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Climate Change Adaptation and Development: A Conceptual Framework

Romina Cavatassi

World Bank

Adriana Paolantonio

World Bank

Teevrat Garg

University of California, San Diego
and IZA@LISER

David L. Vargas

University of California, San Diego

Joshua Graff Zivin

University of California, San Diego

Philip Wollburg

World Bank

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Climate Change Adaptation and Development: A Conceptual Framework

Abstract

Climate change is reshaping the economic environment in which households make decisions, generating diverse adaptive responses and increasing demand for data that can guide effective policy. Yet current measurement efforts remain fragmented, reflecting two central gaps: the lack of systematic data on household adaptation and the absence of a structured diagnostic framework to interpret it. This paper addresses both by developing a literature-informed framework for diagnosing household-level climate adaptation, with a focus on adjustments in income-generating activities as the main channel through which households respond to climate risk. The framework is organised around four stages: mapping income streams, assessing exposure, identifying feasible responses, and analysing take-up and the constraints that limit adoption. It explicitly integrates objective and subjective dimensions of exposure, recognising the role of perceptions, beliefs, and information. By situating decisions within broader institutional and economic contexts, the framework provides a foundation for improving survey design, strengthening diagnosis of adaptation gaps, and generating more policy-relevant and comparable data. In turn, this can support governments and institutions seeking to scale effective adaptation and build up household's climate resilience.

JEL classification

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climate change, adaptation, households, development

Corresponding author

Teevrat Garg

teevrat@ucsd.edu

1 Introduction

As the impacts of climate change intensify, adaptation has become a vital part of the global response. Even under optimistic mitigation scenarios, rising temperatures, altered rainfall patterns, and more frequent extreme weather events are expected to disrupt ecosystems, income generation, and development progress. The ability to adapt, by anticipating, preparing for, and responding to these disruptions, will be central to how societies manage risk and build resilience. For the most vulnerable countries and communities, where climate exposure is high and infrastructure is limited, adaptation is not optional; it is a necessity. To be clear, this is not an argument against mitigation. Sensible mitigation policies remain essential to limit future harms. But some degree of adaptation is unavoidable, and both must advance together as part of any serious climate strategy.

Adaptation, in fact, is already happening, and much of it is materialising at the individual household level. Households around the world are adjusting to climate risks; changing when they plant, shifting occupations, rethinking business strategies, or diversifying income sources. These responses often unfold without formal institutional support and are shaped by both perceived and actual risks. Yet while such adjustments are critical, they are also uneven, constrained, and not always effective. To strengthen and scale these efforts, policy action is required, grounded in a clearer understanding of how households adapt to shocks, the factors shaping their decisions, and the constraints they face.

That recognition is beginning to shape institutional practice. For instance, a recent World Bank policy research report ([World Bank \(2025\)](#)) outlines a five-stage framework for strengthening climate resilience, emphasizing the roles of income, information, insurance, infrastructure, and government interventions; while also placing strong emphasis on how individual perceptions shape adaptive behaviour. This reflects an emerging consensus that adaptation must be approached in a systematic and integrated manner. Further underscoring the growing institutional interest in adaptation and its measurement, the World Bank now includes “resilience to climate change” as a core indicator in its scorecard ¹. Govern-

¹The World Bank Scorecard is available at <https://scorecard.worldbank.org>

ments, donors, and multilateral agencies are scaling up investments in adaptive capacity, yet ensuring these resources are well-targeted and effective requires reliable, comparable, and policy-relevant data on the range of adaptive actions households pursue, the constraints they face, and the broader economic and institutional factors that shape those choices.

Recent efforts to collect such data have grown. An increasing number of household survey programmes now include modules on climate shocks, coping mechanisms, or risk perceptions. A broader body of literature has begun to examine adaptation across various settings, including agriculture, employment, and community contexts. Yet many of these tools remain limited in scope or poorly aligned with the decision-making processes they hope to inform. Some conflate coping with adaptation; others overlook how income sources, resource access, or institutional context shape behavioural responses. The result is often fragmented data, making it difficult to interpret and utilise. Taken together, these limitations reveal a dual gap that motivates this paper. First, there is a lack of systematic data on household adaptation, both in terms of observed behaviours and underlying drivers, including subjective beliefs and expectations. Second, existing household surveys lack a structured approach for diagnosing adaptation, making it difficult to compare across contexts or to inform policy.

This paper responds to that challenge by proposing a structured, literature-informed framework to guide the measurement of household adaptation to climate risk. Its goal is to support the development of household surveys that are both analytically rigorous and practically useful. It is not designed to create a ready-made set of survey modules; rather, it lays out the conceptual framework needed as a first step toward developing instruments that capture the economic and behavioural dimensions of adaptation with greater precision. It is intended to inform measurement, diagnostics, policy formulation, and monitoring by governments and development partners.

The framework focuses on how households adapt through their income-generating activities. For many households, income generation is the main channel through which climate shocks are felt and adaptation responses enacted. Accordingly, the framework is structured

around three domains: agriculture, non-farm enterprises, and wage employment. For each, we apply a consistent four-step diagnostic: (1) mapping income sources; (2) assessing exposure, including both realised events and perceived risks; (3) identifying adaptation options realistically available to households; and (4) examining uptake and the constraints shaping decisions. Throughout, we pay particular attention to behavioural factors. Risk perceptions, climate beliefs, information access, and intra-household dynamics are not treated as separate from material constraints; they are embedded within them. These behavioural elements are integrated at each diagnostic step, recognising that what households believe or perceive can be as influential as the most precise climate model.

This approach allows us to view adaptation as a process rather than a binary outcome. Households may adopt strategies gradually, only partially, or switch between short-term coping and longer-term adjustment. Some responses are proactive; others are reactive. Survey instruments must go beyond yes/no questions and seek to understand how liquidity, labour constraints, information gaps, and household dynamics shape adaptation.

The framework also includes cross-cutting dimensions—such as energy, migration, and institutional support—that help shape the space of feasible responses. As discussed in section 3, these are critical to understanding the broader architecture of household adaptive capacity. They reflect the reality that adaptation is not only influenced by individual characteristics but also by infrastructure, governance, and social systems.

Finally, we follow the IPCC definition of adaptation as an adjustment that reduces harm in response to actual or expected climate-related events. However, we make an effort to account for behavioural and subjective factors in the adaptation process; for this reason, in our analysis, we acknowledge that adaptation does not always achieve a risk reduction and could lead to maladaptation, despite good intentions. Furthermore, the IPCC distinguishes between “exposure” and “vulnerability.” We treat both within a unified diagnostic. In practice, survey instruments often cannot separate these dimensions cleanly (Estoque et al. (2023), Ishtiaque et al. (2022)). The relevance of a given climate hazard depends on how it interacts with income-generating activities, institutions, and social structures. Rather

than isolating physical from socio-economic factors, we focus on identifying the full set of conditions under which climate events become economically and behaviourally significant for households.

The remainder of the document is organised as follows. Section 2 presents the diagnostic framework in detail and applies it to the three main household income sources. Section 3 examines cross-cutting enablers and constraints, focusing on energy, institutions, and mobility, that influence adaptation across various contexts.

1.1 Towards a Mental Model of Adaptation

Climate adaptation is not a static condition but an evolving behavioural and economic process. Designing survey instruments to measure household level adaptation requires more than a list of observed actions; it requires an underlying mental model. That is, a simplified but internally coherent framework that outlines how households perceive climate risk, identify possible responses, weigh constraints, and ultimately act within their social, economic, and institutional context.

Theorising a mental model of adaptation is a necessary preamble to survey design. At its core, any mental model should not aim to replicate the full complexity of household life under climate stress, but rather to organise measurement around the key processes that shape adaptive behaviour. Without a clear guiding theory of the household's decision-making, sparse survey questions risk misrepresenting behaviours, omitting key constraints, and producing data of limited interpretive value.

While a specific theoretical mental model is not developed here, the proposed framework follows fundamental traits that serve as guiding principles for most mental models. Researchers are responsible for adjusting these principles to their specific research needs and context. Mental models should be tailored to the context while remaining sufficiently general to produce policy-relevant and actionable insights.

The framework guiding this paper rests on six foundational ideas:

1. **Adaptation is income-anchored.** It occurs primarily through income-generating activities, which mediate both exposure to climate hazards and the capacity to respond. Understanding household adaptation thus begins with mapping the structure of income: agricultural, wage-based, or entrepreneurial.
2. **Adaptation is diagnostic rather than binary.** It unfolds through identifiable stages: exposure assessment, identification of available options, take-up of strategies, and the constraints encountered along the way. Each step yields distinct information

for policy and measurement, and survey instruments must be tailored accordingly.

3. **Adaptation is a risk management response shaped by behavioural interpretation.** Risk perceptions, climate beliefs, and access to information determine whether climate events are seen as threatening, and whether adaptation is considered necessary or feasible. These subjective elements are embedded in each step of the process and must be measured explicitly. Furthermore, beliefs are malleable, and surveys should aim to capture not only current perceptions but also the sources of information and social cues that shape them.
4. **Adaptation is conditional on structure.** There are public and private adaptation actions in constant interaction. Institutional support, access to infrastructure, energy systems, and mobility opportunities determine what responses are feasible. These cross-cutting enablers and frictions constrain the adaptation space and vary sharply across contexts.
5. **Adaptation is often partial, provisional, and uneven.** Households may adopt strategies temporarily, incompletely, or in combination with short-term coping. These patterns are not measurement noise; they are characteristic of adaptation under constraint and should be captured as such.
6. **Adaptation is actor-specific.** Within the household, roles, resources, and responsibilities are distributed along lines of gender, age, and status. Capturing who adapts, and how, is critical to understanding both capacity and constraint.

These core elements guide the overall approach of this framework and reflect a mental model in which households undergo a learning and adoption process as they assess adaptation strategies, not always perfectly understood or comprehensively mapped. The framework is particularly focused on capturing the underlying behavioural responses to what is fundamentally a risk management problem. Hence, risk is considered an idiosyncratic variable, shaped by personal beliefs, that researchers ought to measure.

1.2 Essential Data Structure

The structure of data significantly influences the usability of survey results. Even minor adjustments can enhance the capture of behavioural change, persistence, and responses to repeated shocks. Opening the possibility to evaluate the effects of adaptation rigorously through quasi-experimental designs. Here, we provide a non-comprehensive list of desirable features of household surveys aimed at capturing adaptation.

Panel data. Panel data structure is essential for treating adaptation as a process rather than a one-off response. Repeated observations make it possible to track behavioural adjustments over time, assess how long adaptations persist, and identify whether households respond differently to repeated shocks or changing environmental conditions.

High-frequency. When possible, collecting data more frequently is useful in climate-exposed sectors like agriculture or informal work, where important shifts happen within the year. Seasonal changes in planting, migration, or income often slip through annual or one-off surveys, but matter for understanding how households respond to risk.

Geo-referencing. Geo-referencing households and assets opens up the possibility of linking survey data to external spatial sources, such as satellite imagery, rainfall estimates, vegetation indices, road networks, or disaster records. This allows for more precise measurement of exposure and helps contextualise observed behaviours within local environmental and infrastructure conditions.

Linking to other data sources. Similar to geospatial data, different data sources, as administrative records, climate services, or price monitoring systems, can help validate survey responses and improve exposure measurement. For example, matching reported losses to localised rainfall anomalies or formal disaster declarations can sharpen the distinction between perceived and actual shocks.

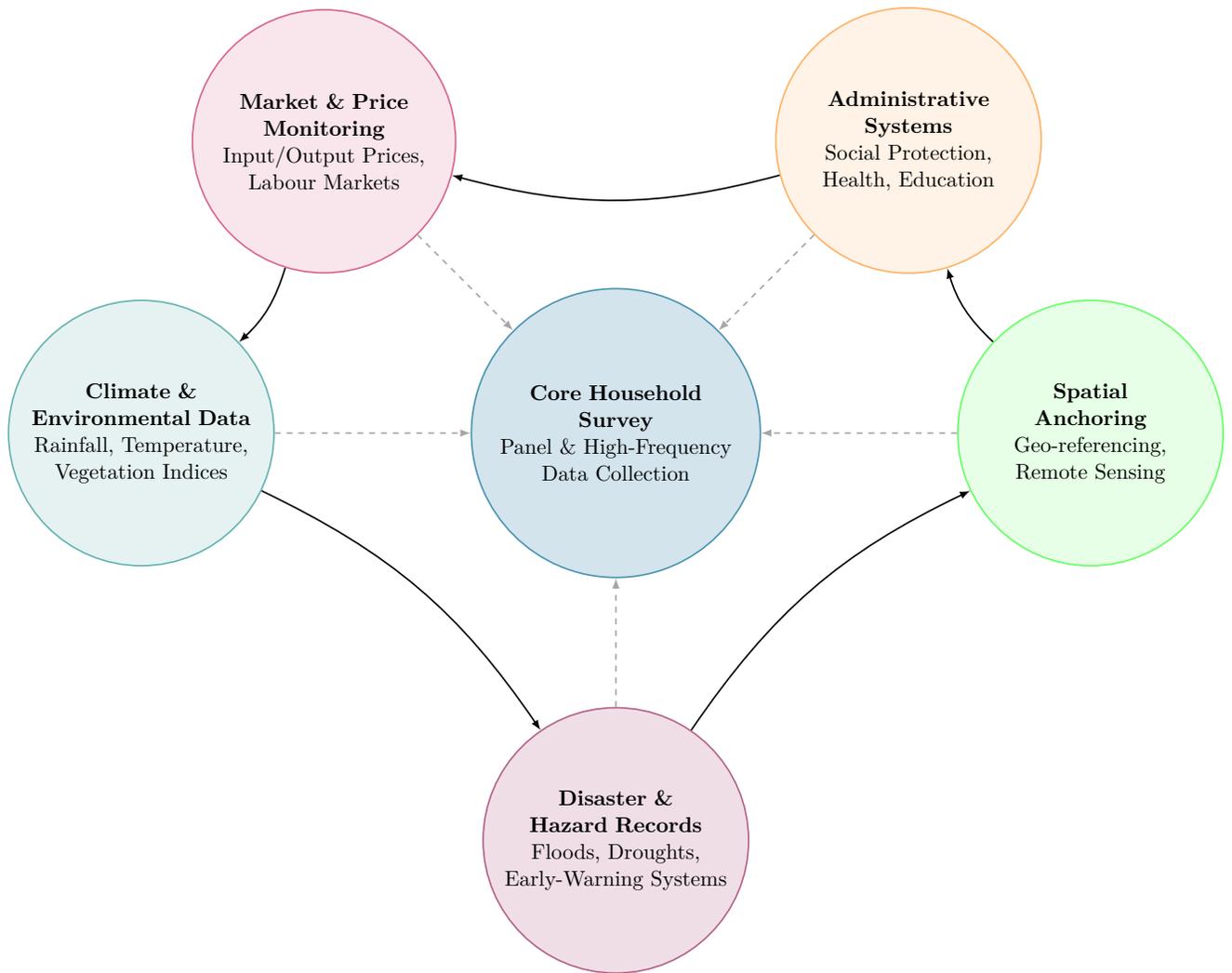


Figure 1: Integrated “Data Ecosystem” for Household Adaptation Measurement

Note: The circular layout represents the iterative ecosystem of data informing adaptation measurement. The **Core Household Survey** anchors primary observations. Surrounding data layers—spatial, administrative, market, climate, and hazard—continuously feed into and validate the survey, forming a dynamic feedback system for monitoring household adaptation.

2 Adaptation in Income-generating Activities

Households’ capacity to adapt to climate change in developing countries is shaped fundamentally by their income-generating activities. These activities influence not only economic security but also the degree of climate exposure and the ability to absorb and respond to shocks (Mertz et al. (2009a), Hultgren et al. (2022), Feriga et al. (2024), Nath and Behera (2011)). When households’ income relies on climate-sensitive sectors such as agriculture, climate variability translates directly into income volatility and heightened vulnerability (Grigorieva et al. (2023)). Diversification into non-agricultural enterprises or wage employment can cushion households against climate risks and expand adaptive capacity (Blakeslee et al. (2020), Macours et al. (2022)). Yet these alternatives often entail their own forms of instability—stemming from market volatility, insecure demand, and informality—and are not equally accessible. Liquidity limitations, infrastructural gaps, and incomplete information frequently constrain transitions into more climate-resilient (Mobarak and Rosenzweig (2013), Lane (2023), McIntosh et al. (2019), Karlan et al. (2014)).

In this context, both the structure and adaptability of income-generating activities are central to understanding how households experience and adapt to climate change (Intergovernmental Panel on Climate Change (IPCC) (2023)). Economic activities, such as paid work and family businesses, serve not only as the main source of income but also as the principal channel through which climate shocks are transmitted. Therefore, any framework for evaluating household-level adaptation must begin with a clear characterisation of household income-generating activities while also being mindful of the institutional constraints, customs and behavioural responses that shape them.

We focus on three principal domains of income-generating activities: agriculture, non-farm enterprise, and wage employment. Each represents a distinct economic role, exposure profile, and set of adaptive strategies. Agriculture—predominant in rural settings—remains highly sensitive to weather variability and climate extremes. Non-farm enterprises, encompassing small-scale commerce, informal services, and small-scale manufacturing, offer diversification potential but are often constrained by limited market access, liquidity shortages, and

operational fragility. Wage employment may provide more stable income flows, particularly in formal sectors, yet such opportunities are unequally distributed, spatially concentrated in urban and peri-urban areas, and subject to their own set of climate-related risks.

This framework builds on and extends prior analytical models of vulnerability and adaptation—such as that proposed by [Reed et al. \(2013\)](#). At its core, the proposed framework outlines three steps for diagnosing household vulnerability and adaptation ability surrounding primary income-generating activities:

1. Mapping household income streams: As a foundation for assessing adaptation, the framework first accounts for the composition of household income across primary activities: agriculture, wage employment, and non-farm household business. Before exposure, options, or constraints can be evaluated, it is necessary to stabilise a clear view of how households combine or rely on these activities.
2. Exposure assessment: This second step identifies the climate-related events and concerns households face regarding their income-generating activities. It encompasses both the objective characteristics of exposure—such as the frequency and severity of climatic events—and subjective dimensions, including risk perceptions, beliefs about climate change, and access to climate-related information. Understanding how households interpret their exposure is critical, as these perceptions shape both the sense of urgency and the perceived need for adaptive action.
3. Availability of adaptation options: This stage maps the menu of adaptation strategies accessible to households across key income generation domains—agriculture, non-farm enterprises, and wage employment. This step captures the extensive margin of adaptation: It considers both the objective availability of viable options (e.g. drought-tolerant crops, access to training or credit, employment in less climate-sensitive sectors) and the perceived availability, encompassing the extent to which households are informed about, or able to act upon, these possibilities.
4. Option take-up and constraints to adoption: This stage focuses on which strategies are adopted, by whom, and under what circumstances. This step captures the in-

tensive margin of adaptation: Take-up is shaped by household attributes (such as assets, education, and gender roles), institutional support, community norms, and the perceived feasibility of different options. Here, household beliefs play a key role; the idiosyncratic beliefs of households are likely to define the likelihood of adoption, or the perceived feasibility and success of an adaptation option. Distinguishing between awareness, access, and adoption is essential to diagnosing barriers to adaptation. Even when options are available, households may face liquidity constraints, time and labour bottlenecks, incomplete information, or trade-offs between short-term coping and long-term resilience. Adaptation strategies can also generate tensions between individual and collective interests.

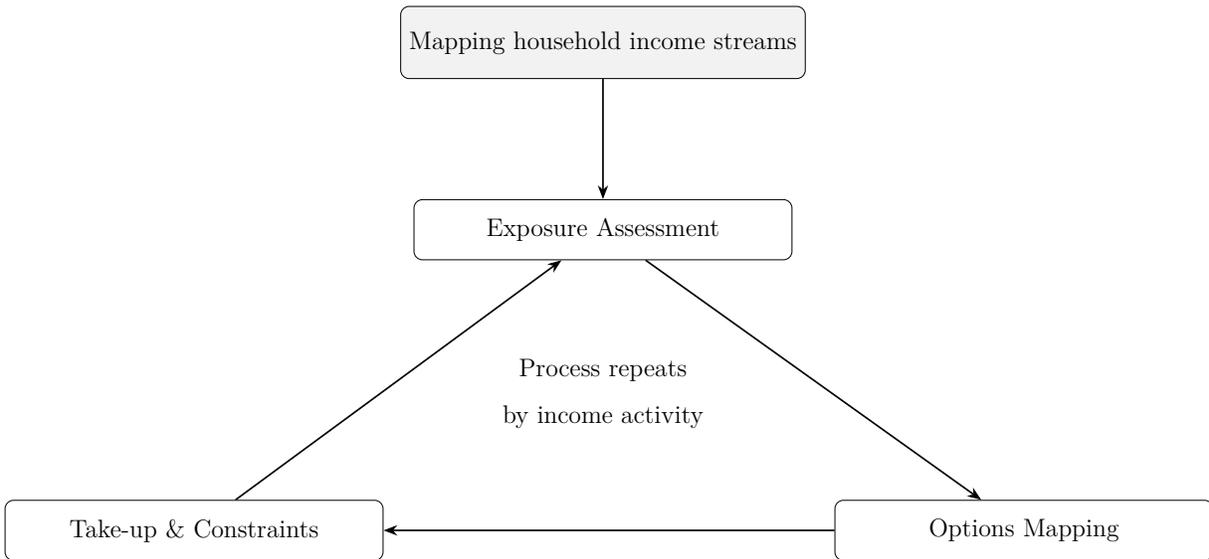


Figure 2: Framework Layout

This chapter offers a roadmap for researchers and practitioners designing household surveys aiming to capture climate adaptation. Flowchart 3 presents a visual guide, which, together with the chapter subsections, provides a structured lens for identifying relevant income sources, analysing patterns of diversification, and anticipating context-specific vulnerabilities. Crucially, it also illustrates the interconnections among the three primary income streams and how households reallocate labour and resources across them in response to climate-related events.

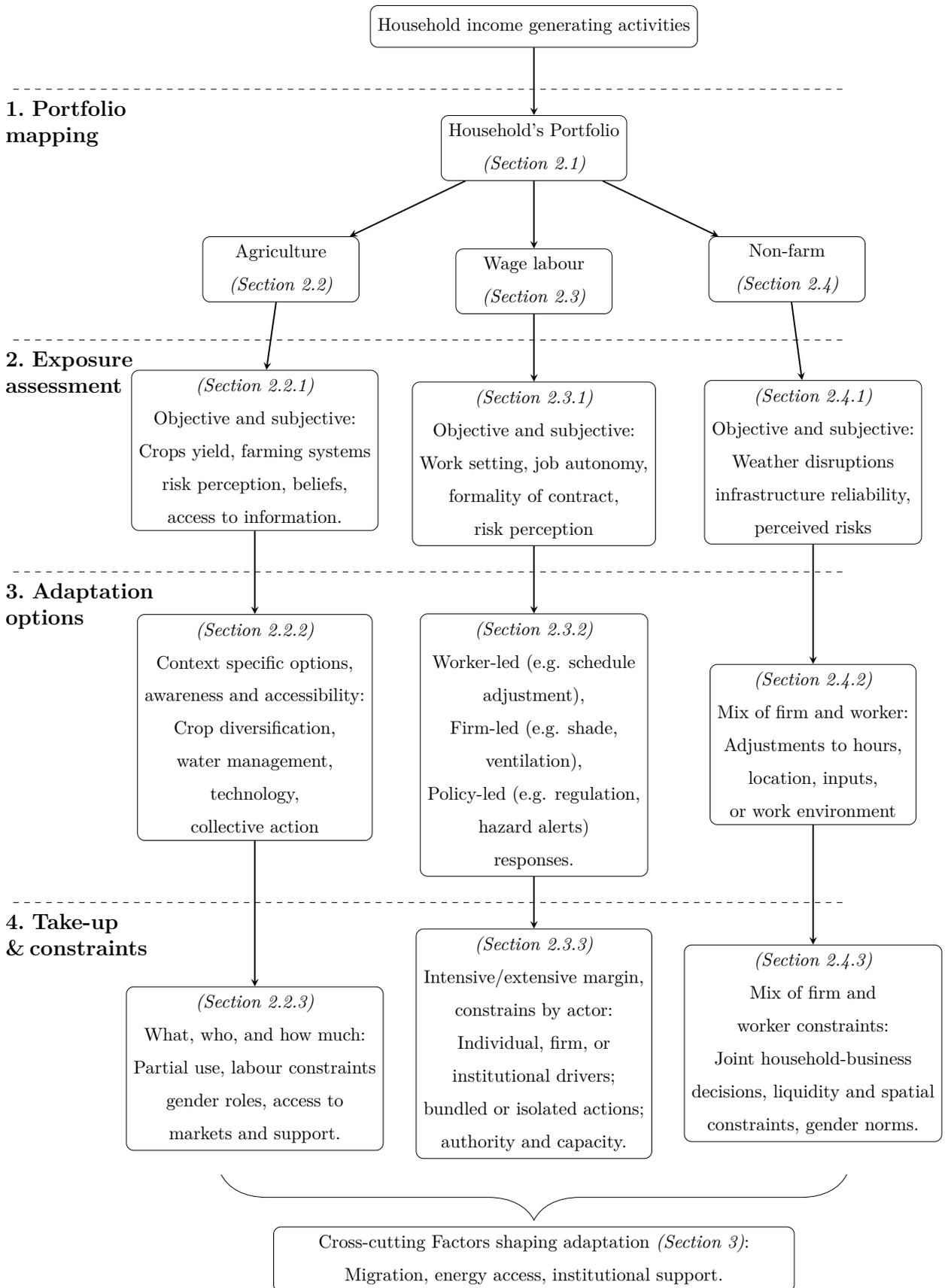


Figure 3: Climate Adaptation in Income-Generating Activities

2.1 Mapping the Households' Income Portfolio

A necessary preamble to understanding how households interact with climate change through their income-generating activities is to define the activities they pursue. This implies both identifying the mix of income sources and assessing the extent to which each contributes to the household's income portfolio.

Mapping the household income portfolio serves two main purposes:

- Anchoring the analysis within the structure of income generation: Exposure and risk differ systematically across income-generating activities. As such, the portfolio each household holds should naturally guide how the analysis is structured—shaping the core questions to address, the channels to investigate, and the opportunities to streamline data collection.
- Serve as a first indicator of resilience: it reveals the extent to which households diversify income across sectors, offering an early indication of resilience. Furthermore, a complete map of the portfolio clarifies which income sources are essential to survival and which function as buffers or transitional supports in times of stress.

Finally, a comprehensive mapping must be informative of intra-household decisions. Gender, age, and education often influence a household's financial decisions (see, [Ashraf \(2009\)](#), [Afzal et al. \(2022\)](#), [Gulati et al. \(2024\)](#), [Arora and Rada \(2020\)](#), [Roberts and Taylor \(2017\)](#), [Udry \(1996\)](#)), which may include who undertakes which activity, with implications for agency, exposure, and constraints in adaptation. Portfolio mapping should therefore aim to be not only activity-based but actor-specific, capturing the economic structure of the household in ways that make visible the pathways through which climate risks and responses unfold. ([Delavallade et al. \(2025\)](#), [Duflo \(2003\)](#), [Lovo and Veronesi \(2019\)](#)).

Household Portfolio Mapping

Mapping households' portfolios:

- Which income-generating activities is the household engaging in.
- Which is the primary activity and buffer activities.
- How does seasonality, time or similar factors define the portfolio composition
- What are the intra-household dynamics at play.

2.2 Adaptation in Agriculture

2.2.1 Exposure Assessment in Agriculture

Assessing exposure is a first step in diagnosing vulnerability to climate change in agricultural settings. Given the high sensitivity of crops and livestock to climatic variation, even modest shifts in temperature or rainfall can generate outsized impacts on rural incomes ([Rosenzweig and Udry \(2014\)](#), [Dell et al. \(2012\)](#), [Blakeslee et al. \(2020\)](#)). A credible exposure assessment must account for both objective and perceived dimensions of risk, recognising that vulnerability is shaped not only by biophysical hazard profiles but also by household-level interpretation and behavioural response ([Magruder \(2018\)](#), [Jack \(2013\)](#)). This requires close attention to local agro-ecological conditions, seasonal production cycles, and the institutional context in which agricultural decisions are made. It also demands an understanding of how households perceive climate trends, evaluate future risks, and engage with available sources of information. The following subsections outline key elements for integrating these considerations into the design of exposure modules within household surveys.

A. Objective Characteristics of Exposure:

Objective exposure refers to the measurable, physical dimensions of climate variability and extremes that directly affect farming households. These include both long-term changes and short-term shocks in key climate variables—most notably temperature, rainfall, and

extreme weather events such as droughts, floods, and heatwaves (Lobell and Burke (2010), Mandal et al. (2025), Acheampong et al. (2014)). The relevance of each variable depends on the agroecological context. In semi-arid regions, temperature and rainfall variability may pose the greatest risks (Mobarak and Rosenzweig (2013), Guiteras (2009)), while in low-lying or coastal areas, flooding and salinity intrusion are often more pressing. But exposure is not defined by climate alone. It is shaped by the types of farming systems in place, how reliant households are on stable weather conditions, the strength of local institutions, and the presence of other stressors—such as land scarcity, market disruptions, or conflict—that can deepen the impacts of climate shocks².

Understanding the context. The climate risks that affect farmers vary widely across agroecological zones. In lowland delta regions such as southern Bangladesh, flooding and salinity intrusion are major threats (eg, Akter et al. (2025), Gazi et al. (2025)), In arid and semi-arid areas, rainfall variability and prolonged dry spells are more pressing (Intergovernmental Panel on Climate Change (IPCC) (2023)). Identifying the most relevant climate variables—such as rainfall timing and distribution, average and extreme temperatures, humidity, or storm frequency—is a necessary first step in anchoring an exposure assessment in local production conditions.

These variables can be identified using regional climate profiles, agricultural calendars, and historical trend data, and should be cross-validated through consultation with local experts, including extension agents, agronomists, and producer groups. For example, Grigorieva et al. (2023) show that mid-season dry spells during key crop growth stages are a major driver of yield losses across sub-Saharan Africa. In the Indo-Gangetic Plain, Eskander and Steele (2023) find that changes in monsoon onset and withdrawal influence sowing decisions and fertiliser application.

Survey modules should reflect these risks by including questions on the incidence, timing, and perceived severity of events such as droughts, floods, heatwaves, or unseasonal rainfall over the past 3–5 years (or the context-specific adequate timeframe). However, this risk

²There have been efforts to create indicator capturing physical exposure, Hoque et al. (2022) provides a short review of commonly used socio-economic and biophysical indicators of exposure

recalls bias issues; hence, where possible, these responses should be linked to meteorological or satellite-derived data to validate patterns and enable spatial comparisons (Chen et al. (2017), Aragón et al. (2022), Leslie et al. (2017)).³

Understanding the farming activities A meaningful assessment of exposure requires close attention to the farming systems and production strategies that households rely on. The nature of agricultural production—what is grown, how it is grown, and with what resources—shapes how climate stressors are felt. Rainfed cereal cultivation (Alimaghan et al. (2024), Fatima et al. (2020)), irrigated horticulture (Thiery et al. (2020)), mixed crop-livestock systems (Srivastava et al. (2025)), and perennial plantation agriculture (Parker et al. (2020)) each exhibit distinct sensitivities to rainfall variability, temperature extremes, or extreme weather events (Sharma et al. (2022)).

Understanding the farming activities

Survey instruments should capture key details on local farming practices, including:

- Primary and secondary crops grown, along with seasonal calendars.
- Use of irrigation and water sources
- Livestock holdings (number and type) and reliance on grazing or purchased feed.
- Ease of access to key inputs, such as seeds, fertiliser, and machinery. In addition to possible limitations, such as high transport costs or lack of bargaining power in seed markets.
- Land tenure arrangements and the degree of plot fragmentation.

This information is essential for identifying exposure pathways and understanding how strongly households' incomes depend on specific agricultural systems. For example, households cultivating short-cycle cereals without irrigation may be more vulnerable to mid-season rainfall shocks (Wakjira et al. (2021)), while producers of perennials may face multi-year losses from a single damaging event (Lobell et al. (2006), Rising (2024)). Livestock-rearing households, in turn, may be more exposed to heat stress and forage scarcity (St-Pierre et al.

³There is a growing literature also measuring economic growth using satellite-derived measures, eg, Henderson et al. (2012)

(2003), [Cheng et al. \(2022\)](#)). Linking farming activities to climate-sensitive periods—such as sowing, flowering, or weaning—helps identify when and where exposure is likely to be most acute. Combined with indicators of household reliance (outlined in the next item), this forms a stronger empirical basis for diagnosing vulnerability in the economic well-being of rural households.

Measure how reliant on climate stability Not all farming households are equally exposed to climate shocks, even within the same agroecological zone. A key factor shaping vulnerability is the degree to which households rely on stable and predictable climatic conditions to sustain their income and consumption (eg. [Guiteras \(2009\)](#), [Kazianga and Udry \(2006\)](#), [Mobarak and Rosenzweig \(2013\)](#)). This dimension of exposure captures not just whether households are located in risk-prone areas, but whether their income and food security depend on climate-sensitive activities with limited buffers or alternatives ([Intergovernmental Panel On Climate Change \(2019\)](#)).

Reliance can be assessed in several ways. At a basic level, this includes the share of household income derived from rainfed agriculture, which is especially sensitive to changes in rainfall timing, intensity, and distribution. It also involves the seasonal structure of production—for example, whether households rely on a single crop cycle or stagger production across multiple seasons to spread risk.

Diversification is another key factor. Households specialising in a single high-risk crop (such as rice or groundnuts in flood-prone areas) or a single livestock species (such as cattle in drought-affected zones) face greater exposure ([Bozzola and Smale \(2020\)](#), [Key et al. \(2017\)](#)). By contrast, households that combine crops, livestock, and other activities like agroforestry or aquaculture are better able to buffer climate shocks ([Zhou et al. \(2021\)](#), [Makate et al. \(2022\)](#)).

Measuring reliance on predictable weather patterns

Survey modules should allow for the construction of indicators, such as:

- Share of land under rainfed versus irrigated cultivation
- Number and types of crops grown per season
- Reliance on a single crop for more than half of income or food needs
- Livestock ownership patterns and feed/water requirements
- Dependence on seasonal labour or climate-sensitive planting and harvesting schedules

These kind of measures help identify households that are not only exposed to climate risk, but structurally dependent on weather stability—providing a key link between exposure and income vulnerability.

Understand other stressors Climate shocks rarely occur in isolation. In many settings, their impacts are shaped—and often intensified—by other stressors that households face (Carleton and Hsiang (2016), Zhou et al. (2022), Jayachandran (2006)). These include the worsening of the physical environment- for example, land degradation (see [Intergovernmental Panel On Climate Change \(2019\)](#) chapter 4), water scarcity (Asprilla-Echeverria (2024), Bandyopadhyay et al. (2011)), or pest outbreaks (Burc et al. (2025), Nega (2025))-but also market-driven stressors, like rising input costs (Deschênes and Greenstone (2007), Aragón and Rud (2020)), and insecure land tenure (Rampa and Lovo (2023), Besley (1995), Pierri et al. (2025), Huntington and Shenoy (2021)). When such challenges overlap with climate risks, they can increase the scale of losses and reduce households' ability to recover.

Institutions play a central role in this broader risk environment. Where key services—such as agricultural extension (Antwi-Agyei and Stringer (2021), Kansime et al. (2019)), credit (Karlan et al. (2014), Chen and Flatnes (2019), Asmamaw et al. (2019)), irrigation (Burke and Emerick (2016), Thiery et al. (2020), Hoque et al. (2022))—are weak or absent, households are more vulnerable to the same climate events. A drought, for example, is more damaging when irrigation is unreliable or when farmers lack access to timely information

or affordable finance. In contrast, well-functioning institutions can help reduce exposure, support recovery, and lay the groundwork for longer-term adaptation.

Evidence from Bangladesh shows that institutional factors—such as access to land rental markets and extension services—can shape both the impacts of climate shocks and the options available to households in their aftermath (Eskander and Barbier (2023)). Grigorieva et al. (2023)’s review similarly find that adaptation outcomes depend not only on climate conditions, but also on access to public services and support systems.

Understanding additional stressors

Survey instruments can capture these additional layers of risk by including questions on:

- Access to land, water, and key inputs.
- Access to information and advisory services.
- Soil quality, pest pressure, and disease outbreaks.
- Infrastructure, such as roads, storage, and drainage.
- Availability and quality of extension, climate information, and early warning systems.
- Access to credit, insurance, and local safety nets.

Additionally, whenever sensible, the survey instruments should be interoperable and complementary to other data sources.

Understanding these stressors is essential for assessing true exposure. It helps identify where climate risks are amplified by structural weaknesses—and where targeted institutional support could make the greatest difference.

B. Subjective Dimensions of Exposure

In addition to measuring climate risk through observed events—such as floods, droughts, or storms—it is essential to understand how households perceive and interpret their own exposure. These perceptions shape how risks are recognised, whether households take action to protect themselves, and how they engage with support systems. If risks are underestimated or misunderstood, households may delay adaptation or rely too heavily on informal coping strategies, increasing their vulnerability (Dercon and Christiaensen (2011), Salman Chowdhury et al. (2025)). This subsection outlines four key aspects of perceived exposure that influence how households respond to climate threats and how these responses affect their welfare.

Risk Perceptions. Perceived risk is a key driver of household adaptation behaviour, yet it often differs from actual exposure. Risk perceptions shape whether climate threats are recognised, taken seriously, and acted upon. Even when households face frequent and damaging climate events, they may not adapt if they do not see these risks as severe, likely, or urgent (Gallagher (2014), Ginbo and Hansson (2023), Angrist et al. (2023)). For instance, Ahmed et al. (2022) show that farmers with higher risk perceptions have a higher propensity to adopt both chemical and mechanical adaptation strategies. At the same time, households may overreact to recent or highly visible events, leading to disproportionate responses or a poor use of limited resources.

In agricultural settings, risk perceptions are shaped by recent experience, shared memory, and the visibility of impacts—such as damaged crops or dead livestock. For example, Cole et al. (2013) show that households exposed to higher rainfall variability report higher perceived income loss risk, and Mertz et al. (2009b) show that farmers in the Sahel often pointed to strong winds and occasional heavy rain—not necessarily the most common or severe events—as the biggest threats to their livelihoods. Likewise, farmers may be more concerned about delayed rainfall than total rainfall, even if the latter is a better predictor of yields.

Perceptions are also shaped by how questions are asked and the broader context. Mertz

et al. (2009a) find that when climate is not mentioned directly, farmers are less likely to name it as the main cause of change. This suggests that risk perception is influenced not only by experience, but also by how climate issues are presented—through conversations, media, or policy.

Measuring risk perception

Survey questions should therefore include both direct and indirect ways of exploring perceived risks. These might include:

- What kinds of weather events farmers worry about (e.g. drought, floods, wind, unusual rain)
- How often they expect these events to happen
- How serious they believe the risks are for their crops, animals, or income
- Whether they think climate risks are increasing, staying the same, or getting smaller

These responses help explain why some households adapt even when they face low actual risk, while others do not respond despite repeated shocks. They also help us understand how behaviour might change in response to new information, advice, or shifts in how climate risks are talked about.

Beliefs about climate change While risk perceptions focus on specific hazards, beliefs about climate change reflect how people understand broader changes in the environment. These beliefs shape whether households see recent weather shocks as unusual one-off events or part of a longer-term trend. They also affect whether people think adaptation is necessary, possible, or even worth doing (Yazdanpanah et al. (2023)). In this way, beliefs provide the mental framework for long-term behavioural change. Beliefs about climate change vary widely across settings. In many cases, households report clear signs of shifting weather—such as later rains, hotter temperatures, or more frequent storms—but do not link these patterns to global climate change (Petersen-Rockney (2022)). Some people may explain these changes through religion, deforestation, natural cycles, or other causes (Miguel (2005)). These explanations matter because they affect whether people feel they can do anything about the

changes. If climate change is seen as beyond human control, then adaptation may seem pointless or even inappropriate. [Mertz et al. \(2009a\)](#) show that farmers in central Senegal were well aware of changing weather patterns, but when asked about land-use change without mentioning climate, they tended to cite economic or institutional reasons instead. This shows that climate is not always the main lens through which people explain changes in their lives—even when weather plays a role. Similarly, [Tenzing \(2020\)](#) highlights that beliefs about what causes change, and whether it can be controlled, strongly influence how people respond to climate risks—especially in places where scientific knowledge is uneven or contested.

Measuring beliefs about climate change

To explore these beliefs, survey modules can aim to provide information on:

- Whether households think the climate has changed in the past 5–10 years
- What they believe is causing these changes (e.g. natural cycles, human actions, deforestation, divine will)
- Whether they think these changes are permanent, temporary, or reversible
- Whether they believe anything can be done to reduce climate risks or improve resilience

These questions help uncover not just what people observe, but how they make sense of those observations—and whether they see adaptation as a useful response. Beliefs are often shaped by education ([Angrist et al. \(2023\)](#), [Dechezleprêtre et al. \(2025\)](#)) religion ([Kane and Perry \(2024\)](#), [Mazaheri \(2024\)](#), [Sharma et al. \(2021\)](#)), social networks ([Anderson \(2017\)](#)), and the information people receive from institutions ([Greaves et al. \(2023\)](#)). As such, they form a crucial link between exposure, perception, and action. Recognising the diversity of belief systems is essential for designing interventions that align with local worldviews and support more effective communication around climate adaptation.

Information Access. Access to information plays a key role in shaping how households respond to climate risks ([Rosenzweig and Udry \(2014\)](#), [Mullins et al. \(2018\)](#)). Earlier, we noted how weak institutions or poor infrastructure can make climate shocks worse. But

just as important is how information affects what people know, believe, and decide to do. Households not only need to receive information—they also need to understand it, trust it, and see it as useful. Farmers who regularly receive credible climate information—through extension officers, radio, mobile messages, or local leaders—are more likely to notice changes, assess risks, and consider adapting. In contrast, those with limited or unreliable access often rely on personal experience, neighbours, or traditional knowledge (Wossen et al. (2022), Ashour et al. (2019), Berazneva et al. (2018)). This can delay recognition of new risks or lead to the belief that climate is random and beyond control. Trust is central to whether information is used. People tend not to act on advice they do not trust. Mertz et al. (2009b) show that in rural Senegal, the way climate messages are framed—and who delivers them—is as important as the content. If extension agents are rarely present, radio broadcasts are unclear, or institutions are viewed as distant or unhelpful, even accurate information may be ignored. Tenzing (2020) also finds that people are more likely to adapt if the source of information fits with their values and experience.

Surveying household's information access

To understand this, surveys should ask:

- What are the household's main sources of climate or farming information?
- How often do they receive forecasts or advice?
- How much do they trust each source?
- Have they ever changed farming or income decisions based on this information?

These questions help separate access to information from its actual influence. They also show where things break down: is the issue a lack of access, poor delivery, low trust, or something else? In many cases, households are aware of risks but don't act because they doubt the advice or its relevance. Reliable, trusted, and locally meaningful information is therefore a key ingredient in successful climate adaptation.

Understanding how households interpret their exposure Beliefs about climate change concern whether people think the climate is changing and why. But interpretation

goes a step further: it reflects how households understand their own position in relation to that change. In other words, even if a household believes that climate change is real, this does not necessarily mean they see themselves as particularly exposed or at risk. Likewise, households that are sceptical of climate change may still believe that their own farming system is vulnerable or that the weather has become more unpredictable (Petersen-Rockney (2022)).

Interpretation is about how households frame the risks they face. It shapes how people explain poor harvests, livestock losses, or shifting seasons, and whether they see these disruptions as isolated events or part of a broader trend. It also influences how households compare themselves to others: some may feel especially vulnerable because of their location, land quality, or income level, while others may see themselves as relatively protected.

Understanding this subjective framing is crucial for explaining why some households take action and others do not. It also helps identify cases where objective and perceived exposure diverge—where people feel safe despite being highly exposed, or feel at risk even when indicators suggest otherwise.

Identifying how households understand their vulnerability

Surveys can explore this dimension by asking:

- Do you consider your household at risk from weather-related events? Why or why not?
- Compared to others in your area, do you think your household is more, less, or equally exposed?
- Has your sense of risk changed in recent years? What made it change?
- How confident are you that you can protect your farm or income from future weather events?

These questions help uncover whether and how households personalise climate risk. Interpretation is what links lived experience with expectations about the future. It shapes whether households feel vulnerable, whether they believe action is needed, and whether

adaptation is seen as within reach.

2.2.2 Measuring the Availability of Adaptation Options in Agriculture

Once exposure is established, the next step in diagnosing household-level adaptation is to identify which strategies are realistically available to farming households. Availability does not refer to the full set of theoretical responses to climate risk, but to the smaller set of strategies that households can actually access and consider within their specific agroecological, institutional, and economic context. It forms a crucial bridge between exposure and take-up.

Importantly, availability is not just about whether a technology or practice exists—it is about whether it is viable in the local environment, known to households, and supported by institutions. Understanding availability means asking what strategies are ecologically appropriate, what is practically accessible given input and labour constraints, and what is actively promoted or supported by trusted sources. Without this step, we risk misinterpreting low take-up as behavioural inertia, when in fact it may reflect limited or absent options.

We focus on three core elements that determine whether an adaptation strategy can be considered available:

Mapping the Menu of Adaptation Strategies. Not all strategies are suitable everywhere. A practice like rainwater harvesting may work well in upland areas but be less useful in low-lying regions with high groundwater. Similarly, salt-tolerant crops or raised-bed planting are most relevant in areas affected by salinity or floods. While this is not typically assessed through household surveys, it is a critical step in designing survey instruments and selecting relevant strategies. Ecological fit should be determined in advance—drawing on agroclimatic data, expert consultation, and landscape-level diagnostics. [McCarthy \(2011\)](#)

Importantly, income diversification, through non-farm enterprises, wage labour ([Colmer \(2021\)](#), [Jesso et al. \(2018\)](#), [Liu et al. \(2023\)](#), [Branco and Fères \(2021\)](#), [Musungu et al.](#)

(2024), Huang et al. (2020)), and temporary migration (Chen and Flatnes (2019), Chen et al. (2017), Letta et al. (2024)), constitutes a central strategy to consider when assessing the menu of available adaptation strategies. Migration, remittances and alternative income sources are both coping strategies ex-post and adaptation strategies ex-ante. As such, any comprehensive assessment of adaptive capacity must consider both intra-sectoral (within agriculture) and inter-sectoral (beyond agriculture) diversification strategies.

Awareness and Institutional Visibility. For a strategy to be available, households must know about it and consider it a feasible option. This depends on whether the strategy is visible in their everyday environment—via extension agents, farmer demonstrations, NGO programmes, or word of mouth (Ahmed and Givens (2025)). Surveys should ask whether households have heard of each strategy, discussed it, or observed it in use.

Practical Accessibility. Many adaptation options depend on access to supporting resources—such as irrigation, improved seeds, hired labour, or credit. Availability is constrained when these inputs are not stocked locally, services are unreliable, or prices are too high. Surveys should assess not only whether a strategy is promoted in theory, but whether it is physically available, seasonally reliable, and economically feasible for the household.

Later in this subsection, we examine which of these strategies are actually taken up, what barriers may prevent adoption, and how households evaluate their effectiveness. For now, we emphasise the importance of identifying which strategies are truly available—grounded in local realities and informed by context-specific diagnostics. As a starting point, table 1 provides an overview of common agricultural adaptation strategies, linking each to its primary goal and examples of practical application.

Adaptation Strategy	Core Objective	Typical Tools / Practices
Crop and Livestock Diversification	Spread production and market risks	Intercropping, mixed cropping, multi-species livestock
Adoption of Climate-Resilient Varieties	Reduce sensitivity to climate stress	Drought- or flood-tolerant seeds, improved breeds
Efficient Water and Irrigation Management	Stabilise production under rainfall uncertainty	Drip irrigation, treadle pumps, water harvesting
Adjusting Planting Calendars and Practices	Match farming schedules to new seasonal patterns	Early sowing, staggered planting, crop switching
Improved Soil and Land Management	Build long-term soil health and reduce erosion	Mulching, terracing, composting, zero tillage
Livestock System Adaptation	Enhance livestock resilience and reduce mortality	Changing herd composition, dry-season feeding
Income Diversification Beyond Agriculture	Buffer agricultural income losses and smooth shocks	Wage labour, microenterprise, remittances
Use of Climate Information Services	Improve planning and reduce uncertainty	SMS forecasts, local advisories, early warning alerts
Accessing Institutional and Risk-Sharing Mechanisms	Mitigate financial and input-related barriers to adaptation	Subsidies, insurance, farmer group support
Leveraging Technology and Local Innovation	Enhance efficiency and expand access to local solutions	Mobile platforms, low-cost irrigation, on-farm innovations
Peer Learning and Collective Adaptation	Reinforce adaptation through knowledge sharing and social capital	Farmer field schools, cooperatives, informal exchanges

Table 1: Aggregate Adaptation Strategy Mapping in Agriculture

2.2.3 Evaluating Adaptation Take-up and Constraints in Agriculture

Understanding whether and how households make use of available adaptation options requires more than measuring adoption. It also requires attention to the factors that shape decision-making: What enables take-up? What prevents it? What trade-offs do households face when trying new strategies? A clear diagnostic must therefore consider both the observed use of adaptation practices and the constraints—economic, social, institutional, or ecological—that limit their uptake, scale, or persistence.

Adaptation is rarely a yes-or-no decision. Households may try a strategy on a small plot, adopt it partially, or abandon it after limited success. Some options are used only in times of crisis, while others reflect longer-term shifts in how people make a living. Households may also combine different strategies—some genuinely adaptive, others more reactive. For these reasons, surveys must go beyond yes/no adoption questions and explore the reasoning behind these adoption decisions.

Take-up: what is adopted, and to what extent? Households often adopt multiple practices at once, introduce them gradually, or experiment with them before deciding whether to fully embrace them. (Mesfin et al. (2020), Bandyopadhyay et al. (2011), Kahn (2016), Burke and Emerick (2016)) Adaptation is therefore better understood as a process rather than a single, discrete decision.

Survey instruments should capture both the type of strategy used and the extent of its use. This means asking not just whether a household has adopted a practice—such as planting drought-tolerant seeds or adjusting planting dates—but also how widely and how regularly it is applied. Is it used on all plots or only a few? Every year or only during particularly difficult seasons? Is it a new approach or something the household has practised for several years?

In most settings, households pursue a mix of strategies, so survey modules should allow for multiple responses. Take-up is rarely exclusive or uniform, and may involve combinations of crop changes, water management, livestock adjustments, or shifts to off-farm income.

Where possible, surveys should gather information on how long each strategy has been used and whether it is ongoing, recently adopted, or discontinued. At the same time, recall bias must be taken into account. For this reason, it is important to use a reference period that balances the trade-off between recall accuracy and policy relevance—typically within the past 12 or 24 months.

Who is adopting? Take-up is shaped by household-level characteristics such as land-holding size, labour availability, gender roles, education, access to credit, and exposure to past climate shocks (Rabassa et al. (2011), Makate et al. (2022), Holden and Quiggin (2017)). These factors influence not only whether a household adopts a strategy, but also which strategies are chosen and how they are applied. For example, wealthier households may be more likely to invest in irrigation or crop diversification, while those with limited labour may avoid labour-intensive practices such as mulching or composting. For example, wealth in India is a major determinant of adaptation to more climate-resilient crop portfolios, Rosenzweig and Binswanger (1993). Gender roles also matter, in many settings, women may manage specific plots or livestock but lack decision-making power over inputs or the adoption of new technologies (Delavallade et al. (2025), Westermann et al. (2005), Walker et al. (2022), Garg et al. (2020)). Collecting information on a diverse set of household characteristics is essential for understanding who is well positioned to adapt and who is being left out.

Trade-offs. As noted earlier, take-up is rarely all-or-nothing. Households often adopt adaptation strategies cautiously or partially testing them on a limited scale or during specific seasons. One reason for this is the presence of trade-offs. Many strategies involve upfront costs, higher labour demands, or reduced short-term returns. For instance, switching to a drought-tolerant crop may reduce yield volatility but produce lower profits in average years (Rosenzweig and Binswanger (1993)). Labour-intensive practices like composting or bund construction may conflict with off-farm work or caregiving responsibilities (Gedikoglu et al. (2011), Touch et al. (2024)).⁴ ⁵ Others, like reducing herd size or delaying planting, may

⁴Becot et al. (2025) shows that managing farm duties and caregiving affects the well-being of women in agriculture.

⁵Mizik et al. (2025) offers a review of the challenges of work in the agricultural sector in developing countries.

protect against risk in the short term but carry longer-term economic costs.

Surveys ideally should probe whether households faced such trade-offs when deciding to adopt a strategy, and whether these influenced the scale, timing, or duration of use. Identifying these tensions helps explain why households may adopt incrementally or abandon strategies over time—even when they appear beneficial in principle. Understanding trade-offs is essential for interpreting adoption patterns and designing support that lowers the costs of adaptation.

2.2.4 Understanding the Gap in Climate-Adaptation Related Agriculture Surveying: What is Being Measured in Practice

Although agriculture’s vulnerability to climate change is increasingly acknowledged, most household surveys still fail to capture the range of adaptive behaviours and constraints rural producers face. Surveys often record input use, yields, and access to extension or credit. However, they rarely capture how farmers perceive climate risks, evaluate adaptation strategies, or adjust their practices in response to environmental and economic changes. As a result, it is harder to assess how effective, scalable, or appropriate these responses are across diverse settings.

Table 2 summarises the main variables identified by the proposed framework as priorities for agricultural survey design. It also provides an indicative sense of how well each variable is currently covered in existing survey tools. This is not a formal meta-analysis, but rather a rough mapping based on a review of commonly used instruments and input from an expert convening on the topic.⁶ The aim is to flag areas where reliable survey data seems limited or missing, pointing to potential gaps that matter for understanding climate adaptation in agriculture.

⁶Expert Convening on Measuring Climate Adaptation in Household Surveys, organized by the World Bank’s Living Standards Measurement Study, Washington, D.C., 20-21 May 2025.

Table 2: Key Gaps in Agricultural Adaptation Measurement

Diagnostic Dimension	Key Question Theme Variable	Evidence Coverage
Exposure (Objective)	What specific climate events (e.g. droughts, floods, temperature anomalies) has the household experienced?	High – common in climate-linked household surveys
	Over what time frame were these events experienced?	High – common in climate-linked household surveys
	How frequently do these events occur?	High – common in climate-linked household surveys
	What were the impacts on crops and yields?	High – common in climate-linked household surveys
Exposure (Subjective)	Does the household perceive that the climate has changed?	Low to Moderate – increasingly present but still variable across surveys
	In what ways is the climate perceived to have changed (e.g. more erratic rainfall, longer dry spells)?	Low to Moderate – increasingly present but still variable across surveys
	What climate-related risks does the household expect in future?	Low to Moderate – increasingly present but still variable across surveys
	Where does the household obtain its climate information, and is the source trusted?	Low to Moderate – increasingly present but still variable across surveys
Adaptation Options (Availability)	What adaptive practices are known to the household (e.g. drought-resistant seeds, improved irrigation)?	Low to Moderate – sporadic coverage, often not linked to actual availability
	Are the necessary inputs or services locally available?	Low to Moderate – sporadic coverage, often not linked to actual availability

Continued on next page

Table 2 – continued from previous page

Diagnostic Dimension	Key Question / Variable	Evidence Coverage
	How accessible are these inputs in terms of cost and distance?	Low to Moderate – sporadic coverage, often not linked to actual availability
Adaptation Options (Perceived Feasibility)	How does the household assess the affordability of adaptation strategies?	Low – few surveys explicitly ask about perceived feasibility
	Are the strategies viewed as too risky or uncertain?	Low – few surveys explicitly ask about perceived feasibility
	Does the household perceive technical or knowledge-related barriers?	Low – few surveys explicitly ask about perceived feasibility
	Is the household’s land or context perceived as unsuitable for the strategy?	Low – few surveys explicitly ask about perceived feasibility
Take-up and Constraints	Which adaptation strategies has the household implemented?	Moderate – many ask about adoption, few probe constraints systematically
	To what extent or scale have these been implemented?	Moderate – many ask about adoption, few probe constraints systematically
	What were the household’s reasons for adopting certain strategies?	Moderate – many ask about adoption, few probe constraints systematically
	What were the reasons for not adopting other strategies?	Moderate – many ask about adoption, few probe constraints systematically
	What barriers—financial, informational, institutional—has the household encountered?	Moderate – many ask about adoption, few probe constraints systematically

Note: Evidence coverage is an indicative, non-exhaustive measure. Classifications (High, Moderate, Low) are informed by an exploratory revision of questions across commonly used household surveys, including the LSMS–ISA, the Rural Livelihoods Information System (RuLIS), and the Rural Household Multiple Risk Survey (RHoMIS). They also draw on discussions from the *Expert Convening on Measuring Climate Adaptation in Household Surveys*, organised by the World Bank’s Living Standards Measurement Study (LSMS), Washington, D.C., 20–21 May 2025.

2.3 Wage Employment

Wage employment plays a critical role in household income portfolios across much of the developing world, particularly as economies transition away from agriculture (Foster and Rosenzweig (2007)). Yet for many workers—especially those in low-wage, informal, or outdoor occupations—climate change introduces direct and growing risks to health, productivity, and earnings stability (Li et al. (2025), LoPalo (2023), Belasen and Polachek (2009), Rode et al. (2022)). Unlike self-employed farmers or entrepreneurs, wage earners have limited autonomy over their working conditions and fewer opportunities to adjust them in response to environmental stress (Iskander and Lowe (2020)).

Adaptation in this domain is shaped not only by individual behaviours or migration decisions, but also—and perhaps more fundamentally—by employer responses, the structure of labour market regulation, and the availability of collective or policy-based support. This subsection considers the proposed framework in the context of wage employment, raising some important considerations for designing survey instruments.

2.3.1 Exposure Assessment in Wage Employment

Climate-related risks to wage employment arise from both the nature of the work performed and the conditions under which it takes place. In many developing economies, large segments of the labour force are concentrated in sectors that are highly sensitive to climatic variation—including construction, transportation, street vending, mining, and manufacturing (Li et al. (2025), Feriga et al. (2024)). For workers in these sectors, exposure is shaped by a combination of environmental conditions—most commonly, heat (Adhvaryu et al. (2020), Neidell et al. (2021), Graff Zivin and Neidell (2014), Somanathan et al. (2021), Seppanen et al. (2006)), air pollution (Hoffmann and Rud (2024), Graff Zivin and Neidell (2012), Hanna and Oliva (2015)), rainfall (Maitra and Tagat (2024), Chen et al. (2025), Desbureaux and Rodella (2019), Adhvaryu et al. (2013)), physical infrastructure (e.g. shading, ventilation), and institutional arrangements (e.g. informality, lack of safety enforcement, Feriga

et al. (2024)). Heat stress, in particular, has emerged as a widespread and under-recognised threat to labour productivity, with evidence pointing to declines in output and heightened health risks as temperatures exceed key thresholds. Yet these impacts are unevenly distributed: informal workers, women, and those in outdoor or poorly ventilated settings tend to face both greater exposure and weaker protection.

The behavioural dimension is also crucial and often overlooked. While exposure can be described in objective terms, workers' awareness of climate risks, their perceived ability to adjust schedules or tasks, and their access to information or grievance mechanisms all mediate how exposure translates into harm.

A. Objective workers' exposure to climate hazards

Objective exposure refers to the measurable environmental and job-related conditions that shape climate risks for workers. These include ambient factors such as temperature, humidity, air quality, and rainfall, as well as features of the work environment, like ventilation, shading, and cooling systems. Exposure is also affected by the terms of employment and how much control workers have over their work—for example, how work schedules (Graff Zivin and Neidell (2014)) are set or tasks are assigned (Adhvaryu et al. (2022))—all influence how environmental hazards turn into real risks. Even under the same climatic conditions, workers with different types of contracts—such as piece-rate workers compared to salaried employees—may face very different levels of exposure, depending on the demands of the job. As climate change worsens, both environmental hazards and the rules and practices that shape workers' exposure are becoming more important, especially for low-wage and informal workers in sectors like construction, transport, street vending, mining, and manufacturing (International Labour Office (2019)).

Economic Sector as Risk Setting. The economic sector plays a central role in shaping workers' exposure to climate risks. Exposure is not uniform across wage workers. Jobs in construction, transportation, and street vending expose workers directly to heat, air pollution, and extreme weather, often with minimal physical protection (Neidell et al. (2021)). By contrast, workers in manufacturing, mining, and services may operate indoors, but frequently

in poorly ventilated, crowded, or heat-retaining environments that also pose serious risks (Scott et al. (2024)). These differences are not incidental: sectoral characteristics—whether work is predominantly outdoor or indoor, mobile or stationary, individually paced or rigidly scheduled—establish the baseline conditions of vulnerability to climate change.

Capturing sectoral variation is essential for assessing climate risk through surveys. Questionnaires should not only record the type of economic activity or occupation but also distinguish between sectors that differ systematically in exposure. Surveys that group all employment—or use overly broad categories—risk overlooking important differences in workers’ vulnerability and capacity to adapt. Designing effective instruments requires covering a broad range of occupations while collecting sufficient detail on work conditions—such as whether the job is outdoors or indoors, mobile or fixed—to enable meaningful assessment of climate risks. This may require preliminary mapping of key sectors in the areas of interest and careful design of survey instruments that capture sectoral diversity in a manner appropriate to the specific context.

Physical Sources of Risk. The environmental risks workers face are heavily dependent on the context; however, we can group the major hazards that threaten workers’ health, productivity, and income security into three broad sources: heat stress, pollution exposure, and extreme weather events.

Heat stress presents a growing risk for outdoor workers in construction, transportation, and street vending, who often lack access to shade or cooling, as well as for indoor workers in manufacturing, mining, and services, where poorly ventilated spaces trap heat (International Labour Office (2019); Lai et al. (2023); Parsons et al. (2022)). Pollution exposure encompasses a range of environmental hazards, including airborne particulates, chemical fumes, dust, and industrial waste. Among these, air pollution is the most common and widespread threat, particularly affecting workers in transportation, construction, and street vending, who are exposed daily to vehicle emissions, dust, and industrial pollutants. Factory workers operating in enclosed, poorly ventilated environments may also suffer from high concentrations of indoor pollutants (International Labour Office (2019); Gosnell et al.

(2019)). Extreme weather events—such as heavy rainfall, floods, and storms—disrupt outdoor and mobile work, leading to physical hazards, work stoppages, and income instability, particularly in informal settings with limited protective infrastructure (Tenzing (2020)).

The integration of spatial data with household survey information could prove particularly valuable in this context, given the well-documented spatial heterogeneity in air pollution exposure and heat (Guo et al. (2010), Chen et al. (2024)).

Appraising physical sources of risk

Surveys aiming to capture climate risks should aim to provide information in elements such as:

- Whether work is primarily performed outdoors or indoors.
- Whether work activities are regularly disrupted by rain, floods, or other extreme weather events.
- Whether protective equipment, shade, ventilation, or shelter is available at the worksite.
- The types of materials workers handle, including exposure to hazardous substances.
- The presence and intensity of pollutants in the work environment.
- The degree and frequency of exposure to extreme heat conditions.
- The level of exposure to air pollution and whether work-related health symptoms linked to pollution are commonly observed.
- Pair and inform survey data with Geospatial data.

Notably, some of these are not easy to assess and possibly require pushing the frontier of surveying. This requires considering previous research on context-specific factors, such as usual pollutants in common industries, and days when extreme heat is more likely to occur indoors.

Job Structure and Worker Control. Exposure to climate risks in wage employment is shaped not only by environmental conditions but also by the way work is structured and the

degree of control that workers exercise over their schedules, tasks, and working environment. Even within the same sector and physical setting, two workers may experience markedly different levels of exposure depending on how their job is organised and the autonomy they possess (Onesti et al. (2024)).

Work flexibility and scheduling control are critical determinants of exposure. Workers who can adjust their hours—such as by starting earlier to avoid peak heat—can significantly reduce their risk (Graff Zivin and Neidell (2014)). Conversely, workers locked into rigid, employer-determined schedules must endure hazardous conditions irrespective of environmental severity. In sectors like construction or street vending, informally employed workers may have greater scheduling autonomy but bear the full income risk of working fewer hours. In contrast, factory workers or service employees on fixed shifts typically have little flexibility, heightening their vulnerability to accumulated heat or poor air quality.

Work pacing and break control are also important. In piece-rate or output-based jobs, where pay depends on output rather than hours worked, there are strong incentives to minimise rest breaks, even under unsafe conditions. Where work pacing is employer-controlled, workers may not be permitted to rest even when physically stressed, intensifying health risks during extreme heat events. Access to health services and emergency support at the workplace can substantially mitigate the consequences of environmental exposure (Mullins and White (2019) show that the access to healthcare can mitigate environmental damages)⁷. The availability of first aid for heat exhaustion, respiratory distress, or injuries related to extreme weather events is particularly critical in high-risk sectors, yet is often absent in informal employment settings.

Risk awareness and information availability further shape workers' capacity to adapt. Workers who receive timely warnings about heat waves, poor air quality, or storms are better positioned to reschedule work or take preventive measures. Song (2024) show that Chinese workers reduce labour supply in response to accurate forecasts of extreme heat, consistent with rational adaptation to climate risk. However, when forecasts are inaccurate, workers

⁷Cheney et al. (2022) shows a case-study of the needs for healthcare in agricultural wage workers

do not adjust their behaviour, resulting in continued exposure and unchanged working hours despite hazardous temperatures. However, in many contexts, particularly among informal and casual workers, systematic dissemination of climate risk information is lacking.

Employment type and contract stability strongly influence the ability to refuse unsafe work. Salaried workers with formal contracts may have greater protections or bargaining power to cease work under hazardous conditions. By contrast, temporary, casual, or informal workers—particularly those paid daily or by piece-rate—often lack any effective mechanism to decline dangerous assignments without risking income loss. [Hoffmann and Rud \(2024\)](#) finds that informal and low-income labour supply decisions are less responsive to pollution exposure. This is augmented by lower-income workers working more hours overall, increasing their exposure across the board [Bick et al. \(2018\)](#).

Understanding job Structure and workers' power

Meaningful survey instruments can therefore capture information on:

- The flexibility workers have to adjust work hours and locations in response to environmental conditions.
- The degree of control over work pacing and the ability to take unscheduled breaks.
- The availability of health services or first aid at the workplace.
- Whether workers receive information or training about climate-related risks.
- Workers' primary sources of environmental information (e.g., employer, radio, phone alerts, word of mouth).
- The stability and type of employment contract (e.g., salaried, temporary, piece-rate, informal).
- Whether workers feel able to adjust work hours, locations, or pace when environmental risks are high.
- Whether unscheduled rest breaks are permitted or self-initiated during extreme heat or pollution events.
- Whether workers feel comfortable refusing tasks or requesting modifications when conditions are unsafe.

B. Subjective Perceived Exposure Amongst Workers

Understanding exposure requires more than measuring environmental conditions or work arrangements. Workers' perceptions of climate risks—their awareness of hazards, recognition of symptoms, and perceived ability to act—strongly influence how risks translate into harm. Even when physical exposures are similar, differences in awareness can significantly shape vulnerability and adaptation. Workers who recognise risks but cannot adjust their work practices may suffer both higher stress levels and reduced ability to cope with hazards (Song (2024), Barwick et al. (2024)). Survey instruments aiming to capture climate risk among wage earners must therefore collect information not only on objective exposures, but also on workers' perceived risks, perceived control over exposure, and access to information that

could support adaptive responses.

Risk perception. Workers' vulnerability to climate hazards is shaped not only by physical exposure but also by how they perceive and interpret the risks they face. Recognising environmental hazards—such as extreme heat, polluted air, or heavy rainfall—and understanding their health and productivity impacts are critical steps toward adopting protective behaviours. However, risk perception is uneven across sectors, job types, and individual workers. In many cases, workers exposed to high temperatures may normalise discomfort and underestimate the dangers of heat exhaustion, dehydration, or chronic fatigue ([International Labour Office \(2019\)](#)). Similarly, respiratory symptoms linked to poor air quality may go unrecognised or unreported, especially where pollution is seen as a normal feature of the work environment ([Gosnell et al. \(2019\)](#)).

Differences in risk perception are influenced by factors such as educational background ([Barsky et al. \(1997\)](#)), experience with extreme weather events, access to health information, and social norms within the workplace. [Dupas \(2011\)](#) show that access to health information shift behaviours in low-income countries. Workers in informal sectors, or those with limited exposure to occupational health and safety practices, may be particularly prone to underestimating climate-related risks. Misperception can also arise when risks are visible but not directly linked to immediate symptoms, leading to delayed or insufficient adaptive responses.

Finally, in a work environment, peer effects are relevant and should be accounted for in surveys. Although not linked to climate, [Bandiera et al. \(2010\)](#) and [Ichino and Maggi \(1999\)](#) show that peers are fundamental to shaping risk perceptions. Meanwhile, [Johnson \(2020\)](#) show the role of public shame in propelling firm-level adaptations.

Measuring risk perception

Surveys aiming to capture risk perception should seek to answer key diagnostic questions, such as:

- Do workers recognise heat, pollution, and extreme weather as serious risks to their health and income?
- Are workers aware of common symptoms linked to environmental exposures (e.g., heatstroke, respiratory issues)?
- Do workers perceive their current job environment as hazardous under climate stress?

2.3.2 Determining Adaptation Options in Wage Employment

In wage employment, the ability to adapt to climate risks depends not only on the nature of the hazards faced but also on who controls the conditions of work. Adaptation measures can be led by individual workers, by employers and managers, or by broader public systems through regulation and infrastructure. Each actor faces different constraints and incentives to undertake adaptation, and not all adaptation strategies are equally accessible to all workers. While some adjustments, such as seeking shade or shifting work hours, may be individually initiated, many others—such as rescheduling shifts, improving ventilation, or enforcing mandatory rest breaks—require collective action or institutional support.

Table 3 summarises the main types of adaptation strategies in wage employment, organised by the actor primarily responsible for initiating them, with examples illustrating each case.

Mapping worker-led adaptations. Worker-led adaptations rely primarily on personal initiative rather than formal workplace changes. Common strategies include adjusting work hours to cooler periods of the day, seeking shade or shelter during breaks, increasing hydration, modifying clothing to improve thermal comfort, or temporarily relocating work to less exposed areas when feasible.

Lead Actor	Adaptation Strategies	Examples
Worker-led	Individual adjustments within existing constraints	Adjusting work hours (early start, late shifts); seeking shade or shelter during breaks; increasing hydration; wearing protective clothing (e.g., hats, masks)
Firm-led	Workplace-level organisational and infrastructural measures	Rescheduling shifts around heatwaves; installing ventilation or cooling systems; providing shaded workstations or hydration stations; modifying tasks or production schedules during extreme events
System-level / Policy-led	Structural interventions through regulations, infrastructure, or public services	Mandatory heat safety standards (e.g., rest breaks); public early warning systems (heatwaves, air quality alerts); public provision of shaded areas, cooling centres; expansion of social protection to enable safer work choices

Table 3: Adaptation strategies by lead actor

The relevance and feasibility of worker-led adaptations depend heavily on the type of work performed. Mobile and informal workers, such as street vendors or day labourers, often have greater autonomy to adjust their schedules and working conditions in response to environmental hazards. Chan (2018) shows how pay-rate structures can crowd out rest breaks, imposing based pay constrains self-initiated safety measures. By contrast, workers in formal employment settings with fixed hours—such as factory operatives, construction crews, or service staff—typically have limited opportunities to make individual adjustments without employer involvement. Similarly, workers paid by output or under strict production quotas may find fewer opportunities to self-initiate protective behaviours.

Dealing with worker-led adaptation

Survey instruments should be designed to identify:

- The types of self-directed adaptations that workers are aware of and consider feasible.
- Whether workers report adjusting their work hours, rest periods, or locations in response to heat, pollution, or weather risks.
- Workers' knowledge of personal protective strategies, such as hydration practices, clothing choices, or informal rest practices.
- Workers' perceptions of the effectiveness of these self-initiated adaptations in reducing risk.
- how does the work environment and peers shape the workers beliefs?

Prior research into the local labour market and predominant employment sectors is critical for designing relevant survey instruments: adaptation options available to mobile street vendors may be irrelevant for factory workers bound to fixed schedules. Moreover, because adaptation practices are often highly context-specific—shaped by local climates, work cultures, and economic structures—survey instruments must be flexible enough to capture a wide range of behaviours, including forms not initially anticipated. Compared to agricultural labour, there is less documented knowledge on self-directed adaptation strategies in wage employment. Pre-coded response options may therefore need to be supplemented by open-ended questions, especially in informal or highly diverse work environments where standardised categories risk missing important forms of adaptation.

Mapping firm-led adaptations. In many wage employment settings, meaningful adaptation to climate risks requires action by firms, supervisors, or managers. Firm-led adaptations involve organisational changes, infrastructure investments, or management practices that protect workers by modifying the work environment or reorganising work processes. These adaptations are critical when individual worker adjustments are insufficient to offset the risks posed by extreme heat, air pollution, or severe weather events.

Common firm-led adaptation strategies include rescheduling work shifts to cooler times of day, rotating tasks to reduce continuous exposure to hazardous conditions, installing ventilation or cooling systems in indoor settings, providing shaded workstations or hydration stations, offering protective equipment such as masks or hats, and modifying production schedules during periods of extreme environmental stress (Adhvaryu et al. (2022)).

The feasibility and availability of firm-led adaptations vary widely across sectors, firm sizes, and employment arrangements. Larger firms and those operating under formal regulatory frameworks are often more likely to implement systematic adaptation practices, particularly where occupational health and safety standards exist. By contrast, small enterprises, informal firms, or subcontracted worksites may leave adaptation decisions to individual workers or supervisors, with little investment in infrastructure or coordinated planning.

Dealing with firm-led adaptation

Survey instruments should be designed to identify:

- The types of adaptation measures firms have implemented or communicated to workers (e.g., shift changes, provision of cooling infrastructure, access to protective equipment).
- Workers' awareness of available firm-led adaptations and their right to request or access them.
- Whether firms provide information, training, or guidance related to environmental risks and adaptation practices.
- Whether formal policies or procedures exist for adapting work during periods of extreme heat, poor air quality, or extreme weather events.

Mapping firm-led adaptation strategies requires recognising the diversity of employment settings and management practices across sectors. Previous research into the context-relevant workplace norms, regulatory environments, and firm characteristics is essential for designing survey modules that capture relevant adaptation behaviours. Because adaptation practices may differ sharply depending on firm size, formality, and sector, survey instruments must be

flexible enough to capture both formal, documented adaptations and informal, supervisor or lower management-initiated practices that may play a critical role in reducing climate risks. Additionally, this is where other sources of data, particularly firm/enterprise-level data (e.g., World Bank Enterprise Surveys, or country-specific administrative data), can provide relevant insights and highlight existing data needs. Once again, this highlights the importance of building survey instruments that can interconnect with other sources of data and provide a more holistic view of the households' conditions.

Mapping policy-led adaptations. Beyond individual and firm-level actions, many critical adaptations to climate risks in wage employment require intervention at the system or policy level. These adaptations involve changes to the regulatory environment, public infrastructure, or broader social protection systems that support safer and more resilient working conditions across sectors.

Policy-led adaptations can take a variety of forms. Notably important, labour regulations mandating heat safety measures—such as compulsory rest breaks, provision of water, or restrictions on outdoor work during peak heat periods—can standardise protections that would otherwise depend on firm discretion. For example, [Johnson et al. \(2023\)](#) show that formal firms only upgrade ventilation or schedule rest breaks when inspections make it incentive-compatible

The public goods provision is equally important. Public early warning systems, including heatwave alerts or air quality advisories, can inform both workers and firms about imminent risks, enabling proactive adjustments. Investment in public infrastructure—such as shaded areas, cooling centres, and flood-resilient transport networks—can reduce ambient exposure risks for outdoor and mobile workers.

Beyond regulation and infrastructure, [Doan et al. \(2023\)](#) underpins the importance of the ability to recover from income losses as one of the core components on identifying the households most exposed to climate change. Expanding access to social protection schemes, including cash transfers, unemployment insurance, or sickness benefits, can also reduce the pressure on vulnerable workers to continue working under dangerous conditions.

The availability, enforcement, and reach of policy-led adaptations often vary across countries, regions, and sectors. Careful research into local policies and the overall policy environment is essential to understand which adaptation options are truly available to workers.

Dealing with policy-led adaptation

Survey instruments should aim to identify:

- Whether workers are aware of regulatory protections related to environmental risks (e.g., heat safety laws, pollution standards, weather-related work stoppage policies).
- Whether workers have access to early warning systems or receive timely information about environmental hazards from public sources.
- Whether workers have access to social protection programmes that could reduce exposure pressures during extreme climate events.
- Whether enforcement mechanisms or grievance procedures exist to uphold climate-related labour protections.

2.3.3 Evaluating Take-up and Adaptation Constrains in Wage Employment

Identifying available adaptation strategies is only the first step. Adaptation in wage employment is a process, not a single decision: it evolves over time, shaped by workers' experiences, employer practices, and changes in environmental conditions. Evaluating climate resilience in wage labour markets therefore requires capturing both the extensive margin—whether any adaptation strategies are adopted at all—and the intensive margin—the extent and depth of implementation once adaptations are initiated.

As outlined in previous sections, adaptation options exist at multiple levels: individual workers can adjust behaviours; firms can modify work arrangements and environments; and system-level interventions can enable or constrain adaptation across sectors. However, significant barriers often limit take-up. Workers may lack the financial flexibility or bargaining power to change risky behaviours. Firms may underinvest in adaptation due to cost pres-

asures, limited managerial attention, or weak regulatory incentives. System-level protections may be poorly enforced, unevenly communicated, or inaccessible to informal workers.

Take up: Extensive and intensive margins. In contexts of limited worker agency and multi-actor settings, adaptation rarely takes the form of a single, isolated response. Strategies are often bundled—firms or supervisors may introduce a set of measures like shift rescheduling, shaded rest areas, and hydration support, or public rules may combine heat thresholds with mandatory breaks. These bundles reflect the fact that effective adaptation often depends on coordination across actors. But not all responses are planned or coordinated. In many settings—especially where jobs are informal or responsibilities are unclear—adaptation happens in a more ad hoc way, shaped by individual initiative or on-the-spot decisions. The result is often a patchwork of measures that differ in coverage, consistency, and effectiveness.

This variation matters for measurement. First, it makes simple yes/no classifications of take-up less useful: we need to distinguish between partial and full adoption, and capture how consistently adaptations are applied. Second, it requires attention to how strategies are combined or fragmented—how efforts by workers, firms, and institutions interact, or fail to, in shaping real protection. To understand adaptation in wage work, it is not enough to track whether measures exist—we also need to know how they are used, how they fit together, and whether they last.

Who’s leading. As important as measuring whether adaptation takes place is understanding who initiates it. Leadership shapes not only which strategies are chosen, but also how coordinated, sustained, and fair adaptation efforts turn out to be. In principle, some insight can be gained by tracking the type of strategy—whether it is worker-led, firm-led, or policy-led. But this can oversimplify a process that often involves interaction across actors. A change in work hours, for example, might start informally with workers adjusting their routines, and later be formalised by supervisors. Firms may only adopt safety measures after external pressure or guidance. Surveys should therefore aim not only to record whether a strategy is in place, but also to ask who initiated it, who is responsible for maintaining it,

and how coordination—or the lack of it—shapes how the strategy works in practice. This is especially important in complex employment settings—such as subcontracted sites, informal jobs, or firms under weak enforcement—where adaptation may rely on actors that are only loosely connected. Understanding who drives adaptation helps reveal where leadership is emerging and where institutional gaps persist.

Constrains by actor. Once again, understanding constraints to adaptation requires considering the different actors involved in wage labour. Workers, firms, and public institutions each face distinct barriers—and these often interact in ways that block or distort effective responses. Workers may be willing to change their behaviour but lack autonomy, fear income loss, or lack access to basic protections. Firms may recognise the need for adaptation but avoid costly changes, especially in competitive or low-margin sectors. Public institutions may provide limited guidance or weak enforcement, particularly in informal labour markets. Importantly, incentives are not always aligned. A worker may want to take breaks during peak heat but be penalised for lost output. A firm may delay action until it is legally required, lack information or motivation, or even face challenges in shifting worker behaviour despite good intentions. These tensions highlight the need to identify not just where adaptation is constrained, but whose incentives block action—and which mechanisms, such as regulation, dialogue, or co-financing, could help close these gaps. Surveys should be designed to capture these points of friction, recognising that adaptation depends on enabling conditions across all three levels—not just individual willingness.

2.3.4 Understanding the Gap in Wage Employment Surveying:

Although wage employment is an increasingly important component of household income in many developing countries, most surveys remain ill-equipped to assess how climate change affects this domain. Standard labour modules tend to focus on occupational status, earnings, and basic working conditions. Yet they often omit crucial dimensions of climate vulnerability and adaptation—such as workplace exposure to heat, the stability and formality of employment arrangements, or the availability of protective measures. Without this information, it

becomes difficult to evaluate how workers and employers respond to climate-related risks, or to identify policies that could strengthen resilience across different labour market segments.

Table 4 summarises key variables identified by the diagnostic framework as priorities for measuring adaptation within wage employment. It also provides an indicative assessment of how frequently these dimensions are captured in existing survey instruments. As with agriculture, this is not a formal meta-analysis, but a broad mapping based on a review of common tools and feedback from an expert convening. The goal is to highlight where survey instruments may fall short in capturing climate-relevant features of work and employment and pointing to potential data gaps.

Table 4: Key Gaps in Wage Employment Adaptation Measurement

Diagnostic Dimension	Key Question / Variable	Evidence Coverage
Exposure (Objective)	Which environmental conditions (e.g. temperature, rainfall, air quality) affect the worker’s job setting?	High – commonly assessed in occupational health or sectoral surveys
	Is the job primarily outdoors or indoors, and is there infrastructure like shade or ventilation?	High – observed in many worksite assessments
	What type of contract or job structure shapes exposure (e.g. shift rigidity, piece-rate, informality)?	Moderate – sometimes included in labour surveys
Exposure (Subjective)	Does the worker perceive heat, pollution, or weather as hazardous to health or income?	Low to Moderate – less consistently measured
	Is the worker aware of symptoms related to exposure (e.g. dehydration, respiratory issues)?	Low to Moderate – some coverage in health modules
	Does the worker feel they can act to reduce risk or raise concerns with employers?	Low – rarely captured in standard instruments
Adaptation Options (Availability)	Are there adaptation options available at the worker level (e.g. rest breaks, hydration)?	Moderate – partial inclusion in labour safety modules

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Table 4 – continued from previous page

Diagnostic Dimension	Key Question / Variable	Evidence Coverage
	Are firm-led adaptations present (e.g. shaded areas, rescheduled shifts, ventilation)?	Moderate – better covered in structured workplaces
	Are policy-level supports (e.g. heat regulations, social protection access) applicable to this worker?	Low to Moderate – often missing for informal workers
Adaptation Options (Perceived Feasibility)	Does the worker feel safe requesting adaptations or breaks?	Low – perceptions are rarely surveyed
	Is it feasible for the worker to adjust hours, location, or pace of work?	Low – few instruments assess this directly
	Do workers know how to access institutional support (e.g. grievance channels, public services)?	Low – rarely assessed
Take-up and Constraints	What adaptation strategies have been implemented by workers, firms, or authorities?	Moderate – often inferred, but not systematically documented
	Who initiated the adaptation (worker, firm, system)?	Low to Moderate – leadership attribution often absent
	How consistently and widely are these adaptations used?	Low – most surveys miss application intensity
	What barriers (financial, institutional, informational) prevent further adaptation?	Low – typically fragmented coverage across surveys

Note: Evidence coverage is an indicative, non-exhaustive measure. Classifications (High, Moderate, Low) are informed by an exploratory revision of questions across commonly used surveys, including the International Labour Organisation (ILO) Labour Force Survey’s (LFS) model questionnaire and Living Standards Measurement Study (LSMS), the European Working Conditions Survey (even if outside the main scope of this paper). The classification also draws on discussions from the *Expert Convening on Measuring Climate Adaptation in Household Surveys*, organised by the World Bank’s Living Standards Measurement Study (LSMS), Washington, D.C., 20–21 May 2025.

2.4 Non-farm household business

Non-farm household businesses play a central role in income generation and income diversification in many developing economies, especially in growing urban areas where formal jobs are scarce. These enterprises—ranging from petty trade and small food vendors to repair services and home-based manufacturing—are typically small, informal, and embedded in local markets. Their vulnerability to climate change arises not only from direct exposure to environmental shocks such as flooding or extreme heat, but also from indirect effects like falling demand, rising input costs, or infrastructure breakdowns.

Household businesses fall somewhat in between categories in the literature. Compared to wage workers, business owners often have more autonomy to adjust operations in response to climate stress—by changing hours, relocating activities, or switching inputs (Chen et al. (2019))—but they also face tighter liquidity constraints and carry the full financial risk of failure ((De Mel et al. (2008))). They are both employer and employee. In this sense, they resemble farming households. Yet they operate in a different context, facing a set of risks and options often closer to those of wage workers or non-agricultural firms.

2.4.1 Exposure of Non-farm household business

Non-farm household businesses face climate risks both as firms and as places of work. As firms, they can be disrupted by heat, flooding, or infrastructure failures that affect operations, inventory, or access to customers—much like in agriculture. As workplaces, they resemble informal wage settings, where family members may be exposed to heat, poor ventilation, and other environmental hazards. Given this hybrid nature, readers should refer to the earlier sections on agriculture and wage employment. Here, we highlight key considerations specific to this mixed setting.

A. Objective Exposure

Exposure as a Firm. From the perspective of a firm, physical risks depend on business

location, infrastructure quality, and type of activity. Outdoor enterprises—such as food stalls, roadside vendors, or informal mechanics—are particularly exposed to extreme heat, heavy rainfall, flooding, and air pollution, all of which can damage inventory, interrupt operations, or deter customers. Indoor businesses are not immune: many operate in informal structures with poor insulation, inadequate drainage, or unreliable electricity, making them vulnerable to overheating and water damage. Indirect forms of exposure also shape business risk. These include climate-related input price volatility (e.g., perishables or fuel), service interruptions (e.g., power, water), and climate-sensitive fluctuations in demand. Enterprises that rely on agricultural products, transport infrastructure, or steady customer flows are particularly sensitive to these downstream effects.

Exposure as a Worker. household businesses also function as workplaces—often employing several household members. From this perspective, exposure includes the physical working conditions experienced by family labour. Outdoor work in vending or repair services exposes workers directly to high temperatures, poor air quality, and rain. Indoor work may occur in confined, poorly ventilated spaces with minimal protection from heat or humidity—especially where tasks involve physical effort, machinery, or handling perishable goods. As in wage employment, the features of the work environment—shading, airflow, access to drinking water, and rest arrangements—determine the risks of heat stress and exhaustion. In many household businesses, particularly those without legal status or formal premises, these risks go unmonitored and unmanaged, compounding the vulnerability of household members who may lack both external protection and decision-making power within the enterprise.

B. Subjective exposure

Subjective exposure refers to how household business owners and workers perceive and interpret climate-related risks—what they see as threats, how they explain those risks, and whether they view them as temporary shocks or long-term constraints. These perceptions influence both the urgency of response and the kinds of strategies seen as possible or necessary. Some business owners may recognise extreme weather as a growing challenge, while others may treat disruptions as normal variability or attribute losses to market conditions

or infrastructure failures rather than to climate.

Perceptions are shaped by several factors. Personal experience with past shocks—such as inventory loss during flooding or heat-related illness—can heighten awareness, though recall biases and the normalisation of hardship may blunt perceived vulnerability. Access to information—through radio, mobile alerts, peer networks, or institutional channels—also shapes awareness of environmental risks and seasonal expectations. Business owners with limited education, weak external ties, or operating in isolated settings may be less attuned to slow-onset risks like rising temperatures or seasonal shifts.

Subjective exposure is also shaped by perceived capacity to act. A business owner who sees climate risks but lacks the means to adapt—due to space, capital, or legal protections—may minimise those risks or see them as unavoidable. In family enterprises, where the boundaries between business and household are blurred, perceptions of risk are also shaped by wider household concerns: food, health, or schooling may take precedence over adapting the business.

To capture this dimension, surveys should go beyond recording past exposure and ask how business owners interpret these events—what they see as their causes, whether they believe they are becoming more frequent or severe, and whether they feel able to respond. As in agriculture, where farmers' beliefs about rainfall or soil shape adaptation decisions, perceptions of climate risk and constraint in non-farm enterprises strongly influence behaviour. Despite sectoral differences, assessing subjective exposure in household businesses shares key features with farm-based diagnostics: both require attention to lived experience, attribution of risk, and the perceived capacity to adapt.

2.5 Mapping the Adaptation Options of Non-farm household businesses

The adaptation strategies available to non-farm household businesses are broadly similar to those described for firms and workers in the wage employment section. These may include

shifting work hours, adjusting operations during heatwaves, investing in shade or cooling, or changing inputs and inventory practices. But a key difference is that in household businesses, the firm and the worker are often the same. As a result, adaptations are usually bundled—decisions about schedules, infrastructure, and income protection are made together—and take place within the constraints of small, often informal, enterprises.

Readers should refer to the previous section on firm-led and worker-led strategies in wage employment as a starting point. However, it is important to recognise that adaptation in non-farm household businesses is much less documented. Capturing the full range of responses in this sector will likely require context-specific, grounded data. Adaptable survey instruments, capable of identifying informal, hybrid, or partial strategies, are essential for understanding how these businesses adapt to climate stress.

2.6 Evaluating Take-up and Constraints in Non-farm Household Businesses

Understanding adaptation in non-farm household businesses requires recognising that, unlike wage workers or larger firms, these units combine the roles of employer, worker, and household. Adaptation is not a one-off decision but an ongoing process, shaped by shifting constraints, lived experience, and overlapping responsibilities. As in other sectors, take-up should be assessed along both the extensive margin—whether any adaptation strategies are adopted—and the intensive margin—how consistently and thoroughly they are implemented.

Because these businesses sit at the intersection of production and labour, many of the dynamics discussed in previous sections apply. Like in agriculture, decision-making is household-based and shaped by liquidity constraints, informal status, and spatial limitations. Like in wage employment, adaptation may involve adjusting the physical workspace or labour routines in response to heat or flooding. But in this setting, the roles are bundled: the same household typically absorbs the risks, makes the decisions, and provides the labour.

Constraints span several dimensions. Financial barriers are key—many businesses

lack capital, credit, or insurance (De Mel et al. (2008), McKenzie and Woodruff (2008)). Physical limitations, such as insufficient space to relocate or modify operations, are common, especially for home-based or mobile enterprises. Informality adds another constraint: without legal recognition, businesses are often excluded from public support or infrastructure services. Intra-household dynamics also matter, particularly where gender roles influence who makes decisions and who bears the costs of adaptation.

Given this dual structure, survey instruments should be designed to capture both formal and informal responses, and to distinguish between constraints affecting the business, the worker, and the household as a whole. Identifying take-up requires not just mapping adaptation actions, but also understanding the bottlenecks—capital, time, information, and institutional access—that shape what is feasible.

2.6.1 Understanding the Gap in Non-farm Household Businesses Surveying:

Non-farm household enterprises play a vital role in income diversification and climate risk management, particularly in rural and peri-urban areas. Yet survey instruments often fail to capture how these businesses respond to climate-related challenges. Standard enterprise modules typically gather information on revenues, inputs, and business registration status, but rarely explore how climate shocks affect business operations, or whether and how owners adapt—by shifting locations, adjusting inputs, changing product lines, or reducing working hours. This limits our ability to assess the resilience of small-scale enterprises or to design policies that support their adaptation.

Table 5 outlines the core variables identified by the diagnostic framework as essential for understanding climate adaptation in non-farm household businesses. It also provides an indicative sense of current measurement coverage, based on a review of existing survey tools and expert input. As with the other domains, this is not a formal meta-analysis, but a loose mapping aimed at identifying potential blind spots in current data collection. The goal is to inform more targeted survey designs that better reflect the adaptive capacity and constraints of these enterprises.

Table 5: Key Gaps in Non-farm Household Business Adaptation Measurement

Diagnostic Dimension	Key Question / Variable	Evidence Coverage
Exposure (Objective)	What physical risks affect the business site (e.g. flooding, heat, power outages)?	Low to Moderate – limited coverage in informal sector modules
	What infrastructure characteristics increase exposure (e.g. open air stalls, poor ventilation, unreliable electricity)?	Low to Moderate – sporadic inclusion
	Are there indirect effects, such as rising input costs or disrupted demand, linked to climate shocks?	Low – rarely captured systematically
Exposure (Subjective)	Does the business owner perceive environmental risks as significant to operations or income?	Low – very limited data in most surveys
	What do owners attribute disruptions to — climate, infrastructure, or market conditions?	Low – attribution logic is rarely explored
	Do business owners feel able to act or are climate risks seen as beyond their control?	Low – perception of agency largely undocumented
Adaptation Options (Availability)	What strategies are known to the business (e.g. adjusting hours, shade, cooling, alternative suppliers)?	Low – options list rarely tailored to informal business settings
	Are the required inputs or adjustments feasible given location, space, and regulatory constraints?	Low – feasibility questions are largely absent
	Has the business received any guidance, training, or peer advice on climate adaptation?	Low – often omitted for informal operators
Adaptation Options (Perceived Feasibility)	Do owners feel safe or authorised to modify operations in response to climate threats?	Low – perceptions of feasibility not measured
	Are financial, time, or space constraints seen as limiting adaptation?	Low – limited treatment across informal business surveys
	How do intra-household dynamics (e.g. gender roles, joint decision-making) shape feasibility?	Low – very rarely captured

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Table 5 – continued from previous page

Diagnostic Dimension	Key Question / Variable	Evidence Coverage
Take-up and Constraints	Has the business implemented any adaptation strategies? What kind?	Low to Moderate – sometimes asked, but inconsistently
	To what extent are adaptations maintained or combined over time?	Low – intensity and bundling rarely observed
	What constraints (capital, space, legal status) block further adaptation?	Low – constraint mapping is ad hoc
	Who within the household leads adaptation decisions, and who bears the costs?	Low – intra-household decision-making largely missing

Note: Evidence coverage is an indicative, non-exhaustive measure. Classifications (High, Moderate, Low) are informed by an exploratory revision of questions across commonly used surveys, including the International Labour Organisation (ILO) Labour Force Survey’s (LFS) model questionnaire and Living Standards Measurement Study (LSMS), Rural Household Multiple Risk Survey (RHoMIS), and European Working Conditions Survey (even if outside the main scope of this paper). The classification also draws on discussions from the *Expert Convening on Measuring Climate Adaptation in Household Surveys*, organised by the World Bank’s Living Standards Measurement Study (LSMS), Washington, D.C., 20–21 May 2025.

3 Other Cross-cutting Factors

Adaptation is rarely something households do alone. While people may change crops, adjust their work practices, or relocate in response to climate pressures, their ability to act depends heavily on the public systems surrounding them: roads, electricity, access to finance, and the institutions that shape rules and enforcement.

Public and private responses don't happen in isolation; they interact, sometimes reinforcing each other. A household might be ready to adapt but lack the resources to act. A policy might exist, but fail to reach those who need it. Understanding where these gaps, reinforcing dynamics, and bottlenecks lie is central to improving how adaptation serves its purpose of effectively manage climate-related risks.

This section examines three areas: institutional support, energy access, and migration, where public provision and private actions coexist and interact.

3.1 Institutions

Households' ability to adapt to climate change depends not only on the risks they face or the strategies available to them, but also on the institutional context in which they operate. As discussed in the previous section, adaptation in income-generating activities—whether in agriculture, wage employment, or small enterprises—relies on access to finance, markets, information, and skills. These, in turn, are shaped by institutions that mediate risk, allocate resources, and influence economic opportunity.

Institutions—both formal (e.g. social protection programmes, extension services, labour regulations) and informal (e.g. kinship networks, customary norms, community organisations)—affect whether households can cope with short-term shocks, invest in alternative revenue sources, or exit climate-sensitive sectors. Yet institutional presence alone is not enough: access, quality, and responsiveness are equally important, especially for low-income or marginalised groups.

This subsection extends the income-generation framework by focusing on the institutional factors that enable or constrain adaptation. It does so across three dimensions: first, the role of institutions in buffering income shocks; second, their contribution to longer-term transitions in households' economic activities; and third, the frictions that limit access to or reduce the effectiveness of institutional support.

3.1.1 Buffering Income Shocks

Climate shocks can cause immediate and sometimes severe disruptions to household income. The extent to which households are able to absorb these losses depends not only on the structure of their income-generating activities but also on the institutional support available to them. These support systems are critical in determining whether short-term disruptions turn into longer-term setbacks.

Both formal and informal institutions help households manage climate-related income volatility—through tools like financial transfers, in-kind assistance, or community-based risk-sharing arrangements. For survey-based analysis of adaptation, this buffering role is central. Measuring resilience requires more than identifying exposure to shocks; it also calls for detailed data on the type, timing, and reliability of institutional support.

Informal Institutions. In many low- and middle-income settings, informal institutions represent the first layer of protection when households experience income losses due to climate shocks (Townsend (1994)). These systems, anchored in kinship ties (Kinnan and Townsend (2012)), religious obligations or neighbourhood reciprocity, often operate independently of the state, relying instead on social trust, local norms, and repeated interaction.

Support from informal networks can take multiple forms: small emergency loans from relatives, food or labour-sharing among neighbours, or credit through mutual aid groups (Dercon (2002), Coate and Ravallion (1993)). In some cases, these arrangements are institutionalised into more structured forms of informal insurance, such as community-based risk-sharing schemes, rotating savings and credit associations (ROSCAs), or burial societies

(Kinnan and Townsend (2012), Fafchamps and Lund (2003)). These mechanisms typically pool small contributions from members to create a fund that can be drawn upon when a member experiences a shock.

Community-based insurance can be particularly relevant in climate-sensitive contexts. It offers a decentralised, locally governed mechanism for spreading risk, often in areas where formal insurance markets are absent. In some settings, farmers' groups or cooperatives organise informal weather-indexed insurance (Carter et al. (2017), de Janvry et al. (2014)) or joint contingency funds (Townsend (1994)). While coverage is usually limited and informal rules may lack enforcement, such schemes can serve as vital buffers against agricultural loss or asset depletion.

However, the reach and reliability of informal institutions can vary substantially. Support may be withheld from households perceived as outsiders, less deserving, or unable to reciprocate. Moreover, covariate shocks—such as droughts or floods—that affect entire communities can strain these systems beyond their financial capacity. When all contributors are affected simultaneously, the very basis of risk pooling can collapse.

Surveying contexts with informal institutions

For survey design, assessing the role of informal institutions requires going beyond generic modules on social capital. Instruments should seek to capture:

- Whether the household received any informal support during a recent shock;
- The type and source of support (family, neighbours, religious or mutual aid groups);
- Membership in any community-based insurance or pooled savings schemes;
- Frequency and size of contributions;
- Experiences with payouts or claims in the past;
- Perceived fairness, accessibility, and reliability of such systems;
- Social obligations or constraints associated with participation.

Formal Institutions and Social Protection. Formal institutions—particularly public social protection systems—play a central role in buffering income shocks linked to climate-related disruptions. Governed by codified rules and financed through public or donor resources, these systems include a range of interventions: cash or food transfers, public works programmes, subsidised insurance, school or health fee waivers, and emergency relief (Haushofer and Shapiro (2016), Dercon (2002), Baird et al. (2011)).

In the context of climate change, such programmes act as vital stabilisers, helping households absorb sudden income losses and avoid harmful coping strategies. For example, public employment schemes like Ethiopia’s Productive Safety Net or India’s MGNREGS provide income during periods of seasonal underemployment, while simultaneously investing in local infrastructure and ecological restoration (Imbert and Papp (2015), ?). Weather-indexed insurance—delivered through public or hybrid schemes—offers compensation for rainfall or temperature anomalies, though uptake and effectiveness remain uneven.

While many climate-relevant interventions operate in a contingent or shock-responsive manner, routine social protection—such as pensions, child grants, or universal transfers—also contributes to climate resilience. These programmes may not be explicitly designed for climate adaptation, but by reducing chronic poverty and income volatility, they enhance households’ capacity to prepare for and recover from shocks (Gilligan et al. (2009), de Janvry et al. (2006)). Regular transfers help sustain consumption, preserve productive assets, and smooth expenditure on essentials such as food, education, and healthcare (Duflo (2000), Edmonds (2006)). In some cases, predictable entitlements also reduce dependence on informal borrowing or distress migration.

Adaptive social protection frameworks aim to integrate routine and shock-responsive components into coherent systems. Key design features include the ability to scale benefits during crises, flexible delivery mechanisms (e.g. mobile payments), and alignment with early warning systems. When effectively implemented, such systems protect not only short-term welfare but also the foundations for longer-term adaptation.

For survey-based analysis, capturing the buffering role of formal institutions requires

more than binary indicators of programme participation.

Surveying the role of formal institutions/social protection

Relevant dimensions include:

- Type and frequency of benefits received (e.g. routine vs. emergency);
- Timing of support in relation to specific climate shocks;
- Mode of delivery (cash, food, voucher, mobile transfer);
- Awareness of eligibility criteria and application procedures;
- Reasons for non-participation (e.g. exclusion errors, administrative barriers);
- Household perceptions of adequacy, fairness, and reliability of support.

Surveys should also distinguish between households receiving regular entitlements and those accessing support only in crises. Understanding the presence and absence of routine institutional support is key to explaining variation in vulnerability and identifying entry points for more anticipatory forms of adaptation.

3.1.2 Institutions and Long-Term Adaptive Capacity.

While short-term support can help households weather climate shocks, long-term adaptation depends on the institutional conditions that shape how people adjust their sources of income over time. As noted in Section 1, exposure and adaptation are closely tied to institutional context. Transitions out of climate-sensitive sectors, the adoption of new technologies, entry into different labour markets, or relocation to less exposed areas are not merely technical or behavioural decisions; they are deeply institutional.

Formal institutions influence this process in multiple ways. Vocational training and adult education expand the set of viable income strategies, particularly for young people and women (Attanasio et al. (2011), Blattman et al. (2014)). Credit programmes—especially those designed for low-asset or mobile populations—can finance diversification, relocation, or the establishment of small enterprises (McKenzie and Puerto (2021), Banerjee et al. (2015)).

Land tenure systems shape whether households are able or willing to invest in climate-resilient infrastructure or shift production practices (Deininger and Jin (2006)). Labour regulations and employment services determine whether off-farm work is accessible, secure, and flexible enough to support gradual transitions of households' economic activities (Card et al. (2018)).

Informal institutions also play a critical role. Kinship networks often provide financial or informational support during periods of change, including migration (Kinnan and Townsend (2012), Munshi (2003)). Community-based organisations may coordinate shared investments or facilitate peer learning. At the same time, prevailing norms may discourage specific forms of adaptation—for example, women entering paid work or young people moving away from the family farm (Alesina et al. (2013), Fernandez et al. (2004)). These dynamics influence who is able to adapt, how, and under what constraints.

Assessing the role of institutions in long-term adaptative capacity

Instruments should aim to capture:

- Access to vocational training, adult education, or agricultural extension services;
- Participation in credit programmes linked to income sources diversification or mobility;
- Land tenure status, perceived security, and rights over key productive assets;
- Barriers to entering higher-return activities (e.g. licensing requirements, capital needs, literacy constraints);
- Perceived risks associated with changing jobs, sectors, or locations;
- Institutional mechanisms that reduce the cost of failed transitions (e.g. fallback employment, loan restructuring);
- The role of family or community networks in supporting, or discouraging, occupational changes.

3.1.3 Access Frictions

Institutional presence alone does not guarantee effective support. Even where formal or informal systems exist to buffer shocks or facilitate adaptation, households may face significant barriers to accessing them. These access frictions—whether administrative, social, geographic, or informational—determine who benefits from institutional support and who is left behind.

In many settings, public programmes are not automatically delivered but require active enrolment, application, or negotiation. Households must navigate eligibility criteria, documentation requirements, travel distances, or interactions with gatekeepers (Muralidharan et al. (2016)). These steps can impose both monetary and time costs, which fall disproportionately on women, migrants, older people, or those with limited literacy (Finkelstein and Notowidigdo (2019), Bhargava and Manoli (2015), Deshpande and Li (2019), Holt and Vinopal (2023)). When access depends on discretionary approval or navigating complex bureaucracy, programmes may systematically exclude the very groups most exposed to weather and income-loss risks (Hanna and Olken (2018)).

Geography often compounds these patterns (Jalan and Ravallion (2002)). Remote rural areas may lack the infrastructure—roads, mobile coverage, administrative offices—required to access public services. Where climate risks are geographically concentrated, such as in floodplains or arid zones, institutional reach often declines just where it is most needed (Dercon et al. (2009)). Urban informal settlements may be physically close to services but remain administratively invisible due to insecure tenure or lack of formal recognition (Galiani and Schargrodsky (2010), Field and Toreto (2006)).

Informal institutions are not exempt from exclusion dynamics. Access to kin-based support may be limited by social distance, reputational concerns, or perceptions of reciprocity. Community networks can reproduce existing hierarchies, reinforcing inequalities along lines of caste, gender, ethnicity, or migration status. In some settings, informal support systems exclude precisely those who deviate from dominant norms or roles (Fafchamps and Lund

(2003), Miguel and Gugerty (2005)).

For survey-based analysis, assessing access frictions requires going beyond whether a household received support to understand how, and under what conditions. Capturing these frictions helps explain why otherwise similar households may respond differently to weather shocks or adaptation opportunities.

Furthermore, disaggregating responses by gender, age, disability, and minority status is essential for identifying systematic exclusions that may not be visible at the household level.

Understanding access frictions on institutional support

Key lines of inquiry include:

- Whether the household is aware of relevant programmes or entitlements;
- If eligible, whether they attempted to enrol or claim support;
- If not, why not: lack of information, prohibitive travel costs, missing documentation, prior negative experiences, or perceived discrimination;
- Mode of benefit delivery and its accessibility (e.g. bank account, mobile money, in-person collection);
- Whether assistance was timely and adequate;
- Trust in the institutions providing support, and past experiences of fairness or exclusion;
- Social or logistical barriers to participating in informal networks (e.g. migration status, marital status, intra-community divisions).

3.2 Energy

Access to affordable and reliable energy is a critical determinant of household resilience. In low- and middle-income countries, energy expenditures constitute a non-negligible share of total household budgets—typically ranging from 2.5% to 6.5%, with the burden disproportionately higher among the poorest deciles, where energy outlays can exceed 10%, especially when reliant on purchased biomass fuels such as charcoal or firewood (Bank (2003); see, also, Imelda (2020)). These costs are not only substantial but many times inflexible, constraining households’ ability to reallocate spending in response to shocks and directly influencing the time and labour they can invest in productive activities.

Given the spirit of this exercise, this brief subsection focuses on the role of energy in shaping household income streams. Rather than treating energy solely as a consumption item or infrastructure concern, we examine how access, reliability, and affordability of energy interact with households’ economic activities, both directly by enabling income-generating activities, and indirectly by mediating exposure to climate-related risks and constraints. The discussion below identifies some key mechanisms through which energy affects the structure, viability, and adaptability of household economic activity and highlights how these dimensions can be effectively captured in survey instruments.

3.2.1 Energy Access as an Enabler (or Barrier) to Income Generation

Energy Access as a Platform for Income Diversification. Access to energy expands the set of income-generating options available to households. Electricity and clean fuels enable a wide range of non-farm and off-farm activities (Grogan and Sadanand (2013), Lipscomb et al. (2013), Dinkelman (2011), Gertler et al. (2016)). In rural and peri-urban areas, such diversification is a critical adaptation strategy, allowing households to buffer against climate-related shocks to farm income or seasonal underemployment.

Even limited or low-capacity energy access can support the creation or expansion of micro-enterprises—for example, Kirubi et al. (2009) find that the introduction of an low-

scale electrical micro-grid in rural Kenya facilitated the use of electric equipment for activities such as tailoring, food preparation, and storage, substantially increasing worker productivity. Electricity also enables basic communication tools such as mobile phones and radios, which in turn facilitate access to services like climate information (Aker (2010)), internet and mobile money. Also, open new income opportunities linked to remote online work or gig-economy platforms (Chen et al. (2019)).

In addition to enabling new forms of economic activity, energy access allows shifts in the spatial and temporal organisation of work. Households can extend productive hours beyond daylight, repurpose domestic spaces for economic activity, and reduce dependence on agricultural labour cycles (Grogan (2018)).

Understanding energy access role in income diversification

To capture the role of energy in enabling diversification, surveys should:

- Identify all income-generating activities and record which require or benefit from electricity or modern fuels.
- Ask whether energy constraints have limited the household's ability to start or expand such activities.
- Include asset inventories for energy-reliant tools (e.g., sewing machines, blenders, cold storage units) and their usage frequency.
- Capture aspirations or planned enterprises that are conditional on improved energy access.

Reliability of Energy Supply as a Stabiliser of Income. For households that depend on energy for income generation, it is not merely access but the reliability and quality of supply that determine economic viability. Frequent outages, voltage fluctuations, or erratic fuel availability can disrupt income flows, raise operating costs, and deter investment in energy-dependent activities (Eifert et al. (2008)). In this sense, unreliable energy becomes a source of income volatility, undermining the very stability that diversification is meant to provide in the face of climate or market shocks.

Micro-enterprises operating under unstable supply—such as informal food vendors, tailors, welders, or cold-chain businesses—often incur losses during outages due to spoilage, idle labour, or cancelled transactions (Falentina and Resosudarmo (2019)). Some adopt coping mechanisms such as backup generators (Steinbuks and Foster (2010)), solar systems, or fuel stacking, but these are costly, environmentally burdensome (in the case of diesel, Kirubi et al. (2009)), or limited in capacity. Poorer households may be forced to suspend operations, absorb repeated losses, or avoid energy-reliant ventures altogether.

Energy reliability also shapes expectations. In areas where supply is persistently erratic, households may hesitate to invest in productive assets, take on advance orders, or build a customer base. This inhibits not just present earnings but also forward-looking decisions around business growth, credit use, and occupational mobility. (Falentina and Resosudarmo (2019), Calderón et al. (2015)) For households seeking to adapt their income sources under increasing climatic variability, the absence of dependable energy adds a layer of risk that discourages transition.

Understanding energy supply role as stabiliser of income

Surveys aiming to understand the stabilising role of energy should:

- Record frequency, duration, and perceived consequences of power outages or fuel shortages.
- Ask about coping strategies: Do households use generators, shift work hours, switch fuels, or temporarily close operations?
- Capture income losses or fluctuations directly attributed to energy supply issues.
- Include perceptions of energy predictability and how this affects planning and investment in income-generating activities.

Reducing Time Burdens and Reallocating Labour. One of the most significant, but often under-recognised, ways energy access strengthens adaptive capacity is through its effects on time use and intra-household labour allocation. In settings where energy is scarce or reliant on traditional fuels, women and girls disproportionately bear the burden

of collecting firewood, managing inefficient stoves, and performing household chores without appliances (Dinkelman (2011), Grogan and Sadanand (2013)). These tasks can consume several hours daily—time that could otherwise be used for paid work, education, or rest. This form of “time poverty” constrains both short-run income generation and longer-term adaptive potential.

Modern energy access can substantially reduce these burdens. Electrification enables the use of labour-saving devices—electric stoves, blenders, water pumps, washing machines—that compress domestic tasks and free up time (Dinkelman (2011), Grogan and Sadanand (2013)). Clean fuels such as LPG reduce the need for daily fuel collection and cut cooking time, while also improving health through reduced exposure to indoor air pollution (Heltberg (2004), Masera et al. (2000)). These gains are experienced most acutely by women, who are then better able to engage in wage labour, initiate home-based enterprises, or participate in social and civic activities.

Importantly, such shifts are not automatic. Social norms, bargaining power within the household, and external labour market conditions shape whether time savings translate into increased economic participation (Chiappori (1988)). Nonetheless, evidence from multiple settings shows that rural electrification is associated with higher female employment, greater school attendance for girls, and delays in marriage and childbearing. These changes represent structural gains in adaptive capacity—broadening income sources while enhancing long-term resilience (Dinkelman (2011), Grogan (2018), Burlig and Preonas (2024)).

Addressing energy role on labour relocation

To adequately capture these dynamics, survey instruments should:

- Include detailed time-use modules that account for fuel collection, cooking, and other domestic tasks—disaggregated by gender and age.
- Probe whether energy access has changed how time is allocated and whether new labour opportunities have been taken up.
- Record ownership and use of labour-saving appliances, and the distribution of their benefits across household members.
- Capture perceptions around whether energy has changed women’s autonomy, mobility, or decision-making roles.

3.2.2 Energy Constraints as a Dimension of Climate Adaptation

Access to affordable, reliable energy is not merely a consumption concern, it is a critical dimension of household adaptive capacity. In many low- and middle-income settings, energy expenditures are quasi-fixed: households cannot readily reduce them without compromising essential needs such as cooking, heating, or lighting. Among the poorest, energy outlays can exceed 10% of total household budgets, particularly where households rely on purchased biomass fuels such as charcoal or firewood (Heltberg (2004)). These rigid costs limit households’ capacity to adjust to income shocks, often forcing compensatory strategies; such as increasing labour supply, deferring food purchases, or withdrawing children from school.

Climatic events exacerbate this rigidity. Heatwaves drive up cooling needs; cold spells increase heating demands. Seasonal and unanticipated climate shocks thus translate directly into greater energy stress, particularly for households already at the margin. As energy costs rise and liquidity tightens, households face reduced room for manoeuvre, exposing them to compounded risks across health, nutrition, and income stability (Dercon (2002)).

The type of energy source also shapes adaptive capacity. Households reliant on traditional

fuels may appear to incur low monetary costs, but this conceals significant non-monetary burdens. Time and physical effort spent collecting firewood—typically by women and children—diverts labour from school or paid work. Meanwhile, indoor air pollution from biomass combustion poses serious health risks, especially in enclosed kitchens, reducing both wellbeing and productivity. These effects are rarely included in adaptation assessments, yet they fundamentally constrain the household’s capacity to manage external shocks.

Modern energy sources such as electricity and LPG offer clear adaptive benefits: they reduce indoor pollution, save time, and enable more efficient domestic routines. However, access remains uneven—often requiring upfront investment in appliances, regular cash flow, and proximity to infrastructure.

Assessing the role of energy on climate adaptation

From a survey design perspective, incorporating energy into climate adaptation diagnostics entails capturing both direct and indirect pathways. Instruments should:

- Disaggregate energy use and spending by source, season, and payment frequency.
- Probe behavioural adaptations to energy stress (e.g., switching fuels, adjusting meal preparation, reallocating labour).
- Include modules on time spent collecting fuel and health symptoms linked to indoor air pollution.
- Explore perceptions of energy reliability and affordability, particularly in relation to seasonal or climate-related changes.

3.3 Migration

Migration is a longstanding response to economic and environmental stress, and under climate change it plays a dual role in household adaptation. As discussed in Section 1, one important form is migration as diversification, where one or more members of the household relocate—temporarily or seasonally—to generate income outside the climate-exposed local economy. This strategy allows households to reduce dependence on farming or informal local employment without severing ties to home assets, land, or community networks (Bryan et al. (2014)). In many cases, remittances from migrants are reinvested in the household economy, supporting education, consumption smoothing, or farm upgrades (Yang and Choi (2007), Calero et al. (2009)).

Migration as Diversification

Surveys can help to identify the use of migration as a diversification strategy:

- **Migration history:** Who has migrated (age, gender, relation to head); duration, frequency, and seasonality.
- **Destination and activity:** Where migrants go (urban/rural, region); type of work; climate sensitivity of activity.
- **Motivations for migration:** Reasons for leaving—economic, climate-related, social.
- **Remittances and usage:** Receipt, frequency, and amount of remittances; uses of funds (consumption, investment).
- **Costs and barriers:** Travel costs, documentation, transport access; gendered or social constraints on mobility.

Migration as diversification is often observed in areas with recurrent but not catastrophic climate stress, where local income-generating activities remain viable but insufficient. It tends to be more accessible to households with social connections at destination or enough liquidity to cover travel and job search costs (Bryan et al. (2014),)Yang and Choi (2007). In survey design, capturing this strategy requires attention to household composition, migration

histories, and the uses of remittances; dimensions addressed in earlier sections.

A second, less frequent but more transformative form is wholesale migration, where the entire household relocates—permanently or indefinitely—due to a perceived collapse in local viability (Dustmann and Kirchkamp (2002)). This may follow acute shocks such as flood displacement or crop failure, or be the cumulative result of environmental degradation, market exclusion, or declining institutional support (Barrios et al. (2006)). Wholesale migration is less reversible and often carries higher social and economic risks. Unlike diversification, which hedges against local volatility, wholesale migration signals a breakdown of adaptive capacity in place.

For surveys, wholesale migration presents both empirical and conceptual challenges (Fafchamps and Shilpi (2013)). Fixed-area sampling frames may systematically omit households that have left, creating blind spots in understanding thresholds of in situ adaptation. Retrospective questions on previous household locations, reasons for relocating, and conditions at departure can help fill this gap. It is also essential to identify barriers to mobility—such as insecure tenure, debt, lack of documentation, or social stigma—and the conditions under which relocation becomes feasible or necessary.

Wholesale Migration

Surveys can help to pin down wholesale migration by addressing:

- **Prior residence history:** Year of relocation; previous location.
- **Reasons for relocation:** Drivers such as climate/environmental change, repeated shocks, or loss of viability.
- **Failed adaptation attempts:** Strategies attempted before relocating; reasons those strategies failed.
- **Conditions at new location:** Access to land, housing, services, employment; institutional or NGO support.
- **Barriers to relocation:** Constraints that delayed or prevented moving; households wishing to move but unable to.

Both forms of migration are deeply shaped by institutional context: by the presence of social networks, labour intermediation, safety nets, and governance systems that make movement possible, desirable, or sometimes unavoidable. Understanding migration as part of the adaptation spectrum requires attention to who moves, who stays behind, and what institutional resources shape that decision.

Cross-Cutting Dimensions

A comprehensive understanding of migration requires also addressing:

- **Social network influence:** Role of relatives, friends, or community members in enabling migration.
- **Perceived risk and future intentions:** Anticipated future migration; perceptions of climate risks in current location.

4 Concluding Remarks

There is an urgent need for systematic and policy-relevant evidence on how households adapt to climate risks. Existing data remain fragmented and poorly suited to inform decision-making, leaving governments and development partners without a clear picture of which adaptive strategies work, for whom, and under what conditions. This paper provides a structured, literature-informed framework for developing survey modules that better diagnose households' adaptation to climate change. In doing so, it seeks to address the dual gap motivating this work: the lack of systematic data on household adaptation and the absence of a structured approach to capture it in household surveys.

The framework places households' income-generating activities at the centre of adaptation analysis, recognising them as the primary channels through which climate shocks affect wellbeing and economic stability. By systematically organising the diagnostic process into four interlinked steps, assessing exposure, identifying adaptation options, examining take-up and constraints, and reassessing outcomes, the framework provides a coherent structure for measuring how households respond to climate stressors. This systematic approach allows adaptation to be analysed consistently across agriculture, non-farm enterprise, and wage employment, revealing both common mechanisms and sector-specific constraints. While the framework focuses on these three domains, it also incorporates overarching factors that shape adaptive capacity, such as energy access, institutional support, and migration dynamics. These elements connect individual decisions to wider structural conditions, ensuring that adaptation is understood not only as a household process but as part of a broader social and economic system. Applying a unified lens across these domains and cross-cutting dimensions clarifies how climate risks propagate through different income-generating activities, while enhancing external validity. Comparable data generated across contexts can inform national and cross-country assessments without losing the granularity of local realities. In this way, the framework bridges household-level decision-making and policy design, offering a practical tool for identifying barriers, benchmarking progress, and evaluating adaptation interventions.

A distinctive contribution of the framework is its explicit integration of behavioural dimensions throughout the diagnostic process. It recognises that adaptation is not driven solely by material constraints, but also by perceptions of risk, beliefs about climate change, social norms, and the credibility of available information. These factors can explain why households facing similar conditions adopt different strategies, or fail to act altogether. By embedding behavioural variables alongside economic and institutional ones, the framework captures both the drivers and the limits of adaptation, including the risk of maladaptation when short-term coping undermines long-term resilience. In doing so, it repositions behavioural responses from the margins to the core of adaptation analysis, providing a more realistic understanding of how households navigate climate risk and why effective policy must engage with both incentives and perceptions.

Together, these elements establish a foundation for more systematic and policy-relevant measurement of household adaptation. By integrating economic, institutional, and behavioural perspectives within a unified diagnostic, the framework moves beyond fragmented or sector-specific approaches that have limited comparability and policy uptake. This integration extends to the broader enabling environment described in Section 3, where infrastructure, social protection, and energy systems condition the space of feasible responses and determine whether household adaptations can scale. It offers a common language for analysing adaptation across contexts and over time, allowing policymakers to identify structural barriers, track progress, and distinguish genuine adaptation from short-term coping. In doing so, it responds directly to the growing demand for data systems that connect household realities to national and global adaptation priorities. The framework is thus both an analytical tool and a practical roadmap; one that can guide survey design, inform programme evaluation, and strengthen the evidence base for resilience planning in developing-country settings.

First-order Recommendations

Building on this framework, several priorities emerge for improving how adaptation is understood, measured, and incorporated into policy and survey design:

1. **Adopt a clear mental model of adaptation.**

Measuring adaptation requires a coherent analytical lens that links exposure, available options, take-up, and outcomes within a single diagnostic process. The framework proposed in this paper helps guide the development of such a mental model by providing a structured pathway for identifying and connecting these elements in practice. Careful design of surveys based on this logic necessarily implies a *context-specific mapping* of how adaptation unfolds; recognising that the relevant shocks, options, and constraints vary across settings. Establishing this shared conceptual basis ensures that adaptation is interpreted consistently across contexts and avoids the fragmentation that stems from treating individual responses in isolation. A systematic, model-based approach also enhances comparability and aligns data collection with the decision processes it seeks to inform.

2. **Integrate behavioural dimensions.**

Risk perceptions, beliefs, and information access are central to understanding household decision-making. Survey instruments should capture these systematically alongside physical exposure and economic variables to explain differences in adaptive behaviour and potential maladaptation.

3. **Link household diagnostics to the enabling environment.**

Household responses depend on broader systems of energy access, infrastructure, and social protection. Integrating these cross-cutting factors into data collection and analysis strengthens the link between micro-level evidence and macro-level adaptation planning.

4. **Ensure cross-domain comparability.**

Applying the same diagnostic across agriculture, non-farm enterprise, wage employment, or any other income domain enhances external validity and enables benchmarking of adaptation gaps across countries and contexts.

5. Identify and monitor maladaptation risks through an agnostic lens.

Linked to the behavioural perspective above, the framework encourages mapping adaptation efforts before labelling them as successful or maladaptive. Taking a more agnostic view of adaptation allows researchers and policymakers to track the full spectrum of household responses, including those with unintended or uncertain outcomes, before classifying them as effective or detrimental. Such an approach enables a clearer understanding of the trade-offs and temporal dynamics that shape resilience and vulnerability.

6. Exploit complementarities with external data sources.

Linking household-level information with administrative records, satellite observations, and climate datasets can validate exposure measures and provide continuous monitoring of adaptive capacity.

7. Create feedback loops between data and policy.

Evidence generated through this framework should inform programme design, evaluation, and refinement within National Adaptation Plans and related development strategies, ensuring that measurement directly supports action.

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A Appendix

Annex A: Glossary of Key Terms

Adaptation

An adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities. Includes both anticipatory and reactive measures.

Maladaptation

Actions or investments that inadvertently increase vulnerability to climate change instead of reducing it. Often the result of short-term coping that undermines long-term resilience.

Exposure

The presence of people, economic activities, environmental services and resources, infrastructure, or economic, social, or cultural assets in environments that could be adversely affected by climate-related hazards. Includes both realised climate events and subjective perceptions of risk.

Vulnerability

The degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change. A function of exposure, sensitivity, and adaptive capacity.

Adaptive Capacity

The ability of a system, community, or household to adjust to potential damage, take advantage of opportunities, or respond to consequences. Includes both tangible (assets, infrastructure) and intangible (knowledge, social capital) factors.

Coping Strategies

Short-term responses to immediate climate shocks or variability. Not necessarily adaptive in the long term and may include dis-saving or temporary migration.

Resilience

The capacity of a system or household to absorb disturbances and reorganise while undergoing change, retaining essential functions and structures.

Income-generating Activities (IGAs)

Economic activities through which households secure income. The three primary domains considered are agriculture, wage employment, and non-farm enterprises.

Diversification

A strategy to expand or adjust income sources across space, time, or sector. Includes both income and geographical diversification to buffer climate risk.

Climate Risk Perception

Households' subjective understanding of the likelihood, severity, and relevance of climate-related threats. Influences the timing and type of adaptive responses.

Migration (in adaptation)

The movement of individuals or households in response to climate-related stress. May function as a risk management strategy—either temporarily or permanently.

Formal and Informal Institutions

Formal institutions include laws, policies, and public programmes (e.g., land registration, insurance, social protection). Informal institutions include community norms, kinship systems, and customary rules that structure adaptation behaviour.

Malleability (Beliefs)

The extent to which individuals revise their understanding of climate risks, adaptation strategies, or institutional trust based on new experiences, information, or social influence. Crucial in shaping dynamic patterns of adaptation, particularly in contexts with uncertainty or weak institutional signalling.