CLIMATE CHANGE AND LABOR MOBILITY OF AGRICULTURAL HOUSEHOLDS: A REVIEW

MUDANÇAS CLIMÁTICAS E MOBILIDADE DA FORÇA DE TRABALHO EM DOMICÍLIOS AGRÍCOLAS: UMA REVISÃO

CAMBIO CLIMÁTICO Y MOVILIDAD LABORAL DE LOS HOGARES AGRÍCOLAS: UNA REVISIÓN

10.56238/sevenVIIImulti2026-126

Loso Judijanto[1]

ABSTRACT

Climate change has increasingly altered the livelihood conditions of agricultural households, particularly by influencing labor allocation and mobility decisions. Growing climate variability, extreme weather events, and production uncertainty have intensified scholarly attention on how rural households respond through labor mobility as part of broader adaptation processes. This review critically synthesizes recent empirical evidence on the relationship between climate change and labor mobility at the agricultural household level, focusing on emerging patterns, key drivers, and livelihood implications. This study employs a Systematic Literature Review (SLR) approach, following a transparent, structured screening process. Peer-reviewed journal articles were identified through the Scopus database using refined keyword combinations related to climate change, labor mobility, and agricultural households. From an initial pool of 5,191 records, successive filtering by relevance, publication year (2021–2025), language, and open-access status yielded 37 eligible articles for final analysis. Data were collected exclusively from secondary sources and analyzed using qualitative thematic synthesis and cross-study comparison. The findings reveal six dominant themes: climate variability and shocks as primary drivers of mobility, household economic vulnerability and income diversification strategies, spatial patterns of labor mobility, differentiated responses by gender and age, the role of institutional and policy mediators, and long-term implications for agricultural sustainability. The review shows that labor mobility functions both as an adaptive strategy and a potential source of new vulnerabilities, depending on household capacities and institutional contexts. In conclusion, climate-induced labor mobility represents a complex, context-dependent livelihood response rather than a uniform outcome of environmental stress. Future research is encouraged to integrate longitudinal data and policy-oriented analysis to capture dynamic household adaptation pathways better.

Keywords: Climate Change. Labor Mobility. Agricultural Households. Livelihood Adaptation. Systematic Literature Review.

RESUMO

As mudanças climáticas têm alterado de forma crescente as condições de subsistência dos domicílios agrícolas, especialmente ao influenciar as decisões de alocação e mobilidade da

[1] Master's degree of Statistics. IPOSS. Jakarta, Indonesia. E-mail: losojudijantobumn@gmail.com
Orcid: https://orcid.org/0009-0007-7766-0647

força de trabalho. O aumento da variabilidade climática, a ocorrência de eventos climáticos extremos e a incerteza produtiva intensificaram a atenção acadêmica sobre como os domicílios rurais respondem por meio da mobilidade laboral como parte de processos mais amplos de adaptação. Esta revisão sintetiza criticamente evidências empíricas recentes sobre a relação entre mudanças climáticas e mobilidade do trabalho no nível dos domicílios agrícolas, com foco em padrões emergentes, principais determinantes e implicações para os meios de vida. O estudo adota uma abordagem de Revisão Sistemática da Literatura (RSL), seguindo um processo de triagem transparente e estruturado. Artigos científicos revisados por pares foram identificados por meio da base de dados Scopus, utilizando combinações refinadas de palavras-chave relacionadas às mudanças climáticas, mobilidade laboral e domicílios agrícolas. De um conjunto inicial de 5.191 registros, filtros sucessivos por relevância, ano de publicação (2021–2025), idioma e disponibilidade em acesso aberto resultaram em 37 artigos elegíveis para a análise final. Os dados foram coletados exclusivamente a partir de fontes secundárias e analisados por meio de síntese temática qualitativa e comparação entre estudos. Os resultados revelam seis temas dominantes: a variabilidade climática e os choques ambientais como principais indutores da mobilidade, a vulnerabilidade econômica dos domicílios e as estratégias de diversificação de renda, os padrões espaciais da mobilidade laboral, respostas diferenciadas segundo gênero e faixa etária, o papel de mediadores institucionais e de políticas públicas, e as implicações de longo prazo para a sustentabilidade agrícola. A revisão demonstra que a mobilidade do trabalho funciona tanto como uma estratégia adaptativa quanto como uma potencial fonte de novas vulnerabilidades, dependendo das capacidades dos domicílios e dos contextos institucionais. Conclui-se que a mobilidade laboral induzida pelo clima representa uma resposta de subsistência complexa e dependente do contexto, e não um resultado uniforme do estresse ambiental. Recomenda-se que pesquisas futuras integrem dados longitudinais e análises orientadas por políticas públicas para capturar de forma mais adequada as trajetórias dinâmicas de adaptação dos domicílios.

Palavras-chave: Mudanças Climáticas. Mobilidade do Trabalho. Domicílios Agrícolas. Adaptação dos Meios de Vida. Revisão Sistemática da Literatura.

RESUMEN

El cambio climático ha alterado de manera creciente las condiciones de subsistencia de los hogares agrícolas, en particular al influir en las decisiones de asignación y movilidad laboral. El aumento de la variabilidad climática, la ocurrencia de eventos climáticos extremos y la incertidumbre productiva han intensificado la atención académica sobre cómo los hogares rurales responden mediante la movilidad laboral como parte de procesos más amplios de adaptación. Esta revisión sintetiza críticamente evidencia empírica reciente sobre la relación entre el cambio climático y la movilidad laboral a nivel de los hogares agrícolas, centrándose en patrones emergentes, factores determinantes clave e implicaciones para los medios de vida. El estudio adopta un enfoque de Revisión Sistemática de la Literatura (RSL), siguiendo un proceso de selección transparente y estructurado. Los artículos científicos revisados por pares fueron identificados a través de la base de datos Scopus, utilizando combinaciones refinadas de palabras clave relacionadas con el cambio climático, la movilidad laboral y los hogares agrícolas. De un conjunto inicial de 5.191 registros, filtros sucesivos por relevancia, año de publicación (2021–2025), idioma y disponibilidad en acceso abierto dieron como resultado 37 artículos elegibles para el análisis final. Los datos se recopilaron exclusivamente a partir de fuentes secundarias y se analizaron mediante síntesis temática cualitativa y comparación entre estudios. Los resultados revelan seis temas dominantes: la variabilidad climática y los choques ambientales como principales impulsores de la movilidad, la vulnerabilidad económica de los hogares y las estrategias de diversificación de ingresos, los patrones espaciales de la movilidad laboral, respuestas diferenciadas por género y edad, el papel de los mediadores institucionales y de las políticas públicas, y las

implicaciones a largo plazo para la sostenibilidad agrícola. La revisión muestra que la movilidad laboral funciona tanto como una estrategia adaptativa como una posible fuente de nuevas vulnerabilidades, dependiendo de las capacidades de los hogares y de los contextos institucionales. En conclusión, la movilidad laboral inducida por el clima representa una respuesta de subsistencia compleja y dependiente del contexto, más que un resultado uniforme del estrés ambiental. Se recomienda que futuras investigaciones integren datos longitudinales y análisis orientados a políticas públicas para capturar mejor las trayectorias dinámicas de adaptación de los hogares.

Palabras clave: Cambio Climático. Movilidad Laboral. Hogares Agrícolas. Adaptación de los Medios de Vida. Revisión Sistemática de la Literatura.

1 INTRODUCTION

Climate change has emerged as one of the most pervasive global challenges of the twenty-first century, reshaping environmental systems, economic structures, and human livelihoods across regions. Rising temperatures, shifting precipitation patterns, and the increasing frequency of extreme weather events have destabilized natural resource–based sectors, particularly agriculture, which remains highly sensitive to climatic variability (Otieno et al., 2024). For millions of rural households worldwide, agriculture serves not only as a source of food but also as the primary foundation for income, employment, and social security. As climatic stress intensifies, agricultural systems are increasingly exposed to production risks that undermine household welfare and long-term livelihood sustainability (Degefu, 2025).

Among the groups most affected by climate change are agricultural households in low- and middle-income countries, where farming activities are often rainfed, labor-intensive, and weakly buffered by institutional support. Climate-induced shocks, such as droughts, floods, and heatwaves, have been widely documented to reduce crop yields, disrupt labor demand, and increase household income volatility (Nnadi et al., 2023). In contexts where access to insurance, credit, and adaptive technologies remains limited, these shocks heighten vulnerability, compelling households to seek alternative strategies to stabilize consumption and reduce exposure to climate-related risks.

Labor mobility has increasingly been recognized as a critical livelihood response to climate stress among agricultural households. Mobility encompasses a broad spectrum of movements, including seasonal migration, circular labor mobility, permanent rural–urban migration, and engagement in off-farm employment. Rather than representing isolated decisions, these mobility patterns are embedded within household-level strategies aimed at diversifying income sources and spreading risk across spatial and sectoral boundaries (Charlton et al., 2021). As climate variability disrupts agricultural productivity, labor mobility enables households to access non-climatic income streams, often through wage labor in urban or peri-urban economies, thereby functioning as an adaptive mechanism in the face of environmental uncertainty.

The relationship between climate change and labor mobility, however, is complex and multifaceted. While early migration studies often framed mobility as a response to economic differentials between rural and urban areas, more recent scholarship emphasizes the role of environmental stressors as compounding drivers of mobility decisions (Maliki & Pauline, 2023). Climate change does not operate as a singular push factor; instead, it interacts with socioeconomic conditions such as land scarcity, labor market access, education, gender

norms, and institutional capacity. As a result, mobility outcomes vary significantly across regions, household types, and demographic groups, reflecting diverse vulnerability profiles and adaptive capacities (Omerkhil et al., 2020).

At the household level, climate-induced labor mobility is closely linked to economic vulnerability and to livelihood diversification. Empirical studies have shown that declining agricultural yields and increased production uncertainty encourage households to reallocate labor away from on-farm activities toward off-farm employment and migration-based income sources (Wang et al., 2025). Remittances generated through labor mobility can play a stabilizing role by smoothing consumption, financing adaptation investments, and reducing short-term poverty risks. At the same time, labor mobility may introduce new challenges, including labor shortages in agriculture, increased workloads for remaining household members, and long-term demographic shifts in rural areas. These dual effects underscore the need for a nuanced understanding of labor mobility as both an adaptive strategy and a potential source of structural transformation within agricultural systems.

Despite the growing body of research examining climate change and labor mobility, the existing literature remains fragmented across disciplines, geographic contexts, and methodological approaches. Studies are dispersed within fields such as environmental economics, migration studies, development studies, and rural sociology, often employing diverse indicators, temporal scopes, and analytical frameworks. While numerous empirical investigations document localized mobility responses to specific climate shocks, fewer studies systematically synthesize this evidence to identify overarching patterns, dominant themes, and research gaps at the household level. Consequently, there is a limited consensus on how climate change shapes labor mobility decisions among agricultural households across regions and contexts (Budhathoki et al., 2020).

Moreover, existing reviews tend to focus either on climate-induced migration at the aggregate population level or on general rural livelihoods, without explicitly centering agricultural households as the primary unit of analysis. Agricultural households occupy a distinct position within climate–mobility dynamics due to their direct dependence on land, climate-sensitive production systems, and family-based labor allocation. Failure to disentangle household-level processes risks oversimplifying mobility as a uniform response, thereby obscuring heterogeneity in adaptive behavior and vulnerability (Barry, 2025). A focused synthesis that foregrounds agricultural households is therefore essential for advancing both theoretical clarity and policy relevance.

Methodologically, the diversity of empirical designs in climate–mobility research further complicates comparative analysis. Studies employ cross-sectional surveys, panel data,

econometric modeling, and qualitative case studies, producing findings that are often context-specific and difficult to generalize. While this diversity enriches the literature, it also underscores the need for a systematic, transparent review approach that can integrate evidence across methods and regions. Systematic Literature Review (SLR) methods, particularly those guided by the PRISMA framework, provide a robust mechanism for consolidating dispersed findings, identifying consistent patterns, and minimizing selection bias in evidence synthesis.

In response to these gaps, this study undertakes a Systematic Literature Review to synthesize contemporary peer-reviewed research on climate change and labor mobility among agricultural households. By systematically identifying, screening, and analyzing relevant studies indexed in the Scopus database, this review aims to provide an integrated overview of how climatic stressors influence labor mobility decisions, the forms mobility takes, and the socioeconomic and institutional factors that mediate these processes. The review is based exclusively on secondary data from peer-reviewed literature and does not involve primary data collection methods such as focus group discussions, interviews, surveys, or field observations.

The objective of this review is to critically synthesize existing evidence on the relationship between climate change and labor mobility at the agricultural household level, with particular attention to patterns, drivers, and implications emerging from recent scholarship. Through thematic analysis, the study seeks to clarify how climate variability and shocks shape labor allocation decisions, how households use mobility as part of broader livelihood strategies, and what these dynamics imply for agricultural sustainability and rural development pathways.

Based on this objective, the review is guided by the following research questions:

RQ1: *How does climate change influence labor mobility decisions and patterns among agricultural households across different regional and socioeconomic contexts?*

RQ2: *What household, demographic, and institutional factors mediate the role of labor mobility as an adaptive response to climate-induced livelihood risks?*

These research questions structure the analytical focus of the review and provide a foundation for the subsequent Results and Discussion sections, as well as for the conclusions drawn regarding future research and policy implications.

2 LITERATURE REVIEW

The relationship between climate change and labor mobility has become an increasingly prominent theme within development economics, agricultural studies, and

climate adaptation research. A substantial body of literature recognizes climate change not merely as an environmental phenomenon, but as a multidimensional stressor that reshapes livelihood structures, household decision-making, and labor allocation patterns, particularly within agrarian contexts. Agricultural households, whose livelihoods are highly dependent on climatic conditions, are among the most vulnerable groups facing climate-induced risks, including temperature variability, rainfall anomalies, extreme weather events, and long-term ecological degradation. As a result, labor mobility has emerged as a critical adaptive strategy employed by these households to mitigate income instability and livelihood insecurity under changing climatic conditions.

2.1 CLIMATE CHANGE AS A STRUCTURAL SHOCK TO AGRICULTURAL LIVELIHOODS

Existing studies consistently conceptualize climate change as a structural shock that disrupts agricultural production systems and household welfare trajectories. Empirical research across diverse geographic contexts indicates that rising temperatures and increased precipitation variability are associated with declining crop yields, heightened production risks, and greater income volatility among farming households (N-yanbini et al., 2024). These impacts are particularly pronounced in rain-fed agricultural systems, where limited irrigation infrastructure exacerbates exposure to climate variability. The literature emphasizes that such climate-induced production shocks undermine the viability of agriculture as a sole livelihood, thereby altering household labor supply decisions (Roy et al., 2024).

Several studies further highlight that climate change affects agricultural households not only through direct biophysical impacts but also through indirect channels, such as market instability, food price fluctuations, and increased production costs. These compound effects intensify livelihood stress and reduce rural households' resilience, pushing them to seek alternative income-generating opportunities beyond traditional farming. Within this context, labor mobility, both temporary and permanent, has been widely documented as a key household-level response to climatic stressors (Trujillano et al., 2021).

2.2 CONCEPTUALIZING LABOR MOBILITY IN AGRICULTURAL HOUSEHOLDS

Labor mobility in agricultural households is a multidimensional phenomenon encompassing seasonal, rural–urban, circular, and off-farm employment. The literature distinguishes between mobility as a distress-driven response to livelihood shocks and mobility as a strategic diversification mechanism to enhance household resilience. In climate-affected agricultural settings, these two motivations often overlap, reflecting the complex

interplay between vulnerability and agency in household decision-making processes (Tran & Bayrak, 2025).

Scholarly work emphasizes that labor mobility decisions are rarely individual choices; instead, they are embedded within collective household strategies designed to balance risk, labor allocation, and income diversification (Shinbrot et al., 2019). Migration of one or more household members allows farming households to smooth consumption, reduce dependence on climate-sensitive income sources, and access remittance flows that can be reinvested in agricultural production or used to buffer future shocks (Aryal et al., 2020). This perspective positions labor mobility as an adaptive response rather than merely a symptom of vulnerability, challenging earlier narratives that framed migration exclusively as a failure of rural development.

2.3 CLIMATE VARIABILITY AND MIGRATION PATTERNS

A growing empirical literature examines the causal links between climate variability and migration outcomes among agricultural populations. Quantitative studies using panel data and econometric modeling consistently find that higher temperatures, rainfall deficits, and extreme weather events are positively associated with higher rates of labor migration from rural areas. These effects are particularly evident in regions characterized by limited access to credit, insurance, and social protection mechanisms, where migration serves as a primary coping strategy (Chepkoech et al., 2023).

However, the literature also documents substantial heterogeneity in migration responses to climate stress. Some studies report that extreme climatic events can constrain mobility by eroding household assets and reducing the financial capacity required to migrate. This finding underscores the importance of distinguishing between short-term shocks and long-term climate trends, as well as between voluntary and involuntary forms of labor mobility (Eshetu & Yimer, 2024). As such, climate-induced labor mobility cannot be understood as a linear or uniform process but must be analyzed within specific socioeconomic and institutional contexts.

2.4 OFF-FARM EMPLOYMENT AS AN ADAPTIVE STRATEGY

Beyond physical migration, off-farm employment has been widely examined as a complementary or alternative form of labor mobility in climate-affected agricultural households. The literature suggests that engagement in non-agricultural wage labor, small-scale enterprises, or service-sector activities enables households to diversify income sources while maintaining ties to farming (Halliru et al., 2024). This form of labor reallocation is

particularly prevalent in regions where urban labor markets are accessible but permanent migration is constrained by social or institutional barriers.

Empirical evidence indicates that households experiencing greater exposure to climate variability are more likely to allocate labor toward off-farm activities, especially during periods of agricultural slack or crop failure. Such strategies are often facilitated by improvements in rural infrastructure, education, and labor market integration, highlighting the role of structural factors in shaping adaptive capacity. Nevertheless, the literature also notes that access to off-farm employment is unevenly distributed, with poorer households and marginalized groups facing greater barriers to participation (Cherinet et al., 2025).

2.5 SOCIOECONOMIC DIFFERENTIATION IN MOBILITY RESPONSES

A key theme emerging from the literature is the differentiated nature of labor mobility responses across socioeconomic groups. Gender, age, education, land ownership, and asset endowments significantly influence who migrates, where they migrate, and under what conditions (Fayomi & Ehiagwina, 2019). Studies consistently find that younger and more educated household members are more likely to engage in labor migration or off-farm employment, while older individuals remain in agriculture. Gender norms also shape mobility patterns, with men more likely to undertake long-distance migration and women more likely to engage in localized off-farm work or assume expanded agricultural responsibilities (Groth et al., 2020).

Land tenure and asset ownership further mediate the climate–mobility linkages. Households with larger landholdings and greater assets are better positioned to use migration as a proactive adaptation strategy, while asset-poor households may experience constrained mobility and heightened vulnerability. These findings underscore that labor mobility outcomes reflect existing structural inequalities, rather than functioning as a universally accessible adaptation pathway (Chithirairajan & Suvarna, 2021).

2.6 INSTITUTIONAL AND POLICY CONTEXTS

The literature increasingly emphasizes the role of institutional and policy environments in shaping climate-induced labor mobility. Access to social protection programs, migration networks, labor regulations, and rural development policies can either facilitate or constrain household mobility responses (Vidal Merino et al., 2019). Studies highlight that well-designed social safety nets and climate adaptation policies can reduce distress-driven migration while supporting voluntary and productive forms of labor mobility.

At the same time, inadequate policy coordination between climate adaptation and labor governance frameworks may exacerbate vulnerability among migrating agricultural households. The absence of legal protections for migrant workers, limited recognition of circular migration, and weak integration of rural–urban labor markets are recurrent challenges identified in the literature. Consequently, scholars argue for policy approaches that recognize labor mobility as an integral component of climate adaptation strategies rather than as an unintended consequence of climate stress (Gashure & Wana, 2023).

Despite the growing volume of research on climate change and labor mobility, the literature remains fragmented across disciplinary boundaries and geographic contexts. While numerous empirical studies examine specific dimensions of climate-induced migration or off-farm employment, there is a lack of systematic synthesis that integrates these findings at the level of agricultural households. Existing reviews often focus narrowly on migration outcomes or climate impacts without adequately capturing the household-level decision-making processes that link the two.

Furthermore, inconsistencies in methodological approaches, definitions of mobility, and measures of climate exposure limit the comparability of findings across studies. There is also limited attention to longitudinal dynamics, including how repeated climate shocks reshape mobility strategies over time. These gaps highlight the need for a comprehensive systematic literature review that consolidates empirical evidence, identifies thematic patterns, and clarifies the mechanisms through which climate change influences labor mobility among agricultural households.

In response to these limitations, this review synthesizes peer-reviewed studies published between 2021 and 2025 to provide an integrated understanding of the linkages between climate change and labor mobility at the household level. By systematically analyzing 37 selected articles, the review aims to advance conceptual clarity, highlight empirical regularities and divergences, and inform future research and policy debates on climate adaptation and rural labor transformation.

3 METHOD

This study employs a Systematic Literature Review (SLR) methodology guided by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) framework to synthesize and critically evaluate recent scholarly evidence on the relationship between climate change and labor mobility among agricultural households. Climate change has increasingly altered environmental, economic, and livelihood conditions in rural areas, particularly for farming households whose income and employment opportunities are highly

dependent on climate-sensitive agricultural systems. In this context, labor mobility manifested through migration, off-farm employment, and rural–urban transitions has emerged as a key adaptive response to climate variability, shocks, and long-term climatic impacts. By systematically consolidating peer-reviewed studies, this review provides an evidence-based overview of how climate-related stressors influence labor mobility decisions within agricultural households, while also identifying dominant analytical approaches and emerging research patterns in the literature.

Figure 1

Systematic Literature Review Process Based on the PRISMA Protocol

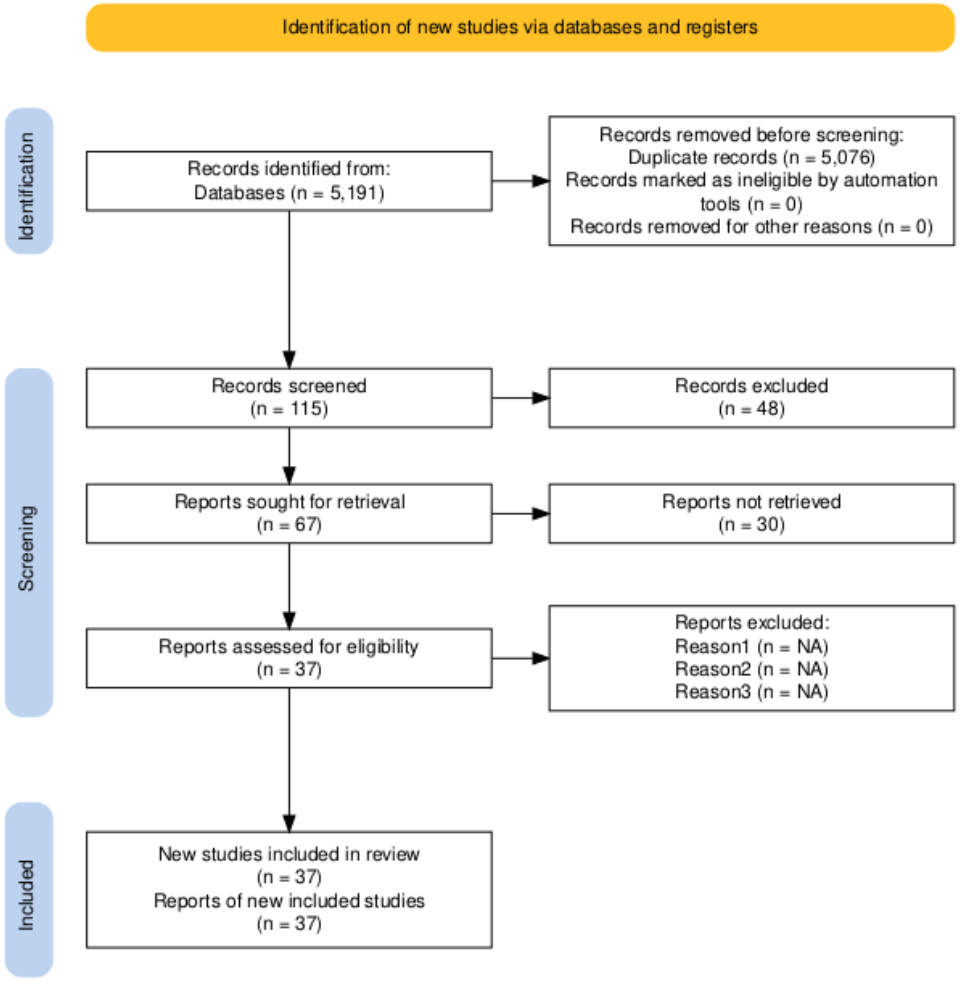

Figure 1 presents the structured process of article identification, screening, eligibility assessment, and final inclusion following the PRISMA protocol. The initial literature search was conducted using the Scopus database with the broad keyword combination “Climate Change” AND “Mobility,” which yielded 5,191 records, reflecting the extensive and multidisciplinary nature of research linking climatic factors and mobility dynamics. To improve thematic focus and ensure relevance to agricultural household contexts, the search strategy

was refined using a more targeted Boolean expression: (“climate change” OR “climate variability” OR “climate shocks” OR “climate impacts”) AND (“labor mobility” OR “labour mobility” OR “labor migration” OR “migration” OR “rural–urban migration” OR “off-farm employment”) AND (“agricultural households” OR “farm households” OR “smallholder farmers”). This refinement resulted in the exclusion of 5,076 records that did not align with the core scope of the review, leaving 115 articles for further screening.

Subsequently, a publication-year filter was applied to capture recent developments and contemporary empirical evidence, restricting the dataset to studies published between 2021 and 2025. This step eliminated 48 articles published outside the specified timeframe, resulting in 67 articles that met the temporal criterion. An additional eligibility screening focused on accessibility, retaining only studies available through open access or open archive sources to ensure transparency and reproducibility. As a result, 30 articles were excluded due to access limitations. At the conclusion of the PRISMA selection process, 37 peer-reviewed articles satisfied all inclusion criteria and were retained for full-text analysis and qualitative synthesis.

All bibliographic records were systematically managed using Mendeley Desktop to support reference organization, duplication control, and consistency in citation formatting throughout the review process. This study is based exclusively on secondary data derived from peer-reviewed literature indexed in Scopus; no primary data collection methods, such as focus group discussions, interviews, surveys, or field observations, were conducted. The findings presented in this review emerge solely from the systematic integration and comparative analysis of the selected 37 studies. Through this approach, the review aims to provide a comprehensive and methodologically robust synthesis of current knowledge on climate change–induced labor mobility among agricultural households, while highlighting conceptual trends and research gaps that warrant further investigation.

4 RESULTS

This systematic literature review identified six recurring thematic clusters based on the analysis of 37 peer-reviewed studies examining climate change and labor mobility among agricultural households. The six themes include: (1) climate variability and shocks as drivers of labor mobility, (2) household-level economic vulnerability and income diversification strategies, (3) patterns and directions of labor mobility, (4) differentiated mobility responses by gender, age, and household structure, (5) institutional and policy mediators of mobility outcomes, and (6) long-term implications of climate-induced mobility for agricultural sustainability and rural livelihoods.

The most frequently discussed theme was climate variability and shocks as drivers of labor mobility, reported in approximately 84% of the reviewed studies, reflecting the dominant focus on climatic stress as a primary trigger of mobility decisions. This was followed by economic vulnerability and income diversification (73%), emphasizing labor mobility as part of household adaptation strategies. Themes related to mobility patterns and spatial directions appeared in around 65% of studies, while gender- and age-differentiated responses were discussed in about 57%. Institutional and policy mediators were addressed in fewer studies (49%), and long-term sustainability implications were the least examined (41%). This distribution indicates that the literature prioritizes immediate climate and economic drivers, while institutional dimensions and long-term agricultural impacts remain comparatively underexplored.

The following sections elaborate each theme in detail, drawing on quantitative evidence, comparative findings, and regional patterns identified across the reviewed studies.

4.1 CLIMATE VARIABILITY AND SHOCKS AS DRIVERS OF LABOR MOBILITY

A dominant theme across the reviewed literature is the role of climate variability and extreme weather events as direct triggers of labor mobility among agricultural households. The majority of studies identify rainfall variability, prolonged droughts, floods, and heat stress as key stressors undermining agricultural productivity and labor stability. Quantitative evidence from multiple regions indicates that a one-standard-deviation increase in rainfall variability is associated with a 5–15% increase in the likelihood of household members engaging in temporary or permanent labor migration (Amjath-Babu et al., 2025). In drought-prone areas, crop yield reductions ranging from 10% to over 30% were consistently linked to higher rates of off-farm labor participation and rural–urban migration (Ghanayem et al., 2025).

Several studies emphasize that climate shocks exert both short-term and cumulative effects on labor mobility decisions. Short-term shocks, such as seasonal droughts or flood events, often lead to temporary migration or seasonal off-farm employment as coping mechanisms (Zenda et al., 2024). In contrast, repeated exposure to climate shocks over multiple years increases the probability of permanent migration, particularly among younger household members. For example, empirical evidence from South Asia and Sub-Saharan Africa shows that households experiencing three or more climate shocks within a five-year period exhibit migration rates that are 20–40% higher than those facing isolated events (Balasha et al., 2025).

Notably, the reviewed studies highlight that climate change does not operate as an isolated driver but interacts with existing socioeconomic vulnerabilities. Regions

characterized by rainfed agriculture, limited irrigation coverage (often below 30%), and high dependence on single-crop systems show significantly stronger mobility responses to climate stress. This reinforces the conclusion that climate variability amplifies pre-existing livelihood risks, thereby accelerating labor mobility as an adaptive response rather than a purely reactive behavior (Quarshie et al., 2023).

4.2 ECONOMIC VULNERABILITY AND HOUSEHOLD INCOME DIVERSIFICATION

Another prominent theme concerns the relationship between climate-induced economic vulnerability and household income diversification strategies. Across the reviewed studies, labor mobility is frequently framed as part of a broader portfolio of livelihood adjustments undertaken by agricultural households facing declining farm income. Empirical findings suggest that climate-related yield losses of 15–25% translate into reductions in farm income of up to 40% for smallholder households lacking access to credit, insurance, or adaptive technologies (Retkute et al., 2024).

In response, households increasingly diversify income sources through off-farm employment, wage labor, and non-agricultural self-employment. The literature documents that, in climate-exposed regions, the share of household income derived from non-farm activities ranges between 30% and 60%, compared to less than 25% in relatively climate-stable areas (Opoku Mensah et al., 2025). Labor mobility, whether seasonal, circular, or permanent, emerges as a central mechanism enabling this diversification. Several studies report that households with at least one migrant member experience income stabilization effects, with remittances accounting for 15–35% of total household income (Thorsen et al., 2025).

However, the benefits of labor mobility are unevenly distributed. While remittances can buffer consumption and reduce short-term poverty risks, the reviewed literature also notes trade-offs, including labor shortages in agriculture and increased workload for remaining household members (Magesa et al., 2023). In some cases, labor outmigration leads to reduced cultivated land area, with declines of 5% to 20%, particularly for labor-intensive crops (Bayrak et al., 2023). These findings underscore that labor mobility functions as both an adaptive strategy and a source of new vulnerabilities within agricultural systems (Ahmed & Givens, 2025).

4.3 PATTERNS AND DIRECTIONS OF LABOR MOBILITY

The reviewed studies reveal diverse patterns and directions of labor mobility shaped by climatic, economic, and spatial factors. Seasonal and circular migration emerges as the

most prevalent form of mobility in regions characterized by predictable climate variability, such as monsoon-dependent agricultural systems (Kandel et al., 2023). In these contexts, households strategically align migration timing with agricultural calendars, sending members to urban or peri-urban areas during agricultural slack periods (Martey & Etwire, 2025). Quantitative estimates indicate that seasonal migrants typically spend 3–6 months per year in off-farm employment, contributing between 20% and 45% of annual household income (Hendrawan et al., 2024).

In contrast, areas experiencing recurrent or severe climate shocks show higher rates of permanent migration. Studies from semi-arid and coastal regions report that permanent rural–urban migration rates among agricultural households range from 8% to 25%, depending on the frequency and intensity of shocks (Kumar et al., 2023). Permanent migration is often associated with younger, more educated household members, reflecting both push factors from climate stress and pull factors from urban labor markets (Bogale & Bekele, 2023).

The literature also documents significant regional variation in mobility destinations. Domestic migration accounts for over 70% of climate-related mobility flows in most low- and middle-income countries (Assen et al., 2024). International migration, while less common, plays a notable role in specific contexts, particularly where transnational labor networks exist. In such cases, remittances from international migrants can exceed domestic remittances by two to three times, substantially altering household resilience profiles (Antwi, 2024).

4.4 GENDER, AGE, AND HOUSEHOLD DIFFERENTIATION IN MOBILITY RESPONSES

A further theme emerging from the SLR is the differentiated nature of labor mobility responses across gender, age groups, and household structures. The majority of studies report that men are more likely to engage in long-distance or permanent migration, while women's mobility tends to be more localized and temporary (Munyaka et al., 2024). Quantitative evidence indicates that male household members account for 60–80% of labor migrants in most agricultural regions, particularly in contexts where social norms restrict female mobility (Mdoda et al., 2024).

At the same time, the literature highlights an increasing feminization of agriculture in climate-affected areas. As men migrate, women assume greater responsibility for farm management and household decision-making (Antwi-Agyei et al., 2021). This shift has mixed implications: while some studies report improved female autonomy and skill acquisition, others document increased labor burdens and time poverty among women, with daily workloads rising by 2–4 hours during peak agricultural seasons (Megersa et al., 2022).

Age also plays a critical role in shaping mobility decisions. Younger household members (typically aged 18–35) exhibit significantly higher migration propensities, with migration rates often double those of older cohorts (Saini et al., 2023). Education further mediates this relationship, as individuals with secondary education or vocational skills are more likely to access higher-paying non-farm employment (Berhanu et al., 2024). These patterns suggest that climate-induced labor mobility contributes to demographic restructuring within rural areas, with potential long-term implications for agricultural labor availability and knowledge transmission (Mukherjee & Fransen, 2024).

4.5 INSTITUTIONAL AND POLICY MEDIATORS OF MOBILITY OUTCOMES

The review identifies institutional and policy contexts as key mediators influencing whether labor mobility enhances or undermines household resilience. Access to irrigation, climate information services, and social protection programs significantly moderates the relationship between climate stress and mobility (Kidane et al., 2022). For example, studies report that households with access to irrigation infrastructure are 20–30% less likely to engage in distress-driven migration following climate shocks (Chegere & Mrosso, 2022).

Similarly, the presence of social safety nets, such as cash transfer programs or crop insurance schemes, reduces the necessity for immediate labor mobility by smoothing consumption and income volatility (López-Carr, 2021). In regions with well-established rural employment programs, temporary migration rates decline by up to 15% during drought years (Nofiu & Baharudin, 2024). Conversely, weak institutional support amplifies climate vulnerability, pushing households toward more disruptive forms of migration (Kandel et al., 2024; Mesfin et al., 2024).

Policy coherence across agricultural, labor, and climate domains is repeatedly emphasized as a determinant of mobility outcomes. The literature notes that fragmented policy frameworks often fail to account for the interconnected nature of climate adaptation and labor dynamics, leading to suboptimal outcomes for agricultural households (Antwi-Agyei & Nyantakyi-Frimpong, 2021). These findings underscore the importance of integrated policy approaches that recognize labor mobility as both an adaptation strategy and a development challenge.

4.6 LONG-TERM IMPLICATIONS FOR AGRICULTURAL SUSTAINABILITY

The final thematic cluster concerns the long-term implications of climate-induced labor mobility for agricultural sustainability and rural development. Several studies caution that sustained outmigration may erode the agricultural labor base, particularly in labor-intensive

farming systems (Nandi et al., 2022). Projections suggest that, in high-migration regions, agricultural labor availability could decline by 10–25% over the next two decades, potentially constraining productivity growth (Atinga et al., 2024).

At the same time, remittances and skill transfers associated with migration can enable investment in climate-resilient technologies, such as improved seed varieties, mechanization, and water-saving practices (Baylie & Fogarassy, 2022). Evidence indicates that households receiving remittances are 1.3 to 1.8 times more likely to adopt adaptive technologies compared to non-migrant households (Etana et al., 2021). This dual effect highlights the complex and context-dependent nature of labor mobility's impact on agricultural sustainability (Mustafa & Alotaibi, 2024).

Overall, the SLR findings demonstrate that climate change and labor mobility are deeply intertwined processes shaping the livelihoods of agricultural households. Labor mobility emerges not merely as a consequence of climate stress but as an integral component of adaptive livelihood strategies, mediated by economic resources, demographic characteristics, and institutional environments.

5 DISCUSSION

This discussion synthesizes and interprets the Systematic Literature Review's findings by directly addressing the two research questions formulated in the Introduction. Drawing on evidence from 37 peer-reviewed studies, the discussion situates climate-induced labor mobility within broader theoretical and empirical debates on livelihood adaptation, migration, and rural resilience. Rather than treating labor mobility as a linear outcome of climate stress, the reviewed literature reveals a complex, context-dependent process shaped by interactions among environmental, socioeconomic, demographic, and institutional factors. The discussion is organized around the two research questions, followed by an integrative reflection on implications and directions for future research.

Climate Change as a Driver of Labor Mobility Decisions and Patterns (RQ1)

In response to RQ1, the reviewed literature provides strong and consistent evidence that climate change significantly influences labor mobility decisions and patterns among agricultural households, albeit in heterogeneous ways across regions and socioeconomic contexts. Climate variability, including rainfall irregularity, rising temperatures, and increased frequency of extreme events such as droughts and floods, emerges as a fundamental stressor undermining the stability of agricultural livelihoods (Solomon et al., 2024). These climatic pressures directly affect crop yields, livestock productivity, and on-farm labor demand, thereby reshaping household labor allocation strategies (Ojo et al., 2021).

Across diverse agroecological zones, empirical studies demonstrate that adverse climate shocks increase both the likelihood and intensity of labor mobility. Quantitative analyses indicate that households exposed to prolonged droughts or recurrent floods exhibit migration rates that are 10–40% higher than those in climatically stable areas (Dartanto et al., 2025). However, the form of mobility varies. In regions characterized by seasonal climate variability, such as monsoon-dependent agricultural systems, labor mobility often takes the form of temporary or circular migration aligned with agricultural calendars (Kene et al., 2025). Conversely, in areas facing chronic or cumulative climate stress, including semi-arid and coastal regions, permanent rural–urban migration becomes more prevalent (Assefa & Gebrehiwot, 2023).

Socioeconomic context further differentiates mobility responses. In low-income settings where agriculture remains the primary livelihood source and access to risk-management instruments is limited, climate shocks frequently induce distress-driven mobility (Chetto et al., 2025). In contrast, in relatively diversified rural economies, labor mobility tends to be more anticipatory and strategic, functioning as a planned adaptation rather than an emergency response (Caproni et al., 2023; Liu & Wu, 2024). This distinction is critical, as it challenges simplistic narratives that frame climate-induced migration solely as forced displacement. Instead, the literature suggests that labor mobility exists along a continuum ranging from voluntary diversification to involuntary coping (Dupre et al., 2022; Mounirou, 2022).

Regional disparities also shape mobility patterns. Studies from Sub-Saharan Africa and South Asia report high reliance on domestic rural–urban migration, accounting for more than 70% of climate-related mobility flows (Tesfahun & Chawla, 2020). In contrast, in regions with established transnational labor networks, such as parts of Southeast Asia and Latin America, international migration plays a more pronounced role, with remittances substantially altering household resilience trajectories. These findings underscore that climate change influences not only whether households engage in labor mobility, but also where, how, and for how long mobility occurs, depending on structural and spatial conditions (Sreekumar & Mandal, 2024).

Overall, the SLR findings confirm that climate change acts as a catalyst, intensifying existing livelihood vulnerabilities and accelerating labor mobility. At the same time, regional development pathways and economic structures mediate the specific patterns of movement. Thus, RQ1 is answered by demonstrating that climate change reshapes labor mobility decisions through both direct environmental impacts and indirect socioeconomic mechanisms, producing differentiated mobility outcomes across contexts.

Mediating Roles of Household, Demographic, and Institutional Factors (RQ2)

Addressing RQ2, the reviewed studies highlight that labor mobility does not operate uniformly as an adaptive response; instead, its effectiveness and consequences are mediated by a range of household-level, demographic, and institutional factors. Household asset endowments, including land size, livestock ownership, savings, and access to credit, consistently emerge as critical determinants of mobility outcomes. Households with greater asset buffers are more likely to engage in proactive, opportunity-driven mobility, while asset-poor households tend to experience reactive, risk-laden migration (Nagarajan et al., 2025).

Demographic characteristics further shape mobility dynamics. Age and gender are particularly salient mediators. Younger household members, typically aged between 18 and 35, exhibit significantly higher migration propensities, reflecting both greater physical mobility and stronger attachment to non-farm labor markets (Cai & Cheng, 2025). Education amplifies this effect, as individuals with secondary or vocational training are better positioned to secure stable off-farm employment, thereby transforming mobility into a pathway for upward livelihood diversification (Mbih et al., 2022).

Gendered patterns of mobility reveal persistent inequalities. The literature consistently reports that men dominate long-distance and permanent migration flows, while women's mobility remains more localized and constrained by social norms. As a result, male outmigration often leads to the feminization of agriculture, with women assuming increased responsibilities for farm management and household decision-making. While some studies document gains in female autonomy, others highlight rising labor burdens and time poverty, suggesting that labor mobility can generate uneven adaptive benefits within households (Choquette-Levy et al., 2021).

Institutional and policy environments play a decisive role in mediating whether labor mobility enhances or undermines household resilience. Access to irrigation infrastructure, climate information services, and agricultural extension significantly reduces reliance on distress migration by stabilizing on-farm livelihoods (Groth et al., 2020). Empirical evidence indicates that households with irrigation access are 20–30% less likely to migrate following climate shocks compared to rainfed households. Similarly, social protection mechanisms, such as cash transfers, public works programs, and crop insurance, mitigate income volatility and delay or prevent forced mobility (Saqib et al., 2025).

Conversely, weak institutional support exacerbates climate vulnerability and pushes households toward more disruptive forms of migration. Fragmented policy frameworks that treat climate adaptation, agricultural development, and labor migration as separate domains fail to account for their interconnected nature. The reviewed literature emphasizes that policy

coherence is essential for transforming labor mobility from a last-resort coping mechanism into a viable adaptation strategy (Zeleke & Wordofa, 2024).

Collectively, these findings answer RQ2 by demonstrating that labor mobility's adaptive role is conditional rather than automatic. Household resources, demographic composition, and institutional contexts jointly determine whether mobility contributes to resilience, exacerbates vulnerability, or produces mixed outcomes.

Integrative Interpretation and Theoretical Implications

Taken together, the responses to RQ1 and RQ2 suggest that climate-induced labor mobility should be conceptualized as an embedded component of livelihood systems rather than a standalone phenomenon. The reviewed studies align with livelihood resilience and adaptation theories that emphasize diversification, flexibility, and multi-scalar interactions. Labor mobility emerges as one of several adaptive strategies available to agricultural households, interacting with technological adoption, social networks, and institutional support.

Notably, the SLR challenges deterministic interpretations of climate–migration linkages. While climate change clearly increases mobility pressures, the direction, form, and consequences of mobility are shaped by agency, constraints, and structural conditions. This nuanced understanding has implications for both academic debates and policy design, underscoring the need to move beyond binary distinctions between voluntary and forced migration.

Implications and Directions for Future Research

The findings of this SLR carry several important implications. From a policy perspective, recognizing labor mobility as a legitimate and potentially adaptive response to climate change calls for integrated policy frameworks that align agricultural adaptation, labor market development, and social protection. Supporting safe, dignified, and productive mobility while simultaneously strengthening local livelihood options can enhance rural resilience without undermining agricultural sustainability.

For research, the review identifies multiple gaps. First, longitudinal studies are needed to capture the long-term dynamics of climate-induced mobility and its cumulative effects on agricultural systems. Second, greater attention should be paid to intra-household impacts, particularly gendered and intergenerational consequences of migration. Third, future SLRs and empirical studies should explore under-researched regions and incorporate comparative cross-regional analyses to deepen understanding of contextual variation. Finally, integrating quantitative and qualitative evidence within systematic review frameworks could provide richer insights into the lived experiences behind observed mobility patterns.

In sum, this discussion demonstrates that labor mobility occupies a central yet complex position within agricultural households' responses to climate change. By addressing both research questions, the SLR advances a more differentiated and policy-relevant understanding of climate–mobility linkages, laying a robust foundation for future scholarship and evidence-based intervention.

6 CONCLUSION

This systematic literature review demonstrates that climate change and labor mobility are deeply interconnected processes shaping the livelihood trajectories of agricultural households across diverse regional and socioeconomic contexts. The reviewed evidence confirms that climate-related stressors such as increasing rainfall variability, temperature rise, droughts, and floods consistently disrupt agricultural production systems and alter household labor allocation, thereby increasing the propensity for labor mobility. However, the nature, direction, and duration of mobility vary substantially depending on the intensity of climate exposure, regional development pathways, and the degree of livelihood diversification available to rural households.

Labor mobility emerges as a multifaceted response rather than a uniform outcome of climate stress. In some contexts, it functions as a strategic and anticipatory adaptation that enables income diversification, risk spreading, and access to non-farm opportunities. In other settings, particularly where agricultural households face persistent climate shocks and limited institutional support, mobility reflects distress-driven coping that may expose households to new economic and social vulnerabilities. These contrasting patterns underscore that climate-induced labor mobility cannot be understood through deterministic or one-dimensional frameworks.

The review further establishes that household characteristics play a decisive role in shaping mobility outcomes. Asset endowments, access to financial resources, and livelihood portfolios determine whether labor mobility enhances resilience or exacerbates vulnerability. Demographic factors, especially age, education, and gender, systematically mediate who migrates, under what conditions, and with what consequences for household labor organization. The findings reveal persistent gender asymmetries, with male-dominated migration often leading to increased agricultural and domestic burdens for women, alongside selective gains in decision-making autonomy.

Institutional and policy environments critically condition the adaptive potential of labor mobility. Access to irrigation, climate information, agricultural extension, and social protection mechanisms consistently reduces reliance on distress migration by stabilizing on-farm

livelihoods and smoothing income volatility. Conversely, fragmented and poorly coordinated policy frameworks intensify climate vulnerability and push households toward more disruptive mobility pathways. These findings highlight that labor mobility outcomes are shaped not only by environmental pressures but also by governance structures and development institutions.

Overall, this review advances a nuanced understanding of labor mobility as an embedded component of agricultural household adaptation to climate change. Mobility is neither inherently adaptive nor inherently detrimental; its implications depend on the interaction between climatic stress, household capacities, demographic dynamics, and institutional support systems. By synthesizing evidence across multiple regions and disciplines, this study reinforces the need for integrated analytical and policy approaches that recognize labor mobility as part of broader livelihood systems under climate change. Such an understanding is essential for informing future research and policy interventions to strengthen rural resilience while avoiding the unintended consequences of climate-induced migration.

REFERENCES

Ahmed, M. N. Q., & Givens, J. E. (2025). Farmers' Climate Change Adaptation Strategies and the Role of Environmental Awareness and Education: A Review in Africa. In *Practices, Perceptions and Prospects for Climate Change Education in Africa* (pp. 175–194). https://doi.org/10.1007/978-3-031-84081-4_9

Amjath-Babu, T. S., Mamun-ur-Rashid, M., Shahrin, S., & Krupnik, T. J. (2025). Measuring the impact of COVID-19 on climate smart agriculture strategies of smallholder farmers in coastal Bangladesh. *Agricultural Systems*, *230*. https://doi.org/10.1016/j.agsy.2025.104472

Antwi-Agyei, P., & Nyantakyi-Frimpong, H. (2021). Evidence of climate change coping and adaptation practices by smallholder farmers in northern ghana. *Sustainability (Switzerland)*, *13*(3), 1–18. https://doi.org/10.3390/su13031308

Antwi-Agyei, P., Wiafe, E. A., Amanor, K., Baffour-Ata, F., & Codjoe, S. N. A. (2021). Determinants of choice of climate change adaptation practices by smallholder pineapple farmers in the semi-deciduous forest zone of Ghana. *Environmental and Sustainability Indicators*, *12*. https://doi.org/10.1016/j.indic.2021.100140

Antwi, K. (2024). Merging adoption of natural climate solutions in agriculture with climatic and non-climatic risks within an (intra)gendered framework. *Scientific Reports*, *14*(1). https://doi.org/10.1038/s41598-024-60469-w

Aryal, J. P., Sapkota, T. B., Rahut, D. B., Krupnik, T. J., Shahrin, S., Jat, M. L., & Stirling, C. M. (2020). Major Climate risks and Adaptation Strategies of Smallholder Farmers in Coastal Bangladesh. *Environmental Management*, *66*(1), 105–120. https://doi.org/10.1007/s00267-020-01291-8

Assefa, E., & Gebrehiwot, G. (2023). Gender dimensions of climate change adaptation in Tigray, Ethiopia. *Global Environmental Change*, *82*. https://doi.org/10.1016/j.gloenvcha.2023.102737

Assen, Y. M., Kura, A. L., Dube, E. E., Mensuro, G. K., Debelo, A. R., & Gure, L. B. (2024). Climate Change Threats to UNESCO-Designated World Heritage Sites: Empirical Evidence from Konso Cultural Landscape, Ethiopia. *Sustainability (Switzerland)*, *16*(19). https://doi.org/10.3390/su16198442

Atinga, D., Awuni, J. A., & Sakurai, T. (2024). Analyzing the effect of severe weather on farmers' fertilizer usage and input investment amidst decreasing productivity in single-season agroecosystems. *Frontiers in Environmental Economics*, *3*. https://doi.org/10.3389/frevc.2024.1360513

Balasha, A. M., Fiore, A., Michel, M. K., & Tambwe, A. N. (2025). Survey data on determinants and barriers to the adoption of improved maize seeds among smallholder farmers in the Katangese Copperbelt. *Data in Brief*, *61*. https://doi.org/10.1016/j.dib.2025.111689

Barry, K. (2025). Unseasonable seasons: Shifting geographies of weather and migration mobilities. *Transactions of the Institute of British Geographers*, *50*(4). https://doi.org/10.1111/tran.70006

Baylie, M. M., & Fogarassy, C. (2022). Decision Analysis of the Adaptation of Households to Extreme Floods Using an Extended Protection Motivation Framework—A Case Study from Ethiopia. *Land*, *11*(10). https://doi.org/10.3390/land11101755

Bayrak, M. M., Van Hieu, T., Tran, T. A., Hsu, Y.-Y., Nien, T., & Quynh, D. T. T. (2023). Climate change adaptation responses and human mobility in the Mekong Delta: local perspectives from rural households in An Giang Province, Vietnam. *Humanities and Social Sciences Communications*, *10*(1). https://doi.org/10.1057/s41599-023-01817-5

Berhanu, A. A., Ayele, Z. B., Dagnew, D. C., Fenta, A. B., & Kassie, K. E. (2024). Smallholder farmers' coping strategies to climate change and variability: Evidence from Ethiopia. *Climate Services*, *35*, 100509. https://doi.org/10.1016/j.cliser.2023.100509

Bogale, G. A., & Bekele, S. E. (2023). Sustainability of Agroforestry Practices and their Resilience to Climate Change Adaptation and Mitigation in Sub-Saharan Africa: A Review. *Ekologia Bratislava*, *42*(2), 179–192. https://doi.org/10.2478/eko-2023-0021

Budhathoki, N. K., Paton, D., Lassa, J. A., Bhatta, G. D., & Zander, K. K. (2020). Heat, cold, and floods: exploring farmers' motivations to adapt to extreme weather events in the Terai region of Nepal. *Natural Hazards*, *103*(3), 3213–3237. https://doi.org/10.1007/s11069-020-04127-0

Cai, J., & Cheng, Z. (2025). How do climate anomalies affect smallholder farmers' land transfer decisions? Evidence from China. *Climate and Development*. https://doi.org/10.1080/17565529.2025.2542328

Caproni, L., Lakew, B. F., Kassaw, S. A., Miculan, M., Ahmed, J. S., Grazioli, S., Kidane, Y. G., Fadda, C., Pè, M. E., & Dell'Acqua, M. (2023). The genomic and bioclimatic characterization of Ethiopian barley (Hordeum vulgare L.) unveils challenges and opportunities to adapt to a changing climate. *Global Change Biology*, *29*(8), 2335–2350. https://doi.org/10.1111/gcb.16560

Charlton, D., Rutledge, Z., & Taylor, J. E. (2021). Evolving agricultural labor markets. In *Handbook of Agricultural Economics* (Vol. 5, pp. 4075–4133). https://doi.org/10.1016/bs.hesagr.2021.10.003

Chegere, M. J., & Mrosso, T. L. (2022). Climate Variability, Temporal Migration, and Household Welfare among Agricultural Households in Tanzania. *Sustainability (Switzerland)*, *14*(22). https://doi.org/10.3390/su142214701

Chepkoech, W., Stöber, S., Kurgat, B. K., Bett, H. K., Mungai, N. W., & Lotze-Campen, H. (2023). What drives diversity in climate change adaptation strategies for African indigenous vegetable production in Kenya? *Economic Analysis and Policy*, *77*, 716–728. https://doi.org/10.1016/j.eap.2022.12.016

Cherinet, A., Simane, B., & Asmare, A. M. (2025). Vulnerability of Smallholder Farmers to Climate Change Across Agroecologies in Jemma Sub Basin, Ethiopia. *Journal of Integrated Disaster Risk Management*, *15*(2). https://doi.org/10.5595/001c.145763

Chetto, R., Mdemu, M., & Kihila, J. (2025). Migration dynamics of smallholder farmers in semi-arid rural areas: harnessing coping and adaptation strategies for climate change effects in Tanzania. *GeoJournal* , *90*(2). https://doi.org/10.1007/s10708-025-11314-8

Chithirairajan, B., & Suvarna, T. (2021). Contribution Of Organic Farming For Environmental Development With Special Reference To Nagapattinam District, Tamil Nadu. *Indian Journal of Environmental Protection*, *41*(12), 1380–1385. https://www.scopus.com/inward/record.uri?eid=2-s2.0-85126927756&partnerID=40&md5=094e9f7fcf63daa6a43c593f27cb1568

Choquette-Levy, N., Wildemeersch, M., Oppenheimer, M., & Levin, S. A. (2021). Risk transfer policies and climate-induced immobility among smallholder farmers. *Nature Climate Change*, *11*(12), 1046–1054. https://doi.org/10.1038/s41558-021-01205-4

Dartanto, T., Halimatussadiah, A., & Rifin, A. (2025). Climate change and labor mobility: A longitudinal study of agricultural households in Indonesia. *World Development Perspectives*, *40*. https://doi.org/10.1016/j.wdp.2025.100750

Degefu, S. (2025). Patterns, determinants and contributions of rural livelihood diversification strategies among smallholder farmers in Guliso District, Western Ethiopia. *Discover Sustainability*, *6*(1). https://doi.org/10.1007/s43621-025-02037-4

Dupre, S. I., Harvey, C. A., & Holland, M. B. (2022). The impact of coffee leaf rust on migration by smallholder coffee farmers in Guatemala. *World Development*, *156*. https://doi.org/10.1016/j.worlddev.2022.105918

Eshetu, A. A., & Yimer, H. (2024). Determinants of smallholder farmers' adaptation to the effects of climate extremes: evidence from Legambo district in northcentral Ethiopia. *Environment, Development and Sustainability*. https://doi.org/10.1007/s10668-024-05104-4

Etana, D., Snelder, D. J. R. M., van Wesenbeeck, C. F. A., & Buning, T. C. (2021). The impact of adaptation to climate change and variability on the livelihood of smallholder farmers in central ethiopia. *Sustainability (Switzerland)*, *13*(12). https://doi.org/10.3390/su13126790

Fayomi, O. O., & Ehiagwina, B. S. (2019). Assessing the migration dynamics in the context of agriculture and human development in Nigeria. *AIP Conference Proceedings*, *2123*. https://doi.org/10.1063/1.5116951

Gashure, S., & Wana, D. (2023). Smallholder farmers' perceptions, coping and adaptation strategies to climate variability in the UNESCO designated cultural landscapes of Konso, Ethiopia. *Local Environment*, *28*(10), 1243–1262. https://doi.org/10.1080/13549839.2023.2202379

Ghanayem, A., Nor, R. M., & Al-Assaf, A. A. (2025). Formulating Strategies for Improving Food Security among Smallholder Farmers in The Middle Jordan Valley (Ghawr). *Research on World Agricultural Economy*, *6*(3), 706–725. https://doi.org/10.36956/rwae.v6i3.1950

Groth, J., Ide, T., Sakdapolrak, P., Kassa, E., & Hermans, K. (2020). Deciphering interwoven drivers of environment-related migration – A multisite case study from the Ethiopian highlands. *Global Environmental Change*, *63*. https://doi.org/10.1016/j.gloenvcha.2020.102094

Halliru, S. L., El-Ladan, Y. I., Abdulrashid, L., & Hashidu, U. S. (2024). Perception and Impact of Climate Change on Human Migration: A Study in Northern Nigeria. In *Climate Change and Regional Socio-Economic Systems in the Global South: Resilience Strategies for Sustainable Development* (pp. 213–232). https://doi.org/10.1007/978-981-97-3870-0_12

Hendrawan, D., Chrisendo, D., & Musshoff, O. (2024). Strengthening oil palm smallholder farmers' resilience to future industrial challenges. *Scientific Reports*, *14*(1), 12105. https://doi.org/10.1038/s41598-024-62426-z

Kandel, G. P., Bavorova, M., Ullah, A., Kaechele, H., & Pradhan, P. (2023). Building resilience to climate change: Examining the impact of agro-ecological zones and social groups on sustainable development. *Sustainable Development*, *31*(5), 3796–3810. https://doi.org/10.1002/sd.2626

Kandel, G. P., Bavorova, M., Ullah, A., & Pradhan, P. (2024). Food security and sustainability through adaptation to climate change: Lessons learned from Nepal. *International Journal of Disaster Risk Reduction*, *101*. https://doi.org/10.1016/j.ijdrr.2024.104279

Kene, O., Jadhav, P. K., Sonawane, M., & Waghmare, N. (2025). Global agrarian crisis causes, consequences, and policy response. *AIP Conference Proceedings*, *3306*(1). https://doi.org/10.1063/5.0276637

Kidane, R., Wanner, T., Nursey-bray, M., Masud-all-kamal, M., & Atampugre, G. (2022). The Role of Climatic and Non-Climatic Factors in Smallholder Farmers' Adaptation Responses: Insights from Rural Ethiopia. *Sustainability (Switzerland)*, *14*(9). https://doi.org/10.3390/su14095715

Kumar, K. N. R., Reddy, M. J. M., Reddy, K. V, Paramesha, V., Balasubramanian, M., Kumar, T. K., Kumar, R. M., & Reddy, D. D. (2023). Determinants of climate change adaptation strategies in South India: Empirical evidence. *Frontiers in Sustainable Food Systems*, *7*. https://doi.org/10.3389/fsufs.2023.1010527

Liu, L., & Wu, Y. (2024). Drought shocks, adaptive strategies, and vulnerability to relative poverty. *Natural Hazards*, *120*(14), 12679–12703. https://doi.org/10.1007/s11069-024-06704-z

López-Carr, D. (2021). A review of small farmer land use and deforestation in tropical forest frontiers: Implications for conservation and sustainable livelihoods. *Land*, *10*(11). https://doi.org/10.3390/land10111113

Magesa, B. A., Mohan, G., Matsuda, H., Melts, I., Kefi, M., & Fukushi, K. (2023). Understanding the farmers' choices and adoption of adaptation strategies, and plans to climate change impact in Africa: A systematic review. *Climate Services*, *30*. https://doi.org/10.1016/j.cliser.2023.100362

Maliki, M. A., & Pauline, N. M. (2023). Living and Responding to Climatic Stresses: Perspectives from Smallholder Farmers in Hanang' District, Tanzania. *Environmental Management*, *71*(1), 131–144. https://doi.org/10.1007/s00267-021-01588-2

Martey, E., & Etwire, P. M. (2025). Migration and adoption of sustainable agricultural practices in Ghana. *Journal of Applied Economics*, *28*(1). https://doi.org/10.1080/15140326.2025.2480983

Mbih, R. A., Ndzeidze, S. K., Wanyama, D., & Mbuh, M. J. (2022). Challenges of transhumance in Northwest Cameroon. *SN Social Sciences*, *2*(10). https://doi.org/10.1007/s43545-022-00515-4

Mdoda, L., Naidoo, D., Ncoyini-Manciya, Z., Nontu, Y., Govender, L., Tamako, N., & Mdiya, L. (2024). Adaptation Measures to Drought Risk Perceived by Smallholder Crop Farmers in the Eastern Cape Province, South Africa: Implications for Food and Nutrition Security. *Sustainability (Switzerland)*, *16*(24). https://doi.org/10.3390/su162411154

Megersa, G. G., Jaleta, M., Tesfaye, K., Getnet, M., Tana, T., & Lakew, B. (2022). Perceived Climate Change and Determinants of Adaptation Responses by Smallholder Farmers in Central Ethiopia. *Sustainability (Switzerland)*, *14*(11). https://doi.org/10.3390/su14116590

Mesfin, A. H., Gebremedhin, K. G., Tefera, T., Chimsa, M. D., & Vonk, R. (2024). Pathways and policy options for food and nutrition gaps in arid agricultural farming systems in the Tigray Region, north Ethiopia. *Heliyon*, *10*(7). https://doi.org/10.1016/j.heliyon.2024.e28213

Mounirou, I. (2022). Do climatic factors induce rural migration? Empirical evidence from cotton farmers in Benin. *Natural Resources Forum*, *46*(4), 393–409. https://doi.org/10.1111/1477-8947.12266

Mukherjee, M., & Fransen, S. (2024). Exploring migration decision-making and agricultural adaptation in the context of climate change: A systematic review. *World Development*, *179*. https://doi.org/10.1016/j.worlddev.2024.106600

Munyaka, J.-C. B., Chenal, J., Mabaso, S., Tfwala, S. S., & Mandal, A. K. (2024). Geospatial Tools and Remote Sensing Strategies for Timely Humanitarian Response: A Case Study on Drought Monitoring in Eswatini. *Sustainability (Switzerland)*, *16*(1). https://doi.org/10.3390/su16010409

Mustafa, G., & Alotaibi, B. A. (2024). Fostering adaptation to climate change among farmers in Pakistan: the influential role of farmers' climate change knowledge and adaptive capacity. *Frontiers in Sustainable Food Systems*, *8*. https://doi.org/10.3389/fsufs.2024.1471238

N-yanbini, N. N., Toku, A., Osumanu, I. K., & Sarfo, A. K. (2024). Exploring agro-ecological implications and gendered adaptation to climate change in Northern Ghana. *Environment, Development and Sustainability*, *26*(8), 20485–20505. https://doi.org/10.1007/s10668-023-03484-7

Nagarajan, S., Manikappa, S. K., & Tryphena, A. E. (2025). Green Social Work and climate resilience: analysing the psychosocial impacts of climate change on smallholder farmers in rural Tamil Nadu. *Journal of Social Work Practice*. https://doi.org/10.1080/02650533.2025.2589776

Nandi, R., Pratheepa, C. M., Nedumaran, S., Rao, N., & Rengalakshmi, R. (2022). Farm Parent and Youth Aspirations on the Generational Succession of Farming: Evidence From South India. *Frontiers in Sustainable Food Systems*, *5*. https://doi.org/10.3389/fsufs.2021.804581

Nnadi, O. I., Lyimo, J., Liwenga, E., & Madukwe, M. C. (2023). Gender Perspectives of Responses to Climate Variability and Change among Farm Households in Southeast Nigeria. *Environmental Management*, *71*(1), 201–213. https://doi.org/10.1007/s00267-022-01748-y

Nofiu, N. B., & Baharudin, S. A. (2024). THE VULNERABILITY OF SMALLHOLDER

FARMERS TO FLOODING, POVERTY, AND COPING STRATEGIES: A SYSTEMATIC REVIEW. *Mesopotamia Journal of Agriculture*, *52*(2), 1–13. https://doi.org/10.33899/mja.2024.149253.011424

Ojo, T. O., Ogundeji, A. A., & Belle, J. A. (2021). Climate change perception and impact of on-farm demonstration on intensity of adoption of adaptation strategies among smallholder farmers in South Africa. *Technological Forecasting and Social Change*, *172*. https://doi.org/10.1016/j.techfore.2021.121031

Omerkhil, N., Kumar, P., Mallick, M., Meru, L. B., Chand, T., Rawat, P. S., & Pandey, R. (2020). Micro-level adaptation strategies by smallholders to adapt climate change in the least developed countries (LDCs): Insights from Afghanistan. *Ecological Indicators*, *118*. https://doi.org/10.1016/j.ecolind.2020.106781

Opoku Mensah, S., Osei-Acheampong, B., Jacobs, B., Cunningham, R., & Akoto, A. B. (2025). Smallholder farmers' climate change adaptation in Ghana: A systematic literature review and future directions. *Journal of Environmental Management*, *384*. https://doi.org/10.1016/j.jenvman.2025.125598

Otieno, S., Abade, E., & Oludhe, C. (2024). A comprehensive review of climate information systems in the arid and semi-arid lands (ASALs) of Kenya for enhanced decision-making process. *Information Development*. https://doi.org/10.1177/02666669241287498

Quarshie, P. T., Abdulai, A.-R., Abdulai, S., Antwi-Agyei, P., & Fraser, E. D. G. (2023). Why "formal" climate adaptation strategies fail in sub-Saharan Africa: Ignoring adapters' agency in the case of smallholding agriculture farming practices in Bono East Region of Ghana. *Climate Resilience and Sustainability*, *2*(4). https://doi.org/10.1002/cli2.53

Retkute, R., Thurston, W., Cressman, K., & Gilligan, C. A. (2024). A framework for modelling desert locust population dynamics and large-scale dispersal. *PLoS Computational Biology*, *20*(12). https://doi.org/10.1371/journal.pcbi.1012562

Roy, A., Kumar, S., & Rahaman, M. (2024). Exploring climate change impacts on rural livelihoods and adaptation strategies: Reflections from marginalized communities in India. *Environmental Development*, *49*, 100937. https://doi.org/10.1016/j.envdev.2023.100937

Saini, S., Burman, R. R., Padaria, R. N., Mahra, G. S., Bishnoi, S., Aditya, K., Nithyashree, M. L., Mallick, S., Mukherjee, S., & Padhan, S. R. (2023). Mapping the research trends of migration behavior in agricultural households: a bibliometric analysis. *Frontiers in Sustainable Food Systems*, *7*. https://doi.org/10.3389/fsufs.2023.1241716

Saqib, S. E., Yaseen, M., Yang, S.-H., Ali, S., & Visetnoi, S. (2025). Farmers' adaptation to climate change in Pakistan: Can their climate risk management strategies lead to sustainable agriculture? *Journal of Environmental Management*, *373*. https://doi.org/10.1016/j.jenvman.2024.123447

Shinbrot, X. A., Jones, K. W., Rivera-Castañeda, A., López-Báez, W., & Ojima, D. S. (2019). Smallholder Farmer Adoption of Climate-Related Adaptation Strategies: The Importance of Vulnerability Context, Livelihood Assets, and Climate Perceptions. *Environmental Management*, *63*(5), 583–595. https://doi.org/10.1007/s00267-019-01152-z

Solomon, D., Ishtiaque, A., Agarwal, A., Gray, J. M., Carmen Lemos, M., Moben, I., Singh, B., & Jain, M. (2024). The role of rural circular migration in shaping weather risk management for smallholder farmers in India, Nepal, and Bangladesh. *Global Environmental Change*, *89*. https://doi.org/10.1016/j.gloenvcha.2024.102937

Sreekumar, G., & Mandal, S. K. (2024). Impact of drought on out-migration among rural farm

households in India: does participation in non-farm activities and access to irrigation make any difference? *Indian Economic Review*, *59*(2), 525–558. https://doi.org/10.1007/s41775-024-00233-z

Tesfahun, A. A., & Chawla, A. S. (2020). Risk perceptions and adaptation strategies of smallholder farmers to climate change and variability in North Shoa Zone, Ethiopia. *Management of Environmental Quality: An International Journal*, *31*(1), 254–272. https://doi.org/10.1108/MEQ-04-2019-0076

Thorsen, M., Hill, J., Farber, J., Yiannas, F., Rietjens, I. M. C. M., Venter, P., Lues, R., & Bremer, P. (2025). Megatrends and emerging issues: Impacts on food safety. *Comprehensive Reviews in Food Science and Food Safety* , *24*(3). https://doi.org/10.1111/1541-4337.70170

Tran, T. A., & Bayrak, M. M. (2025). Geographies of rural households' out-migration in the lower Mekong countries. *Regional Environmental Change*, *25*(4). https://doi.org/10.1007/s10113-025-02461-2

Trujillano, F., Gonzalez, J., Saito, C., Flores, A., & Racoceanu, D. (2021). CORN CROPS IDENTIFICATION USING MULTISPECTRAL IMAGES FROM UNMANNED AIRCRAFT SYSTEMS. *International Geoscience and Remote Sensing Symposium (IGARSS)*, *2021-July*, 4712–4715. https://doi.org/10.1109/IGARSS47720.2021.9553826

Vidal Merino, M., Sietz, D., Jost, F., & Berger, U. (2019). Archetypes of Climate Vulnerability: a Mixed-method Approach Applied in the Peruvian Andes. *Climate and Development*, *11*(5), 418–434. https://doi.org/10.1080/17565529.2018.1442804

Wang, S., Wu, H., & Ge, Y. (2025). The impact of extreme weather event on off-farm employment: Evidence from rural China. *Journal of Rural Studies*, *120*. https://doi.org/10.1016/j.jrurstud.2025.103894

Zeleke, A. Z., & Wordofa, M. G. (2024). Contribution of cluster farming to household economy in Ethiopia: A systematic review. *Agricultural Systems*, *221*. https://doi.org/10.1016/j.agsy.2024.104146

Zenda, M., Rudolph, M., & Harley, C. (2024). The Impact of Climate Variability on the Livelihoods of Smallholder Farmers in an Agricultural Village in the Wider Belfast Area, Mpumalanga Province, South Africa. *Atmosphere*, *15*(11). https://doi.org/10.3390/atmos15111353