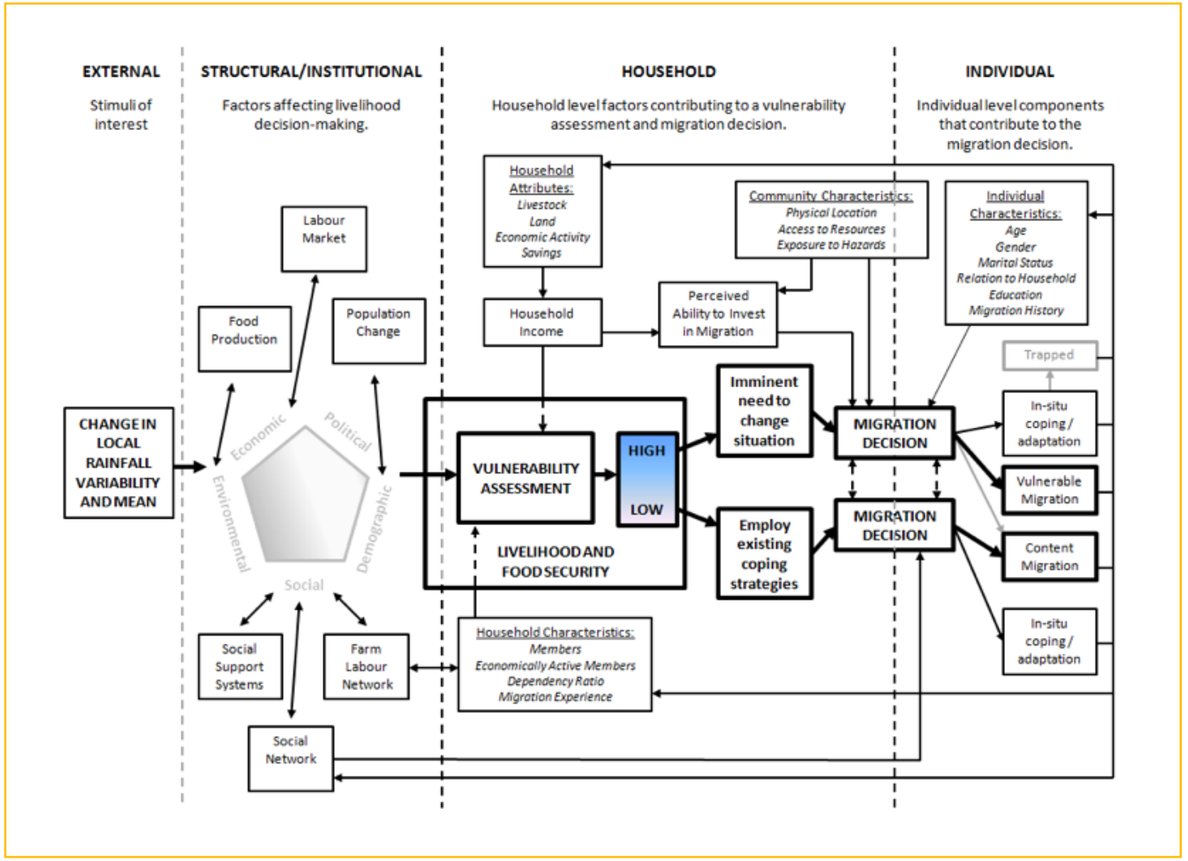

Figure 11 : Rainfalls Agent-Based Migration Model Conceptual Framework

6.3 Futures Analysis : Modelling the case of Same District, Tanzania

Although created with all eight Rainfall case study locations in mind, the conceptual framework shown above has been first developed and tested as a working ABM for the research site in Tanzania. Both households and individuals within the Tanzania model are represented as agents that interact with each other (household-household or individual-individual) and their environment. The characteristics of both household and individual agents are derived directly from the household survey data collected in the three villages studied. The rules of action and interaction that govern the behaviour of agents under different degrees of rainfall variability are also generated through analysis of the wide range of livelihood, food security and migration data captured by the survey. From this foundation the vulnerability assessments and migration decisions undertaken by model agents are intended to reflect those witnessed on the ground.

The future rainfall scenarios used as the stimulus for change modelled in runs of the Tanzania RABMM are provided by Monte Carlo simulations that represent the stochastic probability-distributed nature of the variation in future rainfall around a longer-term trend. The flows of migrants modelled under different scenarios of future rainfall change can thus be used to further understand the impact of rainfall as a driver of migration. The rainfall scenarios tested for Tanzania are intended to represent the approximate degree of rainfall change forecast for the country.

Approximating the rate of change estimated by Paavola (2003)[38] as having occurred by 2100, Scenario 1 represents a **drying** trend with mean annual rainfall decreasing by up to -5 per cent by 2040 and variability around that mean increasing by up to 5 per cent by the same year. Scenario 2 represents a converse **wetting** trend with both mean annual rainfall and variability around that mean increasing by up to 5 per cent by 2040. Approximating the rate of change forecast by Agrawal et al. (2003)[39] as having occurred by 2100, Scenario 3 represents an **extreme wetting** trend with both mean annual rainfall and variability around that mean increasing by up to 22.5 per cent by 2040. The fourth and final scenario represents the converse **extreme drying** trend with mean annual rainfall decreasing by up to -22.5 per cent by 2040 with variability around that mean increasing by up to 22.5 per cent by the same year.

Tanzania Results : Migration from 2014 - 2040 under drier, wetter, & extremely drier/wetter rainfall scenarios

Using the conceptual framework described above, the Tanzania RABMM outputs the number of migrants originating from contented and vulnerable households across the case study villages. Each household assesses its vulnerability to the impacts of rainfall change each calendar month. Seasonal changes such as the *Vuli* and *Masika* rainy seasons affect the income, food production and therefore vulnerability of households throughout the year. Whether contented or vulnerable, a household may identify the migration of one or more of its household members as a viable livelihood strategy. Figure 12 displays the normalised difference rate of migration modelled from vulnerable households. Migrant flows, which are normalised against the numbers of migrants modelled as departing under an 'average' rainfall scenario (with no change in variability or mean), are the mean of five-member ensembles and are shown as five-year moving averages in order to reveal a clearer trend.

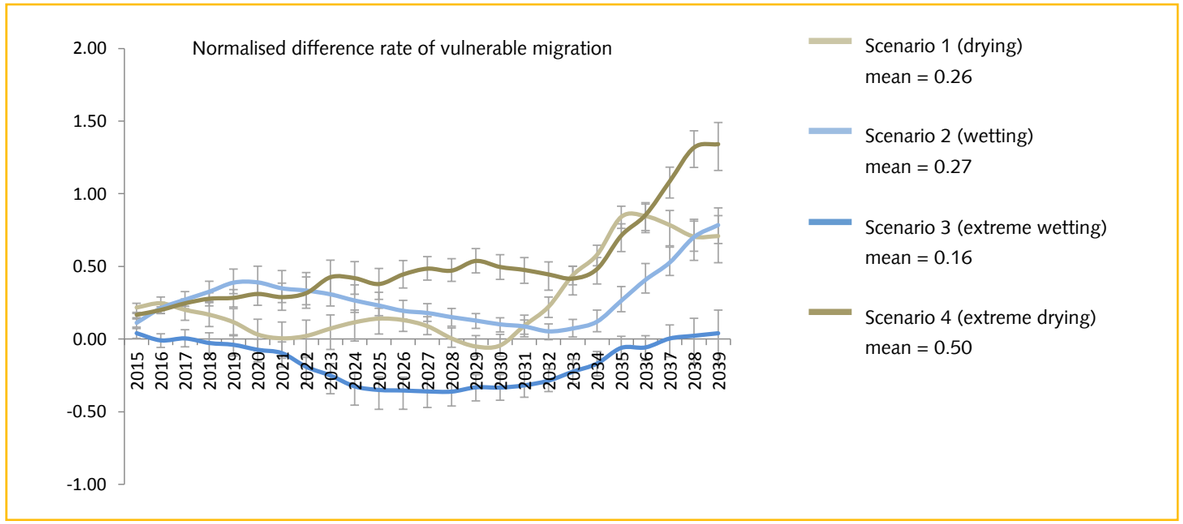

Figure 12 : Five year moving averaged normalised difference in the rate of RABMM modelled vulnerable migration.

Throughout the majority of the simulation period, the normalised rate of migration modelled from vulnerable households is generally greatest under Scenario 4 (**extreme drying**). Under this scenario, the mean annual normalised rate of vulnerable migration stands at 0.5 (an increase of 50 per cent over those simulated under 'average' conditions). By contrast, Scenario 3 (**extreme wetting**) tends to result in the lowest rate of migration from vulnerable households and is the only scenario to result in consistently lower rates of vulnerable migration (mean annual rate of -0.16) than the 'average' scenario against which the simulation outputs are normalised.

Scenarios 1 (**drying**) and 2 (**wetting**) show similar rates of positive change in normalised vulnerable migration over the simulation period, averaging 0.26 and 0.27 respectively.

These results are logically consistent with what might be expected in the sort of semi-arid context (long-term average annual rainfall of just 560mm/year) of which the Tanzania research site is characteristic. In such a setting, an **extreme drying** scenario would be expected to result in increased vulnerability of households and therefore a clear increase in vulnerable forms of migration. Furthermore, a moderately high level of vulnerable migration under a **drying** scenario might also be anticipated for the same reason.

Conversely, the relative abundance that may result from an **extreme wet** scenario may be explained by the lesser vulnerability of most households under periods with more abundant water. The moderately high level of vulnerable migration under a **wetting** scenario contrasts with such findings. One possible explanation for such an outcome may relate to the interaction between the desire and capacity of a household to send a migrant. The marginal wetting seen under Scenario 2 may result in an increase in the number of households able to invest in migration without increasing their livelihood state to the point that they are no longer deemed vulnerable. Alternatively, the mean annual 5 per cent increase in rainfall by 2040 under the moderate wetting scenario may simply be insufficient in the marginal, semi-arid context of the Tanzania research site to lessen the vulnerability of poor households and enable them to improve their in situ livelihood options to the degree necessary to avoid further increases in vulnerable migration.

Although the error bars shown in Figure 12 suggest some degree of variation in the simulation results for vulnerable migrants, the nature of the relationships between scenarios remain unchanged even at the extremes of each envelope. Although of considerable value to this research, the number of vulnerable migrants modelled under each of the scenarios tested is dependent both upon the identification of households as vulnerable and the tendency of their inhabitants to migrate. As such, it is important to also consider the number of contented migrants modelled under the four scenarios in question (Figure 13).

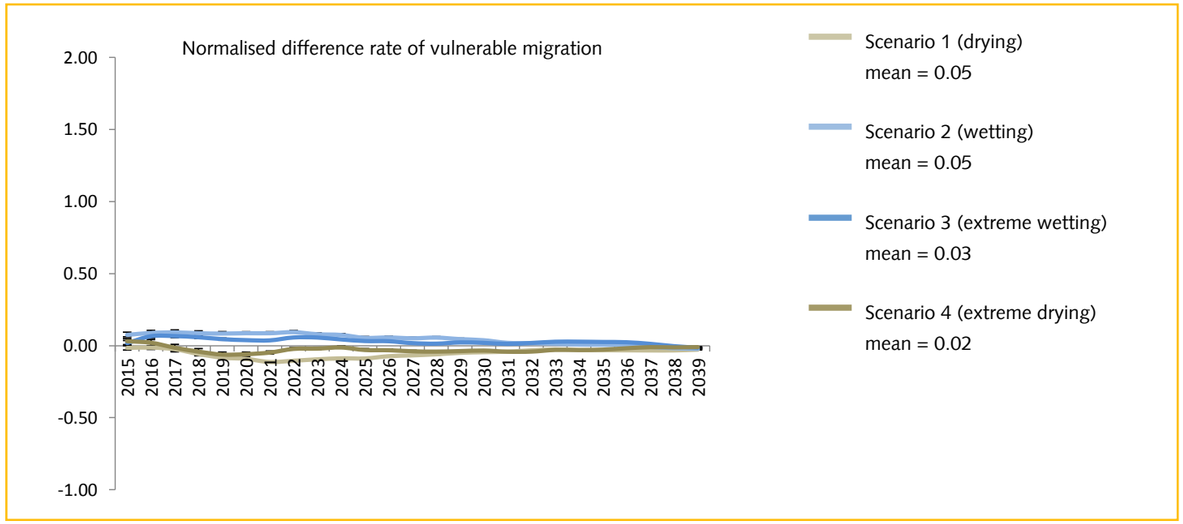

Figure 13 : Five year moving averaged normalised difference in the rate of RABMM modelled contented migration.

The results of the modelling for contented migration shown in Figure 13 show a much lower level of sensitivity to changes in rainfall than is the case for vulnerable migration. Throughout the majority of the simulation period, Scenario 2 (**wetting**) results in the highest rate of modelled migration from contented households. However, the mean annual normalised rate of contented migration under the scenario is 0.05, only 5 per cent greater than that seen under the 'average' scenario. Again for the majority of the simulation period, Scenario 1 (**drying**) results in the lowest rate of normalised contented migration with an equal but opposite annual mean normalised rate of -0.05.

Between these two relative limits, Scenarios 3 and 4 (**extreme wetting** and **extreme drying**) show even smaller overall trends but retain the same sign as their more moderate equivalents. While the extreme wetting scenario therefore reveals a more moderate positive rate than wetting (annual mean of 0.03), the extreme drying scenario reveals a more moderate negative rate than drying (annual mean of -0.02). The error bars shown on the simulation results for contented migration suggest that there was very little deviation from the mean under the complete envelope of changes simulated under five member ensembles.

It is interesting to note that while both wetting scenarios result in a consistently positive change in contented migration, both drying scenarios result in a negative change when normalised against the contented migration modelled under an 'average' scenario. Such outcomes align well with the likelihood that households will have a greater capacity to invest in contented, or opportunity-seeking, forms of migration during the relative abundance brought about by increased rainfall and a conversely reduced capacity under the more restrictive conditions resulting from decreased rainfall. However, due to the small scale of change in contented forms of migration seen in Figure 13, it is deemed impractical to undertake a more in-depth comparison of the precise relationships between scenarios.

In summary, vulnerable forms of migration are far more sensitive to different rainfall scenarios with the greatest vulnerable migration modelled under an extreme drying scenario and the lowest under extreme wetting. Changes in rainfall patterns can impact food and livelihood security in the future and have the potential to increase the vulnerability of many households worldwide. Meanwhile, the agent-based modelling results for Same District in Tanzania suggest a low degree of sensitivity of contented forms of migration to changes in rainfall variability. Slight increases in contented migration are simulated to result from more rain while slight decreases are seen to occur as a result of less rain. With vulnerable forms of migration being clearly affected by different rainfall scenarios, the agent-based modelling approach presented here illustrates how migration may be used in the future in order to manage climatic stressors.

7- Conclusions

Understanding how households manage impacts of changing rainfall patterns on livelihoods and food security today is of paramount importance for adaptation planning, development, and transition to a more climate-resilient future. People in vulnerable communities worldwide are already experiencing impacts associated with extreme weather events and slow-onset climate change. They report changing rainfall patterns, shifting growing seasons, and increasingly severe weather events[40]. Climate change threatens to decrease agricultural productivity, increase food insecurity, and challenge the livelihoods and survival of poor people, particularly smallholder farmers, livestock keepers and the landless in least developed countries. This will prompt some to seek livelihoods elsewhere and may trap others in poverty. Climate change is increasingly calling into question the very habitability of some areas, forcing people to move. The Rainfalls research shows that the question to be asked regarding the interactions between global (and local) climatic change and human migration is not *whether* environmental drivers are the *sole* driving factors of mobility, but rather *how factors* interact to shape migration choices. A more nuanced understanding of how climatic and other variables, including food and livelihood security, interact to affect migration choices will help shape adaptation investments to ensure that whatever strategies households do use – including migration – *contribute to increased resilience to climate change.*

Rainfalls modelling results for Tanzania indicate that migration decisions are clearly affected by changing rainfall variability and the vulnerability of households to these changes. Those households with more or better adaptation options are seen to be less sensitive to changes in rainfall and less likely to have to undertake need-driven migration under adverse conditions. In coming decades, the way affected households manage changing livelihoods and food security will drive patterns of population distribution in areas of the world that are highly vulnerable to climate change. Such areas include mountain regions, densely populated deltas, and arid and semi-arid locations where rain-fed crop and livestock production are already under pressure. Most households will seek to manage the risk of changing rainfall patterns by attempting to diversify their livelihoods in their own areas of origin, with seasonal and temporal migration playing a role.

The need for large-scale, unplanned human mobility may be prevented through effective adaptation measures, particularly in the areas of sustainable agriculture and rural livelihoods diversification. However, poorer countries and communities are under-equipped to support widespread adaptation. As a result, societies affected by changing rainfall patterns – too much or too little rain at particular times of the year, longer-term drying or wetting – may find themselves in a downward spiral of deteriorating well-being, livelihoods and food security, towards the bottom of which social networks could become unduly stressed and tension or violence could rise for those forced to move or remain behind. Human mobility related to changing rainfall and food and livelihood insecurity can only be successfully addressed if seen as global processes and not just local crises. The burden of assisting and protecting vulnerable populations cannot be borne by the most affected states and communities alone. All countries have a role to play in minimizing pressure on vulnerable populations and providing adaptation options, including for dignified, safe movement of people if this becomes unavoidable.

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8- Reflections for policymakers and practitioners : Enabling informed choices globally, nationally, locally

The Rainfalls research examined the relationship between rainfall variability, food and livelihood security, and human mobility, as well as the circumstances under which households use migration as a risk management strategy to respond to rainfall variability and food insecurity. The research revealed that some households use migration as a successful means of increasing their resilience. For others, it is a last resort that perpetuates the negative cycle of poverty and hunger or – worse – erodes their resilience to current and future climatic stressors. For still other households and for some particularly vulnerable populations, migration is not a feasible option either for increasing resilience or for avoiding the worst consequences of food insecurity.

These findings have repercussions for policy aimed at helping people adjust to – and even thrive in the face of – climatic and other stressors : *if approaches are not devised to expand livelihoods and risks management options for those households on the threshold between development and destitution, they will fall further and further behind in the quest for adaptation and sustainable development, and migration under adverse circumstances may result*. The hard-fought gains in human welfare will be reversed, and governments will be faced with increasingly acute needs among an ever-larger group of marginalized, possibly mobile citizens.

Understanding the circumstances and factors (at the national, local, and household levels) that shape household migration choices can help policymakers create enabling environments that allow people to adapt to a changing climate and to access migration as a resilience-enhancing strategy, rather than an erosive survival strategy.

The policy and practice reflections that follow are grounded in a synthesis of country-specific reflections in the eight case study reports. Climate change impacts are local; however, global policy processes on climate change, food security, and sustainable development influence national governments' policy choices and access to support. For some challenges, global action is imperative ; for others, actions at the national and local levels are the primary means of supporting vulnerable communities and households. The recommendations here represent a suite of actions that, taken together, can enable poor populations to make informed, resilience-enhancing decisions about migration, adaptation, and food security.

8.1 Global policymakers

Parties to the UN Framework Convention on Climate Change

The Rainfalls research documents that communities are already grappling with the effects of changing rainfall conditions. The longer governments wait to tackle climate change through ambitious mitigation and adaptation actions, the worse the impacts and the higher the costs – in human and financial terms.

Past emissions have already locked in significant climate change impacts. And recent estimates indicate that current emissions trends and reduction pledges could lead to a 3.5°-6° C[41] warmer world. Even after mitigation actions have been taken and adaptation choices have been made, climate impacts are likely to outstrip the options available to vulnerable countries, communities, and households. This may push some into a downward spiral of deteriorating livelihoods and food security, creating loss and damage to their well-being that exceeds in aggregate anything yet experienced[42]. UNFCCC Parties must urgently tackle three areas – mitigation, adaptation (including finance), and loss and damage – to address the causes of climate change and its disproportionate impact on those people most vulnerable to and least responsible for climate change.

Commit to an equitable approach to reduce greenhouse gas emissions in line with what science says is necessary to keep average global temperature increases below 2° C and potentially below 1.5° C.

Parties must agree to peak emissions by 2015 and reduce global emissions by at least 80 per cent below 1990 levels by 2050. They must also agree on a process to increase emissions reduction targets, as necessary, based on new science to ensure we meet global temperature goals and prevent runaway climate change. As laid out in Article 2, the ultimate objective of the Convention – to avoid dangerous climate change – is the anchor point in addressing the needs of vulnerable communities and in avoiding loss and damage.

Increase commitments and agree innovative mechanisms to ensure delivery of adequate, sustainable, predictable, new and additional adaptation finance in developing countries.

Parties must ensure that the Green Climate Fund promotes transparency, participatory approaches, and accountability to ensure that funds and programmes meet the needs of the most vulnerable people. Adaptation cannot be undertaken without robust funding. The greater the reach – through the provision of adequate, pro-poor funding – of efforts to enable vulnerable communities to adapt to climate change impacts, the more they will be empowered to make informed decisions that enhance their resilience in the context of a changing climate. Developed countries committed to mobilize US$ 100 billion a year by 2020 for all climate finance.

Yet even this number falls far short of the need, and pledges have not yet translated into agreement on finance sources to meet these commitments. At the same time, the current, « default » mitigation pathway in the climate negotiations means that impacts of climate change will likely exceed the bounds of adaptation. Therefore, specific additional actions and support to address loss and damage will be required, above and beyond the adaptation agenda.

Established in 2010, the UNFCCC *Cancun Adaptation Framework* created a global adaptation architecture[43]. Portions of that Framework, including the Adaptation Committee and the Loss and Damage Work Programme, are already in effect; others will be operationalised in the next few years and must deliver on effective bodies and support mechanisms for developing countries to enable them to meet the needs of vulnerable populations.

Facilitate global and regional coordination to enable developing countries to access support and undertake national adaptation planning.

As local communities facing food and livelihood pressures endeavour to adapt to changing rainfall and other climatic stressors, including through the use of migration, national governments' efforts to plan will shape the options available to them. In turn, the Adaptation Committee can play a vital role in enabling national governments to access necessary information, resources, and technical and capacity support to ensure effective, pro-poor efforts that reach these vulnerable communities. The Adaptation Committee's three-year workplan should include the mapping of international, national, and regional adaptation bodies and resources related to food and livelihood security and human mobility. The Adaptation Committee should identify concrete ways to facilitate coordination among these bodies to address emerging issues as well as capacity, resource, and information gaps in these areas. The Adaptation Committee should also include in its mapping and coordination efforts the ongoing work of the UNHCR, IOM and others on human mobility, and initiatives like the Nansen Initiative[44] dedicated to specific types of mobility (migration, displacement, planned relocation), to develop guiding principles for migration to occur under safe, dignified conditions. Finally, the Adaptation Committee's review of the capacity of regional centres should include their role in facilitating regional cooperation on transboundary adaptation challenges and opportunities.

Assess and address loss and damage in ways that help vulnerable people.

Global efforts to address loss and damage must support national governments to take into account the needs of the most vulnerable people, including those who cannot access adaptation or migration options or who may be forced to move when areas become uninhabitable. The UN Framework Convention has a role to play in enabling systematic assessment of actual and potential loss and damage, especially hard-to-quantify or non-economic losses or damage to livelihoods, food security, and well-being. A loss and damage mechanism should support assessments and monitoring of changes in rainfall patterns in order to signal to the Conference of the Parties potentially critical changes in food and livelihood security, human mobility, and the long-term viability of landscapes. A loss and damage mechanism should also support measures, such as safety nets, social protection, and affordable insurance or other risk management and transfer tools, which enable poor populations to retain or transfer risk in the face of increasing climatic uncertainty.

Assessments are also needed of the capacity of national governments and regions to manage loss and damage and the related needs of vulnerable communities. The Convention has a role to play, particularly where national capacity may be exceeded, in facilitating exchange of experiences across regions and guiding systematic approaches to address loss and damage. Approaches could include coordination of standards, policies, and principles, such as those to ensure that loss and damage measures, including migration and resettlement, are transparent and participatory and respect the rights of affected populations. To facilitate comprehensive global and national efforts to address increased human mobility, the Convention should also coordinate with bodies with mandates particular to the management of food and livelihood security and human mobility. Finally, the Conference of the Parties must also acknowledge the need to consider approaches to address rehabilitation, restitution, and a range of operational issues such as financial provisions or compensation for affected communities.

Global food and nutrition security and sustainable development policymakers

Recent years have highlighted the challenge of tackling global hunger – as almost one billion people continue to suffer from chronic food insecurity. At the same time, the experience of the communities in the Rainfalls research demonstrates the interconnectedness of climate change, food security, poverty, natural resource management, and human mobility. These issues cannot each be tackled in isolation. As links are made among them, and as the impacts of human action on natural resources become more apparent, policymakers and practitioners must also see the imperative of a comprehensive approach to sustainable development.

Reinforce the call to tackle the climate crisis and integrate climate change and gender considerations into global food and nutrition security efforts.

It is critical that global food and nutrition security policymakers, including the Committee on World Food Security and the Scaling Up Nutrition initiative, recognize and vocalize the threat that climate change poses to shared goals. These policymakers must integrate climate change impacts in food and nutrition policy and practice, and the differential impact on women and men. They should also reinforce the call for global action to confront the climate crisis in order to demonstrate the importance of leadership and strengthen political will for robust action.

Craft goals for the post-Millennium Development Goal period that support the right of all people to sustainable development.

As we approach the 2015 deadline for the Millennium Development Goals, leaders must craft and agree to another round of « Sustainable Development Goals » that address the linkages among poverty, the environment, climate change, and human mobility. Leaders must acknowledge the drivers of environmental change and their impact on poverty and food security. Goals must call for actions by all nations to reduce these drivers and to guarantee everyone's right to sustainable development.

8.2 Governments and implementing partners

The Cancun Adaptation Framework[45] represented a significant step forward in global adaptation efforts, establishing processes to support national action and providing guidance on adaptation principles, support and action, including migration. It also referenced numerous interrelated issues – migration, vulnerability, and food security – that call for holistic approaches. Following on progress made at the global level, action now must shift to national and local levels to enable poor, vulnerable people to adapt to climate change and capture options, including migration, which can enhance their resilience. **Developing country governments'** plans, policy and practice at national and local levels will have significant implications for the ability of poor, vulnerable populations to adapt to and manage increasing climate impacts and variability. **Developed country governments** and aid agencies can support these efforts and promote principles and approaches to adaptation that address the needs of the most vulnerable populations. Development, humanitarian, and conservation NGOs, multilateral institutions and UN agencies, as **implementing partners** with national and local governments, have a responsibility to ensure that their practice reflects these principles and incorporates projected climate impacts and vulnerabilities so as to enhance the adaptive capacity of poor, vulnerable communities and populations. All these actors must also strive for greater collaboration in order to promote effectiveness and efficiency and to address increasingly complex and multisectoral challenges.

Support, promote, and implement comprehensive, participatory national and local plans.

Governments should anticipate and plan for potential food and livelihood security issues and human mobility related to climatic stressors. To do so, national and local government planning processes must consider all relevant sectors. Plans must also integrate climate change projections and should include analysis and improvement of policies that can expand or limit adaptation options, including policies governing labour, land and natural resources, relocation, and access to services to support migration or resettlement. Planning and implementation efforts must enable the participation and respect the rights of vulnerable populations, including migrants, members of their households and people who may be forced to move, and should adhere to internationally agreed principles and human rights instruments. Effective planning and implementation require engagement of all levels of government and a range of ministries – and the capacity and resources for these actors to engage in these processes. Gaps in capacity must, therefore, be identified and addressed.

Collaborate and support efforts to address transboundary challenges and opportunities related to adaptation and human mobility.

Some localized climate change impacts are the result of activities and events far upstream or can be exacerbated or alleviated by efforts to manage risk or resources in the same ecosystem or watershed. Similarly, rapid and slow-onset extreme climate change impacts may displace populations across borders or render entire areas uninhabitable, forcing populations to resettle. As climate impacts and potentially human mobility increase, nations must cooperate regionally to identify transboundary challenges and leverage opportunities. Collaboration should include sharing of information on projected climate change impacts, consideration of potential cross-border effects of activities such as hydroelectric dams or improved irrigation, publication of climate change strategies, and regular dialogue about shared challenges and opportunities.

Localized impacts of severe weather events, such as the 2011 flooding observed in central Thailand and the Mekong Delta in Vietnam during the project's field research can be the result of both weather conditions and human activity far upstream.

Support and promote resilient livelihoods and food security.

Actions to enhance livelihoods, food security and adaptation options for smallholder farmers, fisherfolk, livestock keepers, and pastoralists, as well as landless households, include promoting sustainable livelihood diversification; climate-resilient, sustainable agriculture; and improved access to and cultivation of a diverse range of nutritious foods. Community-based natural resource management and integrated watershed/water resource management (including for irrigation, sanitation and hygiene) can protect ecosystems that underpin livelihoods. Access to localized climate data, markets, microfinance, micro- and index-based insurance, and social protection and safety net programmes enhance the ability of poor households to withstand shocks. Education and training programmes can increase livelihood options available to migrants and non-migrants alike.

Of the people in the research district in Ghana, 85 per cent live mainly from subsistence agriculture and livestock production, yet farmers have no access to irrigation, making agriculture completely dependent on rainfall. The research communities in Thailand demonstrated a higher level of resilience, with greater access to markets, infrastructure, and credit as well as diversified sources of income, agricultural production, and government safety net programmes.

Strengthen and expand disaster risk reduction and links with long-term development.

In accordance with the Hyogo Framework for Action, early warning systems and other disaster risk reduction measures, including those that capitalize on and build local capacity and knowledge, must be incorporated into development programming to enable poor households to plan and to save lives. Disaster response should take into account and leverage existing long-term, sustainable development strategies, assets, and services, including support for livelihoods, education and health services. These efforts can help minimize the impact of disasters on displaced populations and build resilience and decrease vulnerability among all populations. This requires greater collaboration among national and local governments, the UN system, and humanitarian and development actors, to facilitate coordination of efforts and to maximize funding streams. These stakeholders should also develop and test contingency plans to identify solutions, challenges, and gaps to be addressed. Efforts to build resilience and adaptive capacity must happen before disasters strike to protect lives and assets and enable poor populations to escape – and stay out of – poverty.

In Vietnam, research was conducted at a time when the area was experiencing the highest flood level in ten years. A potential sea-level rise of one metre in a province further south would reduce the discharge capacity of the Mekong River – inundating large tracts of land and potentially increasing the frequency and intensity of floods upstream. During the last 13 years, four extreme precipitation events associated with hurricanes and tropical storms have seriously affected Guatemala : Mitch (1998); Stan (2005); Agatha (2010); and tropical depression 12-E (2011). All four events resulted in abnormally high precipitation and significant storm-related damage.

Integrate gender considerations.

When migration breaks up households, not only do labour burdens shift to women who are left behind, but unequal decision-making power and access to resources like inputs and technology also can render women left in charge of agriculture more vulnerable. Integrating gender involves examining impacts on men and women, girls and boys as part of different social groups, to ensure that actions do not exclude or harm other social groups. Integrating gender requires engaging different social groups to examine and promote awareness of gender roles and power dynamics and inequities and how these can support or limit people's adaptive capacity. This, in turn, can promote the engagement of both women and men, address barriers to equal participation in community and household decision-making, and ensure gender-equitable benefits from adaptation efforts.

In Bangladesh, women whose husbands migrateassume increased agricultural responsibilities in addition to household duties, and young women and girls often experience sexual harassment in their communities. Because harassment stigmatizes young girls, fathers who migrate often marry them off early, making girls vulnerable to negative health consequences and cutting short their education.

Prioritize and engage vulnerable populations.

Priority must be placed on the needs of the most vulnerable populations, such as those who may use migration as an erosive coping strategy or who are unable to migrate. Vulnerability assessments that examine socio-economic, political and environmental dynamics can identify these populations and the underlying causes of their vulnerability. Further, their full and effective participation in all stages of adaptation can ensure that their needs are identified and addressed and that local and indigenous knowledge is captured and leveraged in adaptation strategies. Community-level capacity building and participation can build social capital within communities, increase understanding of local needs and impacts, and improve the effectiveness of government-run programmes.

Climate change presents new, dynamic and significant challenges to already poor and vulnerable populations. Fundamentally, addressing the climate crisis requires more than business as usual from national and local governments, in developed and developing countries and by the global community in the areas of food security, the environment, and sustainable development more broadly. These recommendations form a package of mutually reinforcing actions for stakeholders at multiple levels, and taken together, can enable vulnerable communities and households to access migration and adaptation options that increase their resilience. Poor people are part of long-term solutions and should be empowered and equipped with better information, resources and livelihood options that take changing rainfall patterns into account. But lasting solutions will take more than local people and communities working to fix the problems: it will take all of us working together to enable positive change.

9- Technical annex

9.1 Agent-based modelling

As illustrated by the conceptual framework (Figure 11) that forms the basis of the Tanzania Rainfalls Agent-Based Migration Model (RABMM), the influence of changes in rainfall variability and mean upon migration is manifest through the changing vulnerability status of households within the three communities included in the model. This technical annex provides further information on the means by which rainfall affects household and community processes and therefore influences migration of agents within the model.

The Tanzania RABMM runs using monthly timesteps during which an event generator calls a series of interrelated functions. These functions control the inner workings of the model so that relationships between elements may be numerically solved under the conditions prevailing at time t. The outcomes of these functions at time t then affect the conditions under which the same functions occur at time t+1 by slightly modifying the situations of both agents and their social and physical environments.

The primary form of change experienced by modelled agents with each timestep is the rainfall scenario and the impact of changes to that scenario upon household and individual level functions. However, population-related functions affecting the number and characteristics of agents will also deliver changes both to the individual and household agents themselves and to others through modelled social interactions. Each of these three major forms of simulated change (the impact of rainfall, population dynamics and social interaction) will then affect the conditions within which a household agent undertakes their vulnerability assessment. The outcome of such an assessment then affects the subsequent decision made by the household to send or retain potential migrants. The following simulation month (t+1), the same interrelated functions are called again.

The Impact of Rainfall :

The impact of rainfall is manifest at the structural level by its seasonal influence upon labour market and food production systems.

Seasonal interpretation of Rainfall :

Monthly rainfall for the Same District of Tanzania is assessed on a monthly basis and classified as *extreme-dry, dry, average, wet* and *extreme-wet* using quintile-derived thresholds. These monthly classifications (r) are given seasonal relevance through their interpretation into Vuli (V), Masika (M) and three-monthly (R) scenarios. Depending on the simulation month at t, the V, M and R values represent the relevant rainfall scenario.

$$V = (r(oct)+r(nov)+r(dec)+r(jan))/4$$

$$M = (r(feb)+r(mar)+r(apr)+r(may))/4$$

$$R = (r(t1)+r(t-1)+r(t-2))/3$$

Rainfall and Labour Market :

The structural labour market in the region each month is simulated to be a function (f) of the three-month rainfall scenario (R). The scenario for the past three months therefore affects the structural labour market (L) which can be *less opportune, average* or *more opportune*. Due to the non-linear relationship between rainfall and labour market success, whether or not a rainfall scenario results in a particular category of labour market depends upon the rate of household responses to survey Q412b (months when household tends not to have enough money to buy food).

$$L = f(R)$$

Rainfall and Food Production :

The general state of food production (F) each month is assessed as a function (x) of both the Vuli (V) and Masika (M) rainy periods described above and can be low, average or good. Due to the non-linear nature of the relationship between rainfall and food production, whether or not the rainfall scenario at time t results in a particular category of food production depends upon the rate of household responses to survey Q412a (months when household tends not to be able to grow enough food).

$$F = x(V, M)$$

Population Dynamics :

Birth, marriage and death functions within the model occur annually. Birth rates defined using medium variant UN World Population Prospects data permit agents to be born and randomly assigned to existing households. Agents aged 18 and over who are unmarried have a 10 per cent chance of becoming married each year. Such marriage does not represent any link between households and is not dependent upon there being an eligible partner. Death in the model occurs according to death rates defined using medium variant UN World Population Prospects data.

Social Interaction :

Two opportunities for agent interaction exist in the model : farm labour market competition ; and migrant communication.

Farm Labour Market Competition :
Household agents are located in one of three village environments. Households that identified themselves as offering labouring opportunities to others in the household survey retain that capacity throughout each simulation. Equally, those households that identified themselves as offering labour do so throughout the simulation (one household can offer both labouring opportunities and labour).

The rate of labouring opportunity (o) offered by eligible households to their village on a monthly basis is a function (h) of the rainfall scenario (R) affecting the region. This labour is then divided between available labourers on a pseudo-competitive basis (b) whereby the number of work days (w) offered to an individual may not represent the share they would receive if divided equally.

$$o = h(R)$$

$$w = b(o)$$

Migrant Communication :
Individual agents in the model are located in a social network with ten of their peers with whom they share information on each migration activity they undertake. Agent networks are structured as a small world with 75 per cent of connections made with neighbours. In addition to sharing migration behaviour with their peers, agents also share this information with all other members of their household.

Household Vulnerability Assessment :
As a result of the impact of a change in rainfall upon structural labour market and food production levels, each household agent undertakes a vulnerability assessment that is affected by the degree of livelihood and food security they are experiencing at t. Each household's degree of vulnerability, or vulnerability score (v), is therefore affected by their income (I) and food production (E) and dependent upon household size (H).

$$v = I/H+E/H$$

Income :
Household income is simulated to be a function (i) of crop yield (c), livestock yield (l), farm labour (w) and migrant remittances (s).

$$I = i(c, l, w, s)$$

Only those households that, in the household survey identified their crop/livestock use as contributing to household income, are able gain such a benefit from their land/livestock. Income from crops is a function (j) of the area of land farmed by a household (D) and the level of structural food production (F), itself dependent upon the success of the Vuli and Masika rainy seasons.

$$c = j(D, F)$$

Income from livestock is also affected by the three-month rainfall scenario (R) and is a function (k) of household ethnicity (e) and the degree of impact (k) that households identified changes in rainfall as having on their livestock yield.

$$l = k(R, e)$$

Farm labour income (w) is determined on the basis of the competition for farm labour detailed above. Individuals that belong to a household but are migrating at t also contribute remittances (s) to the household's income each month. In the model's current format, the relative value of income components and their potential monthly maximum and minimum are shown in the Table 5 below.

Component equivalents :		**Relative value :**	**Max monthly income :**	**Min monthly income :**
Crop yield per acre of land (y)		6	0,5	0-0,05
Livestock score (l) :	1 x Cow	1	0,25	0-0,05
	1 x Donkey	0,5	0,125	0-0,025
	1 x Oxen	0,5	0,125	0-0,025
	1 x Pig	0,5	0,125	0-0,25
	1 x Goat	0,25	0,063	0-0,0125
	1 x Chicken	0,1	0,025	0-0,05
One person/day labour (w)		0,25	5	0-0,25
One migrant's remittances (s)		1	1	1

Table 5 : Relative value of income components

Food Production :

In order for livelihood security to be considered from the perspective of income and food security, food production (E) is a function (q) of crop yield (c) and livestock yield (l).

$$E = q(c, l)$$

Due to the double-edged approach (income and food production), different household types may be classified as vulnerable for different reasons. One household with very low income may not become vulnerable because of the level of food production that they use to subsist. By contrast, a household with very low food production may not be vulnerable because of a relatively higher income. Crop and livestock yield functions for food production work in the same manner as those seen to contribute to income but are dependent upon households having identified their crop/livestock production as being used for the production of food for the household as opposed to for sale.

Vulnerability Threshold :

By comparing their vulnerability score (v) with a vulnerability threshold (T), a household may be deemed vulnerable to the change in rainfall variability affecting them and identify an imminent need to change their situation. Those households that have a vulnerability score adequate to prevent them from becoming vulnerable are deemed to be contented and able to continue to employ existing coping strategies.

The vulnerability threshold (T) is set at 0.04 following a process of sensitivity testing. When the Tanzania RABMM is run with no migration of household members (and therefore zero contribution of remittances to household income) and a constant classification of both the structural labour market and structural food production as average, a vulnerability threshold of T=0.04 results in a steady state of household vulnerability classification throughout the simulation period. Deviation away from T=0.04 results in a gradual change in content and vulnerable classifications over time.

Migration Decision-Making :

Whether or not a household is identified as vulnerable, they undertake a migration decision that, although mediated by the household agent, is based largely upon the attributes of the individuals. Whether from a vulnerable or content household, individual members each develop a propensity (P) towards migration that a results from their attitude (A) towards migration and their subjective norm (S).

$$P = A+0.5S$$

An individual's attitude (A) towards migration is a function (u) of their household's land category (d) and the individual's age (a), gender (g) and marital status (m).

$$A = u(d, a, g, m)$$

The attitude of an individual towards migration is gained from analysis of the attributes of those individuals recorded in the household survey data as having migrated. If an individual's attitude is greater than 0, their subjective norm is derived from the number of current migrants from the agent's family (B) and peer network (n) in relation to the size of their household (H) and peer network (N).

$$S = \frac{B}{H} + \frac{n}{N}$$

Each individual's propensity towards migration is reported to their household and ranked from highest to lowest. A household then assesses their ability to invest in migration, their perceived behavioural control (C), derived as a function (y) of their income (I), assets (G), the number of migrants from the household that have already left (B) and the cost of migration (Q).

$$C = y\ (I, G, B, Q)$$

The cost of migration (Q) is set as 1 (for direct comparison with the relative potential income sources in Table 5 above). However, the cost of vulnerable forms of migration is set as 50 per cent (0.5Q) of the normal cost of migration (0.5).

Key Assumptions/Demography :

- Death can affect any agent at any point in model time regardless of age.
- No new households are formed. Marriage is a statistical function and does not represent a union between households.
- Agents become economically active and eligible to marry at the age of 18.

Vulnerability :

- One acre of land results in a yield that is standard across locations.
- Farm labouring opportunities in a village will be met by those already inhabiting the same village, therefore not introducing a 'pull' factor for migrants towards case study locations.
- No input to household income is generated from non-farm activities (in this preliminary model).
- The primary form of input to household income and food production is crop production rather than livestock. Agricultural land therefore represents a flow of assets while livestock represent a stock. This is less the case for Maasai people.
- Surplus income at the end of a calendar month results in a marginal increase in household assets.

Migration :

- The cost of migration for all households is the same, although vulnerable and content forms of migration are different.
- All migration modelled is labour migration.
- All migration is successful and results in a standard return for the household.
- A household's ability and willingness to invest in migration decreases with more migrants.
- The propensity of an individual towards migration is the same under impacted (vulnerable) and non-impacted (content) circumstances.

9.2 Mapping approach and references

The maps (and associated rainfall variability graphs) produced for this report were developed using data sets from multiple sources. Here we provide the citations for the data sets that were employed. If a data set was only employed for certain countries, then those countries are indicated in the parentheses following the data set citation.

The production of these maps was completed by Tricia Chai-Onn and Dara Mendeloff (GIS staff) and Al Pinto (Map Designer) under the overall supervision of Alex de Sherbinin at the Center for International Earth Science Information Network (CIESIN), a unit of the Earth Institute at Columbia University. All mapping work was completed in ArcGIS v10 and converted to images for final production in Adobe Illustrator. The climate data analysis for the charts in the lower right hand corner of each of the maps was completed by Michael Bell and John Del Corral of the International Research Institute for Climate and Society (IRI), also of the Earth Institute. They used the IRI Climate Data Library to produce the trend and variation data set based on grid cells overlapping the study area.

Poverty Data

Azzarri, C., Wood, S., Hyman, G., Barona, E., Bacou, M. and Guo, Z. 2012. Sub-national Poverty Map for Sub-Saharan Africa at 2005 International Poverty Lines (r12.04). http://harvestchoice.org/. (Ghana, Tanzania)

Center for International Earth Science Information Network (CIESIN)/Columbia University. 2005. Poverty Mapping Project : Small Area Estimates of Poverty and Inequality. Palisades, NY : NASA Socioeconomic Data and Applications Center (SEDAC). http://sedac.ciesin.columbia.edu/data/set/povmap-small-area-estimates-poverty-inequality. (Guatemala, Vietnam)

Center for International Earth Science Information Network (CIESIN). 2011. Global Infant Mortality Grid, 2008. Palisades, NY : CIESIN, The Earth Institute at Columbia University. [This data set represents a 2008 update of the following publicly available data set : Center for International Earth Science Information Network (CIESIN)/Columbia University. 2005. Poverty Mapping Project: Global Subnational Infant Mortality Rates. Palisades, NY: NASA Socioeconomic Data and Applications Center (SEDAC). http://sedac.ciesin.columbia.edu/data/set/povmap-global-subnational-infant-mortality-rates.] (Bangladesh, India, Peru, Thailand).

Urban Areas

Center for International Earth Science Information Network (CIESIN)/Columbia University, International Food Policy Research Institute (IFPRI), The World Bank, and Centro Internacional de Agricultura Tropical (CIAT). 2011. Global Rural-Urban Mapping Project, Version 1 (GRUMPv1): Urban Extents Grid. Palisades, NY : NASA Socioeconomic Data and Applications Center (SEDAC). http://sedac.ciesin.columbia.edu/data/set/grump-v1-urban-extents.

Basemap

DeLorme Publishing Company, Inc., 2010, Roads.sdc: A subset of DeLorme World Base Map (DWBM). 2010, DeLorme Publishing Company, Inc., Yarmouth, Maine, USA.

Lehner, B., Reidy Liermann, C., Revenga, C., Vörösmarty, C., Fekete, B., Crouzet, P., Doll, P., Endejan, M., Frenken, K., Magome, J., Nilsson, C., Robertson, J.C., Rodel, R., Sindorf, N., Wisser, D. 2011. Global Reservoir and Dam Database, Version 1 (GRanDv1): Reservoirs, Revision 01. Data distributed by the NASA Socioeconomic Data and Applications Center (SEDAC). http://sedac.ciesin.columbia.edu/data/collection/grand-v1.

National Geographic Basemap. 2012. National Geographic, ESRI, DeLorme, NAVTEQ, UNEP-WCMC, USGS, NASA, ESA, METI, NRCAN, GEBCO, NOAA, IPC.

Ocean Basemap. 2012. GEBCO, NOAA, CHS, OSU, UNH, CSUMB, National Geographic, DeLorme, NAVTEQ, and ESRI.

Average Precipitation (Map Inset)

New, M., Lister, D., Hulme, M. and Makin, I. 2002: A high-resolution data set of surface climate over global land areas. Climate Research 21:1 25. Data available from http://www.cru.uea.ac.uk/cru/data/hrg/tmc/.

Agricultural Land (Map Inset)

Fischer, G., Nachtergaele, F., Prieler, S., van Velthuizen, H.T., Verelst, L. and Wiberg, D. 2008. Global Agro-ecological Zones Assessment for Agriculture (GAEZ 2008). Laxenburg, Austria and Rome, Italy: IIASA and FAO.

Rainfall Variability/Drought Frequency (Map Inset)

This represents the rainfall coefficient of variation multiplied times the drought standardized precipitation index (SPI) with a six-month interval. The SPI is the number of standard deviations that the observed value would deviate from the long-term mean, for a normally distributed random variable. Since precipitation is not normally distributed, a transformation is first applied so that the transformed precipitation values follow a normal distribution. The data were downloaded from :

UNEP (United Nations Environment Programme). 2010. Global Risk Data Platform : Drought Coefficient of Variation. Available from http://preview.grid.unep.ch/ (accessed July 2010).

Rainy Season Rainfall Deviation from the Mean (Graph)

All data were obtained from and analyzed using the IRI Climate Data Library. The following were the data sets used. Full documentation on original data sources is available by clicking on the « dataset documentation » link available from each of the URLs listed below.

It is important to note that the original data sources represent globally gridded reanalysis data based on available meteorological station data (for CPC Unified) and satellite data and numerical models (for CMAP and Aphrodite), with often sparse coverage of observed data. This means that results of the rainfall variability and trend analysis will differ from the results obtained from local meteorological stations, as reported in the country study reports.

National Oceanographic and Atmospheric Administration (NOAA) National Centers for Environmental Prediction (NCEP) Climate Prediction Center (CPC) : CPC Unified Precipitation gauge based global data set, v1p0. These data are produced at a 0.5° lat/lon resolution. Available from http://iridl.ldeo.columbia.edu/SOURCES/.NOAA/.NCEP/.CPC/.UNIFIED_PRCP/.GAUGE_BASED/.GLOBAL/.v1p0/. (Peru only)

National Oceanographic and Atmospheric Administration (NOAA) National Centers for Environmental Prediction (NCEP) Climate Prediction Center (CPC) : CPC Merged Analysis of Precipitation (CMAP) : Analyses of global precipitation using gauge observations, satellite estimates, and numerical model predictions.

These data are produced at a 2.5° lat/lon resolution. Available from http://iridl.ldeo.columbia.edu/SOURCES/.NOAA/.NCEP/.CPC/.Merged_Analysis/.monthly/. (Ghana, Guatemala, Tanzania) Research Institute for Humanity and Nature (RIHN) and Meteorological Research Institute of Japan Meteorological Agency: RIHN aphrodite Asian precipitation from APHRODITE V1003R1. These data are produced at a 0.5° lat/lon resolution. Available from http://iridl.ldeo.columbia.edu/SOURCES/.RIHN/.aphrodite/.V1003R1/. (Bangladesh, India, Thailand, and Vietnam)

10- Endnotes

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[2] Tubiello, F. N., and G. Fischer. 2007. Reducing climate change impacts on agriculture: Global and regional effects of mitigation, 2000-2080. Technological Forecasting and Social Change 74 : 1030-56

[3] Jennings, S. and J. Magrath. What happened to the seasons? Paper presented at the Conference on Seasonality, Future Agricultures Consortium International. IDS Sussex, UK, July 2009.

[4] Environmental Change and Forced Migration Scenarios (EACH-FOR), research project financed by the European Commission in the 6th Framework Programme (FP6), (2007-2009), (contract No.: 044468) available at: http://www.each-for.eu/

[5] IPCC, 2012 : Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation. A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change [Field, C.B., V. Barros, T.F. Stocker, D. Qin, D.J. Dokken, K.L. Ebi, M.D. Mastrandrea, K.J. Mach, G.-K. Plattner, S.K. Allen, M. Tignor, and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, UK, and New York, NY, USA, 582 pp.

[6] 3.5° C : according to the Climate Action Tracker http://climateactiontracker.org/news/116/Durban-Agreements-a-step-towards-a-global-agreement-but-risk-of-exceeding-3C-warming-remains-scientists.html; 6° C: according to the IEA.

[7] El-Hinnawy, E. (1985) introduced the first definition for 'environmental migrants' in a United Nations Environmental Programme (UNEP) report. His definition has been refined and made more comprehensive by other authors and institutions, such as the International Organization for Migration (IOM) in 2007.

[8] See some attempt to place estimate numbers on current and future environmentally induced migration, such as : Myers, N. (2005) Environmental Refugees : An Emergent Security Issue. 13th Economic Forum, Prague, 23-27 May.
-Christian Aid (2007) Human Tide: the Real Migration Crisis, available at www.christianaid.org.uk/Images/human_tide3__tcm15-23335.pdf. -International Organization for Migration (2007) Facts and Figures: Global Estimates and Trends. International Organization for Migration, Geneva available at www.iom.int/jahia/page254.html

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[17] All research methods and instruments are described in Rademacher et al. (2012), « Rainfall variability, food security and human mobility. An approach for generating empirical evidence », available at www.ehs.unu.edu.
[18] What distinguishes sample random sampling from stratified random sampling is that the latter ensures that key subpopulations are included in the sample.
[19] A first step in classifying the research countries is to rank them in terms of overall levels of socio-economic development. For this purpose, and in keeping with the particular interest of the project in food security, three widely available indicators were used : (1) Gross Domestic Product per capita (source: World Development Report 2012. Gender Equality and Development, copyright 2011 The International Bank for Reconstruction and Development/The World Bank, Washington, DC; (2) Human Development Index (source: Human Development Report 2011, Sustainability and Equity: A Better Future for All, copyright 2011 by the United Nations Development Program; and (3) Percentage of Children Under-Five with moderate and severe stunting (source: The State of the World's Children 2012, Children in an Urban World, copyright United Nations Children's Fund (UNICEF), February 2012. Countries were classified as high, medium, or low using the following cut-off points: Per capita annual income (low=less than $1,000, medium= >$1,000 and <$3,000, high= >$3,000); Human Development Index (low, medium, high, and very high as defined by UNDP); and Nutrition (moderate and severe stunting of >40%= low, >20%<40%= medium, and <20%= high).
[20] The eight research countries were also classified using a number of indicators selected to capture changes in economic and demographic conditions. The following three variables were selected as relevant to the WtRF research : (1) Average Annual Growth in GDP, 2007 2011 (source : World Development Report 2012, World Bank) ; (2) Percentage of GDP Still in Agriculture (source: World Development Report, World Bank) ; and (3) Annual Rate of Population Growth, 2011 (source : World Development Report, World Bank). Countries were classified for each of these variables using the following cut-off points : Economic Growth (high= >6% annual growth, low= <4% annual growth) ; Non-agricultural employment potential (high= <20% of value added in agriculture, low= >20% of value added in agriculture); and Progress in Managing Population Growth (high= <1%

annual growth, medium= >1%<20% annual growth, low= >2% annual growth).

[21] Information from this section is based on Promburom, Panomsak; Sakdapolrak, Patrick (2012). « Where the Rain Falls » project. Case study: Thailand. Results from Lamphun Province, Thailand. Report No. 7. Bonn: United Nations University Institute for Environment and Human Security (UNU-EHS).

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[24] Information from this section is based on Ho, Raúl; Milan, Andrea (2012). « Where the Rain Falls » project. Case study: Peru. Results from Huancayo Province, Peru. Report No. 5. Bonn: United Nations University Institute for Environment and Human Security (UNU-EHS).

[25] MINAM (Peruvian Ministry of Environment). *Segunda Comunicación Nacional del Perú a la Convencion Marco de las Naciones Unidas sobre Cambio Climático*. Lima, Peru : MINAM, 2010.

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[27] Information from this section is based on Murali, J.; Afifi, T. (2012). « Where the Rain Falls » project. Case study : India. Results from Janjgir-Champa, India. Report No. 4. Bonn : United Nations University Institute for Environment and Human Security (UNU-EHS).

[28] Information from this section is based on Ahsan, Uddin Ahmed; Hassan, Selim Reza; Etzold, Benjamin; Neelormi, Sharmind (2012). « Where the Rain Falls » project. Case study : Bangladesh. Results from Kurigram District, Bangladesh. Report No. 2. Bonn : United Nations University Institute for Environment and Human Security (UNU-EHS).

[29] Information from this section is based on Rademacher-Schulz, Christina, and Edward Salifu Mahama (2012). « Where the Rain Falls » project. Case study : Ghana. Results from Nadowli District, Upper West Region, Ghana. Report No. 3. Bonn : United Nations University Institute for Environment and Human Security (UNU-EHS).

[30] Seasonal migration in this study is defined as a move of less than six months, while temporal migration refers to moves between six months and two years. Permanent migration refers to moves of more than two years.

[31] Laux 2009. Statistical modeling of precipitation for agricultural planning in West Africa, Mitteilungen/Institut für Wasserbau, Universität Stuttgart, Heft 179, ISSN 0343-1150, 198 pages.

[32] The balance of migrants not moving for « work » or « education » indicated « marriage » (5 per cent) and « other » (2 per cent) as their reason for migration.

[33] Information from this section is extracted from field research done by Sergio Rolando Ruano and Andrea Milan in the Cabricán District, Guatemala.

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[36] Information from this section is based on Liwenga, Emma T.; Kwezi, Lukas; Afifi, Tamer (2012). « Where the Rain Falls » project. Case study: Tanzania. Results from Same District, Tanzania. Report No. 6. Bonn : United Nations University Institute for Environment and Human Security (UNU-EHS).

[37] In the household survey, sometimes respondents did not give a clear answer, which made the interviewer drop the respective question. In other cases, respondents gave two answers where the question required only one answer. Therefore, in some exceptional cases in this table (particularly the cases of Thailand, Peru and India), adding up percentages gives a sum of slightly less or more than 100 per cent.

[38] Paavola, J. 2003 Vulnerability to Climate Change in Tanzania : Sources, Substance and Solutions. A paper presented at the inaugural workshop of Southern Africa Vulnerability Initiative (SAVI) in Maputo, Mozambique June 19-21, 2003.

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[43] The Cancun Adaptation Framework includes provisions for a range of risk management approaches (paragraph 14), as well as guidance on the range of climate-change related human mobility issues (paragraph 14(f)). Food and livelihood security are referred to in footnotes.

[44] Nansen Initiative: Press release from UN (http://www.un.org/apps/news/story.asp?NewsID=42298&Cr=refugee&Cr1=climate), link to 2011 Nansen conference (http://www.nansenconference.no/) and to conference report (http://www.unhcr.org/4ea969729.pdf).

[45] 1/CP.16, paragraphs 11 35; paragraph 14(f) addresses migration in the context of adaptation to the impacts of climate change.

About Where the Rain Falls project

The research project « Where the Rain Falls : Climate Change, Food and Livelihood Security, and Migration » (« Rainfalls »), undertaken in partnership between CARE International and the United Nations University Institute for Environment and Human Security (UNU-EHS), and financially supported by the AXA Group and the John D. and Catherine T. MacArthur Foundation, aims to improve understanding among academics, practitioners, and policymakers about how rainfall variability affects food and livelihood security, and how these factors interact with household decisions about mobility/migration among groups of people particularly vulnerable to the impacts of climate change. The research focuses on perceived as well as measured changes in rainfall (e.g., extended dry or wet periods, droughts or floods, erratic rainfall) and shifting seasons. These rainfall changes influence crop yields and livestock rearing, which may impact local food production, food availability, and prices, leading in turn to food insecurity and shortages. Usually, people develop different strategies to cope with stress and variability related to food and livelihood security. The project is interested in understanding why people react differently to stress caused by changing weather patterns and food insecurity and explores to what extent changing weather patterns influence people's migration decision, as one of the mechanisms used by people experiencing this kind of stress.

The project has three objectives : (1) to understand how rainfall variability, food and livelihood security, and migration interact today ; (2) to understand how these factors might interact in coming decades as the impact of climate change begins to be felt more strongly ; and (3) to work with communities to identify ways to manage rainfall variability, food and livelihood security, and migration.

The project investigates the following three questions (related directly to the three research objectives above) :

1- Under what circumstances do households use migration as a risk management strategy in response to increasing rainfall variability and food insecurity ?

2- Under what scenarios do rainfall variability and food security have the potential to become significant drivers of human mobility in particular regions of the world in the next two to three decades ?

3- In the context of climate change, what combination of policies can increase the likelihood that human mobility remains a matter of choice among a broader range of measures to manage risks associated with changing climatic conditions, rather than « merely » a survival strategy after other pathways have been exhausted ? The project explores such policy alternatives in hotspot areas of the world.

For case studies, modelling, and further information visit our websites : www.wheretherainfalls.org ; www.ehs.unu.edu ; www.carefrance.org ; and www.careclimatechange.org

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WHERE RAIN FALLS

The Where the Rain Falls Project investigates how changes in rainfall interact with societies.The project provides a more nuanced understanding of the links between changing rainfall patterns, food and livelihood security, as well as migration in eight case study countries :

Bangladesh : Kurigram District, Rangpur Division
Ghana : Nadowli District, Upper West Region
Guatemala : Cabricán Municipality, Quetzaltenango Department
India : Janjgir-Champa District, Chhattisgarh State
Peru : Huancayo District, Junín Region
Tanzania : Same District, Kilimanjaro Region
Thailand : Thung Hua Chang District, Northern Thailand
Viet Nam : Dong Thap Province

Changing weather patterns are already causing weather extremes, including droughts and flooding, leading to food insecurity and displacement of people. Research results will help climate change policy and its implementation with important practical aspects to tackle poverty, protecting the most vulnerable people.

The full project findings – a research protocol, case study reports and a synthesis report for policymakers – are available at www.wheretherainfalls.org.

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