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Psychological and Behavioral Drivers of Sustainable Smallholder Agriculture under Climate Change in Sub-Saharan Africa

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Abstract

Understanding the psychological and behavioral factors that influence smallholder farmers' decisions is crucial for promoting sustainable agriculture in the context of climate change in sub-Saharan Africa (SSA). Smallholder farming systems are the backbone of the agricultural sector in SSA and are crucial for sustaining rural communities, securing food and nutrition, and preserving the environment. However, these systems are particularly prone to the effects of climate fluctuations and long-term shifts in climate. While much research has been directed towards agronomic techniques, livestock care, technological progress, and economic challenges, there is a noticeable gap in understanding the psychological influences on farmers' adaptive and sustainability-focused behaviors. This theoretical paper synthesizes interdisciplinary evidence from psychology, behavioral economics, and agricultural development to explore the cognitive and behavioral determinants of sustainable smallholder agriculture in the context of climate change (CC). Specifically, it examines how risk perception, climate beliefs, cognitive biases, social norms, identity, motivation, experiential learning, and perceived self-efficacy influence decision-making processes related to climate adaptation and the adoption of climate-smart agricultural practices. The review identifies both enabling psychological drivers and behavioral barriers that affect sustainable land management, crop and livestock productivity, and the long-term resilience of the system. Building on this synthesis, this study introduces an integrative framework that connects individual cognitive and behavioral processes to broader sociocultural, institutional, and structural contexts. The framework clarifies the pathways through which behaviorally informed policies, extension systems, and climate communication strategies can enhance adaptive capacity and sustainability. By identifying theoretical gaps and research priorities, this study advances the emerging field of agricultural behavioral science and emphasizes the importance of incorporating psychological insights into climate-resilient development strategies for sub-Saharan African smallholders.

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1. Introduction

Psychology offers a rigorous theoretical and empirical foundation for understanding the behavioral processes that shape sustainable smallholder agriculture under climate change in sub-Saharan Africa (SSA). Behavioral and agricultural economic research increasingly demonstrates that farmers' decisions are not driven solely by prices, incentives, or resource endowments but also by cognitive processes, risk perceptions, identity, and social norms (Omotoso, & Omotayo, 2024; Dessart, *et al* 2019)[16].

Emerging scholarship further links pro-environmental farming behaviors to attitudes toward sustainability transition and net-zero agricultural systems. Research in the field of agricultural behavioral science has demonstrated that sustainable farming practices are influenced by psychological constructs, including perceived behavioral control, motivation, learning orientation, and trust in institutions (Ortega de Jesus Sangali *et al.*, 2024; Framing behavior change for sustainable agriculture review, Ofosu-Ampong *et al.*, 2025; psychological drivers in Kenyan farmers, 2025). Despite this progress, the integration of psychological theory into rural development Eco-generativity, an extension of Erikson's generativity theory that emphasizes intergenerational responsibility and ecological stewardship, provides a valuable perspective for understanding how farmers and other stakeholders cultivate the long-term motivation to implement sustainable agricultural practices (Di Fabio & Svicher, 2023). This study expands on the concept of eco-generativity within a broader psychological and sustainability framework, exploring its origins in generativity theory and its significance for pro-environmental involvement. Integrating such psychological constructs into sustainability science enhances efforts to tackle productivity limitations, technology adoption challenges, poverty, and resource degradation in rural economies in the SSA.

Smallholder farms dominate agricultural production in SSA and support the livelihoods of most rural households. According to the World Bank (2023), smallholders produce a substantial share of the region's food supply and are central to employment and poverty reduction. However, these systems are highly exposed to climate variability and long-term climatic shifts, as emphasized by the Intergovernmental Panel on Climate Change (2022), which identified Africa as one of the most climate-vulnerable regions globally. Rising temperatures, erratic rainfall, and an increasing frequency of extreme events intensify production risks and undermine rural resilience. Earlier adaptation studies have largely concentrated on structural determinants such as credit access, extension services, and infrastructure (Thornton *et al*., 2019) [42]. While these factors are essential, they often assume rational responses to information and incentives are necessary. Contemporary behavioral research challenges this assumption, showing that farmers' decisions are filtered through subjective beliefs, heuristics, trust networks, and culturally embedded norms (Morel and Cartau, 2023). Therefore, integrating psychological and socioeconomic perspectives provides a more comprehensive explanation of adaptation behavior and sustainability transitions.

Recent empirical evidence underscores the urgency of incorporating behavioral insights into climate adaptation strategies in SSA. Studies have documented how affective risk perceptions, experiential learning from climate shocks, and perceived self-efficacy significantly influence the uptake of climate-smart agricultural practices (Incoom *et al*., 2025). The bidirectional relationship between agriculture and climate change, where farming both contributes to and is affected by greenhouse gas emissions, adds complexity to farmer decision-making (Yuan *et al*., 2024; Huo *et al*., 2024; Kabato *et al*., 2025; Pérez-Lucas *et al*., 2024). Behavioral barriers, such as status quo bias, loss aversion, and distrust of institutions, can slow the adoption of sustainable innovations, even when technologies are available. In contrast, social learning, peer effects, and collective efficacy can accelerate adaptation **9Xing and Wang, 2024).** These findings align with the broader climate behavior literature, emphasizing that policy effectiveness depends on aligning interventions with psychological drivers rather than relying solely on technical dissemination models.

The psychology of agriculture compassing cognition, emotion, identity, and social influence plays a pivotal role in shaping climate action among smallholders. Affective responses to climate risks are among the strongest predictors of mitigation and adaptation behaviors, technology acceptance, and policy support (Brosch 2021) [12]. Emotionally resonant climate communication and participatory engagement strategies can enhance advocacy and pro-environmental behaviors (Nabi *et al*., 2018; Wynes & Nicholas, 2017; Clayton *et al*., 2015) [14]. In SSA, where adaptive capacity is often constrained by limited resources and institutional support, behaviorally informed interventions can strengthen resilience by addressing motivational and perceptual barriers. Therefore, this study advances a psychologically grounded framework for sustainable smallholder agriculture under climate change, positioning behavioral science as a critical complement to agronomic, technological, and economic approaches. By linking individual cognition to broader socio-ecological systems, this study contributes to a more integrative understanding of sustainability transitions in sub-Saharan Africa.

2. Conceptual Framework: Psychology and Farmer Behavior in Smallholder Farming Systems

Understanding farmer behavior and behavioral change is central to advancing sustainable practice transitions in smallholder agriculture. Psychological inquiry provides critical insights into how farmers process information, evaluate risk, and translate intentions into action under conditions of climate uncertainty (Brosch, 2021) [12]. Despite the dominance of agronomic and economic explanations in African agricultural research, there is comparatively limited integration of behavioral science into smallholder development frameworks. Agricultural decision-making is not purely rational; it is shaped by cognition, emotions, social influence, and contextual constraints. Theoretical models from social and behavioral psychology therefore offer structured approaches for explaining why farmers adopt—or resist—climate-smart and sustainable innovations in agriculture. This section synthesizes four complementary perspectives: the Theory of Planned Behavior, risk perception and mental models, behavioral economics, social norms and cultural cognition.

2.1. Theory of Planned Behavior (TPB) and Its Applicability in Smallholder Agriculture

The Theory of Planned Behavior (TPB), developed by Ajzen (1985) [2], posits that behavioral intention is the most proximal determinant of action and is shaped by three core constructs: attitudes toward the behavior, subjective norms, and perceived behavioral control. In smallholder contexts, this framework provides a powerful lens for understanding the adoption of climate-smart agriculture (CSA). Farmers are more likely to adopt conservation agriculture, improved livestock management, or drought-resilient crop varieties when they hold favorable attitudes toward these practices, perceive community approval, and believe that they possess the necessary skills and resources to implement them (Hosen *et al*., 2022; Savari *et al*., 2023). The inclusion of perceived behavioral control distinguishes the TPB from the earlier Theory of Reasoned Action and is particularly relevant in SSA, where resource limitations, land tenure insecurity, and gendered access to input shape farmers' sense of agency (Jiar *et al*., 2022).

Recent empirical applications (2022–2025) confirm that TPB constructs significantly predict pro-environmental agricultural intentions and behaviors (Ho *et al*., 2022; Shankar *et al*., 2025; Yee al., 2024). Although TPB does not explain attitude change per se, it remains one of the most robust and widely validated models of voluntary behavior (Fishbein, 2015; Sun *et al*., 2022). Evidence linking TPB variables to biodiversity conservation and sustainable land management further reinforces their relevance in smallholder systems (Ajzen & Schmidt, 2020; Yuriev *et al*., 2020) [4, 47]. For SSA, the TPB provides a structured basis for designing behaviorally informed extension strategies that strengthen farmer motivation, enhance perceived control, and leverage positive social norms to accelerate sustainability transitions under climate change.

2.2. Risk Perception and Mental Models

Smallholders' perception and response to climate change are deeply influenced by their understanding of risk and the mental models they employ to interpret environmental changes. These mental models—internal cognitive representations shaped by personal experiences, indigenous knowledge, and cultural narratives—are pivotal in determining whether climatic changes are viewed as unusual threats or typical seasonal variations (Roncoli, Ingram, & Kirshen, 2009) [35]. Individuals' perception of risk is largely determined by mental models, which act as cognitive structures that help them interpret and evaluate uncertain scenarios. Instead of relying purely on objective probabilities, people tend to assess risks subjectively, with their evaluations influenced by emotions, past experiences, cultural backgrounds, and social settings **(Tversky, & Kahneman, 1974)** [43]**.** These mental models, shaped by personal experiences, education, and cultural narratives, assist individuals in organizing information about potential threats and deciding whether a situation is perceived as serious or routine.

The theory of cultural cognition suggests that individuals' perceptions of climate change risks are molded by their social values and the worldviews of their groups, which accounts for the varied interpretations of identical environmental evidence (Kahan *et al*., 2012) [25]. Farmers' understanding of climate risks is integrated into a broader context of livelihood risks, where their historical experiences and socio-economic backgrounds influence whether they perceive climate variability as a significant threat or routine fluctuation (Eitzinger *et al*., 2018) [18]. Collectively, these theoretical perspectives highlight those mental models, shaped by experience, cognition, and culture, are vital for comprehending how agricultural stakeholders perceive and respond to the risks posed by climate change (Botzen *et al*., 2025) [11].

Research increasingly shows that experiential exposure to droughts, floods, and heat stress strengthens perceived climate risk and increases adaptive intention (Incoom *et al*., 2025). However, mismatches often arise between scientific climate projections and farmers' local interpretations. Cognitive biases, such as confirmation bias and the availability heuristic, can distort these models, leading to an overestimation of rare but dramatic events and an underestimation of more common risks (Kahneman, and Tversky, 1979) [26]. Emotional states, including fear, anxiety, and perceived control, also play a role in how risks are interpreted and responded to by the public. As mental models are embedded within social contexts, community norms and shared values influence how risks are perceived and communicated. Understanding the connection between risk perception and mental models is crucial for effective risk communication and decision-making, particularly in fields such as public health, environmental management, disaster preparedness, and climate adaptation.

Risk perception is influenced not only by cognitive assessment but also by affective responses, trust in institutions, and perceived efficacy (Brosch 2021) [12]. When farmers perceive high vulnerability, but low adaptive capacity, fatalism or inaction may result. Conversely, a high perceived self-efficacy can stimulate proactive adaptation. Integrating risk perception research into agricultural planning highlights the importance of aligning climate communication with farmers' experiential realities and strengthening adaptive confidence, alongside technical support.

2.3. Behavioral Economics and Cognitive Biases

Behavioral economics further enriches our understanding of smallholder decision-making by demonstrating that choices under uncertainty are systematically shaped by cognitive biases. Prospect Theory, developed by Daniel Kahneman and Amos Tversky (1979) [26], illustrates how loss aversion, where potential losses weigh more heavily than equivalent gains, can discourage the adoption of unfamiliar technologies. In smallholder agriculture, the fear of crop failure or livestock loss may outweigh the potential productivity gains from innovation (Deressa *et al*., 2011) [15]. Status quo bias, present bias, and ambiguity aversion limit experimentation with climate-smart practices.

Studies have demonstrated that nudging strategies, peer comparisons, and risk-sharing mechanisms can mitigate these biases and encourage incremental behavioral changes (Ofosu-Ampong *et al*., 2025). Recognizing these behavioral tendencies is crucial for policy design. Interventions that reduce perceived losses through insurance schemes, demonstration plots, or social proof are more likely to succeed than purely informational campaigns. Therefore, behavioral insights complement structural support mechanisms in promoting sustainable adoption pathways.

2.4. Social Norms and Cultural Cognition

Farmer behavior is deeply embedded in social networks and culturally structured belief systems that shape the formation and sustainability of agricultural decisions are formed and sustained. Social norms—defined as perceptions of what others do (descriptive norms) and what others approve of (injunctive norms)—exert a strong influence on behavioral choices in farming communities (Schultz *et al*., 2007; Dearing & Steadman, 2016) [36]. Decisions regarding technology adoption, climate adaptation, and sustainable practices are often socially reinforced through peer interactions, opinion leaders, and shared collective expectations within their networks (Valente & Davis, 1999) [44]. Moreover, social capital and trust embedded in community structures further condition how environmental information is interpreted and acted upon (Pretty and Ward, 2001). These social dynamics collectively illustrate that farmers' choices are influenced not only by personal factors but also by normative pressures and the effects of networks within culturally established systems. Recent evidence underscores that community-based adaptation initiatives succeed when they leverage trusted local leaders, farmer groups and participatory learning approaches (Ho *et al*., 2024; Shankar *et al*., 2025). Social identity and collective efficacy also enhance climate action, particularly when adaptation is framed as protecting shared livelihoods and future generations.

Figure 1 presents a comprehensive psychological model of smallholder decision-making, integrating four interrelated domains: (1) cognition (perceptions, beliefs, attitudes), (2) social norms (peer influence, community expectations), (3) experiential learning (past successes and climate shocks), and (4) structural constraints (resource access, gender norms, institutional support, and market connectivity). Dynamic feedback loops illustrate that behavioral outcomes shape and are shaped by social and environmental contexts. This integrative framework underscores that advancing sustainable smallholder agriculture in SSA requires context-specific, behaviorally informed interventions that simultaneously address the psychological, sociocultural, and structural determinants of climate adaptation.

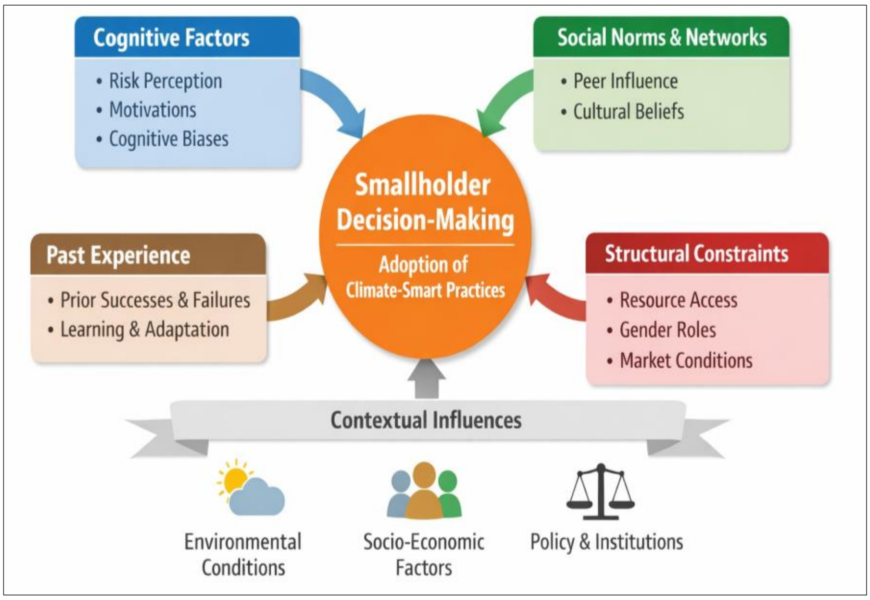

Fig 1: Integrative Psychological Framework for Smallholder Decision-Making

3. Psychological Determinants of Climate-Smart Decisions in Smallholder Farming Systems

Psychological determinants shape how smallholder farmers interpret climate threats, evaluate adaptive options, and decide whether to adopt climate-smart agricultural (CSA) practices. In Sub-Saharan Africa (SSA), where livelihoods are closely linked to climatic stability and resource constraints are pervasive, cognitive and affective processes play a decisive role in sustainability transitions. This section synthesizes five key determinants: risk perception, attitudes and beliefs, cognitive biases, self-efficacy, and social networks. Together, these constructions provide a behaviorally grounded explanation for variations in climate adaptation and sustainable practice adoption among smallholders.

3.1. Perception of Climate Risk in Smallholder Agriculture

Risk perception is a central predictor of adaptive behaviors. Sander van der Linden (2015) proposed an integrative social-psychological model demonstrating that climate risk perceptions are shaped by cognitive evaluations, affective responses, experiential learning, and socio-cultural influences on climate change. Risk is not an objective entity but a psychological construct (Sjöberg, 1997); as Slovic (1992) [38] argued, risk is socially constructed and interpreted through cultural lenses. Therefore, climate change represents what evolutionary scholars describe as a "novel risk," requiring individuals to respond to slow-moving and probabilistic threats (Griskevicius *et al*., 2012; Sih *et al*., 2011) [22].

In smallholder systems, farmers continuously assess whether to plant under uncertain rainfall conditions, invest in improved seeds, diversify crops, or adopt irrigation technologies. Emotional responses strongly influence these judgments. When statistical probabilities are unavailable, individuals rely on affective cues—positive or negative feelings associated with perceived risks—to guide their decisions (Sobkow *et al*., 2016). Research conducted in sub-Saharan Africa reveals that farmers who view the increasing frequency of droughts or unpredictable rainfall as significant and ongoing threats are more inclined to diversify their crops, implement soil and water conservation techniques, and invest in drought-resistant varieties (Deressa *et al*., 2009; Maddison, 2007; Slegers, 2008).

The perception of climate risk serves as a pivotal psychological catalyst that transforms environmental uncertainties into proactive adaptation strategies. When individuals comprehend climate variability through personal experience and this understanding is reinforced by social networks, it increases the likelihood of technological advancements and investments that enhance resilience.

However, when climatic irregularities are perceived as normal fluctuations, adaptation efforts are often limited or postponed. Studies across SSA indicate that farmers who recognize increasing drought frequency or erratic rainfall as serious threats are more prone to diversifying crops, adopting soil and water conservation strategies, and investing in drought-tolerant varieties (Maddison, 2007; Gao *et al*., 2020; Kori *et al*., & Kelso, 2024). However, when climate variability is interpreted as a normal seasonal fluctuation or attributed to non-scientific causes, adaptation may be delayed. Therefore, aligning climate information with farmers' mental models and lived experiences is essential for strengthening adaptive motivation and mitigation engagement (Van der Linden, 2015; Chassang *et al*., 2025) [7]

3.2. Attitudes, Perceptions, and Beliefs

Attitudes, perceptions, and beliefs are foundational psychological constructs that influence smallholder decision-making (Nyairo *et al*., 2022). Attitudes reflect evaluative judgments about specific practices, such as conservation agriculture or improved livestock management, whereas beliefs represent underlying convictions about environmental processes and farming systems. Positive attitudes often arise when innovations are perceived as compatible with local knowledge, culturally appropriate, and economically beneficial (Zeweld *et al*. 2017). Conversely, distrust of external technologies, perceived complexity, and prior negative experiences can generate resistance.

Studies from Sub-Saharan Africa indicate that smallholder farmers' intentions to adopt new agricultural practices are heavily influenced by their attitudes towards innovation, the perceived advantages of these technologies, and the degree of social approval within their communities (Ho *et al*., 2022; Ho *et al*., 2024; Nyairo *et al*., 2023; Kpadonou *et al*., 2024). Farmers are more likely to implement agricultural innovations when they see clear benefits in terms of increased productivity, reduced risks, and improved livelihoods, particularly when these innovations are endorsed by peers, extension agents, and community leaders. Recent research has also shown that social networks, trust in institutions, and perceived performance expectations play a crucial role in reinforcing the intention to adopt climate-smart and productivity-enhancing technologies in resource-limited agricultural systems. Behavioral models based on the Theory of Planned Behavior and technology acceptance frameworks consistently demonstrate that subjective perceptions of usefulness and social influence are strong predictors of technology adoption across various agroecological environments in Africa.

In Ghana and Ethiopia, farmers who believed that soil fertility management practices improved long-term productivity were more likely to adopt composting and mulching practices (Teklu *et al*., 2020). In Kenya, concerns about cost, unfamiliar management requirements, and uncertainty have limited the uptake of improved maize varieties despite documented yield benefits (Gao *et al*., 2020). These findings highlight that adoption is not merely a function of access but also of perceived relevance, compatibility, and trust. Therefore, addressing attitudinal barriers is critical for designing context-sensitive CSA interventions.

3.3. Cognitive Biases and Decision Heuristics

Under uncertainty, smallholders rely on heuristics—mental shortcuts—to simplify complex decision-making (Tversky & Kahneman, 1974) [43]. Although adaptive in some contexts, heuristics can introduce systematic biases. Prospect Theory, advanced by Kahneman and Tversky (1979) [26], demonstrates that loss aversion leads individuals to weigh potential losses more heavily than equivalent gains. In smallholder agriculture, fear of initial crop failure or livestock mortality can deter experimentation with improved technologies (Deressa *et al*., 2011) [15].

Present bias, which favors immediate returns over delayed benefits, may discourage investments in agroforestry, soil conservation, or crop rotation, which require upfront labor but yield long-term resilience (Lybbert *et al*., 2018) [29]. Status quo bias similarly reinforces reliance on traditional practices, even when climate projections suggest the need for transformation. Recent behavioral interventions (2023–2025) indicate that incremental adoption pathways, risk-sharing mechanisms, and peer demonstrations can reduce perceived losses and overcome this inertia (Dean & Schultz, 2023; Ofosu-Ampong *et al*., 2025). Recognizing cognitive biases allows policymakers and extension systems to design "behaviorally smart" interventions that reframe risks and lower psychological barriers to sustainable innovation.

3.4. Self-Efficacy and Agency

Self-efficacy, which refers to the belief in one's ability to effectively carry out specific tasks, was introduced by Bandura (1997) [9]. and continues to be a strong indicator of persistence in behavior and adaptive decision-making. In smallholder farming systems, a higher level of self-efficacy boosts farmers' readiness to embrace climate-smart practices, even when faced with financial, informational, and institutional challenges. Studies from sub-Saharan Africa show that training methods where people participate, farmer field schools, and learning from each other help increase confidence and support the continued use of sustainable practices (Doss *et al*., 2018; Incoom *et al*., 2025) [17].

When farmers witness their peers successfully implementing innovations, the perceived feasibility of these practices increases and uncertainty decreases, thereby strengthening behavioral intentions through social learning. In Ethiopia and Uganda, practical extension programs have strengthened farmers' confidence in techniques like composting, water harvesting, and integrated soil fertility management, resulting in more consistent and sustained adoption (Teklu *et al*., 2020). Consequently, enhancing self-efficacy boosts farmers' agency, resilience, and long-term commitment to sustainability transitions.

3.5. Social Networks and Norms

Smallholder farmers' decisions are embedded within social systems. Social norms—shared expectations regarding acceptable behavior—strongly influence climate-smart adoption (Dearing & Steadman, 2016). Farmers are more likely to adopt innovations when respected peers, cooperative leaders, or extension agents model this behavior. Social learning and collective efficacy reinforce diffusion processes, particularly in tightly knit rural communities.

Evidence from Kenya and Uganda shows that participation in farmer cooperatives and community networks increases the adoption of drought-tolerant crops, irrigation technologies, and soil conservation practices (Doss *et al*., 2020; Doss *et al*., 2018) [17]. Recent studies (2024–2026) further emphasize that leveraging trusted local networks enhances both the adoption speed and durability of behavior change (Ho *et al*., 2024; Shankar *et al*., 2025). Social influence accelerates diffusion and normalizes sustainable practices, embedding them within community identity and shared livelihood goals. Collectively, these psychological determinants—risk perception, attitudes and beliefs, cognitive biases, self-efficacy, and social norms—interact dynamically to shape climate-smart decision-making in smallholder systems in SSA. Integrating these behavioral insights into policy and extension design is essential for strengthening resilience and advancing sustainable agricultural transformation in the face of climate change.

4. Behavioral Constraints and Facilitators in Improving Agricultural Productivity within Smallholder Farming Systems Amidst Climate Change

Behavioral factors can either constrain or accelerate the adoption of productivity-enhancing and climate-resilient practices in smallholder agriculture in developing countries. While structural barriers, such as limited credit or infrastructure, are well documented, psychological constraints—including information processing limits, cultural beliefs, stress, and risk aversion—also significantly influence decision-making. Conversely, participatory learning, social capital, and behaviorally informed interventions can strengthen agency and innovation uptake. This section synthesizes the key behavioral barriers and enablers that shape sustainable agricultural productivity in Sub-Saharan Africa (SSA).

4.1. Barriers

4.1.1. Information Overload and Conflicting Messages

Smallholder farmers increasingly operate in dense information environments. Guidance is delivered through extension systems, NGOs, radio programs, private agro-dealers, and digital advisory tools, such as SMS alerts and mobile applications. While diverse information access can enhance adaptive capacity, excessive or contradictory messages may produce cognitive overload, reduce clarity, and weaken confidence in decision-making (Rossi *et al*., 2020; Rusmayadi *et al*., 2024). When farmers receive inconsistent recommendations, for example, on drought-tolerant varieties or fertilizer regimes they may revert to familiar, traditional practices despite potential long-term gains.

Behavioral research shows that individuals rely on cognitive shortcuts when confronted with complex or conflicting information, often defaulting to established routines and heuristics. Trust and perceived credibility strongly mediate the interpretation of information (Sangali *et al*., 2024; Oladele *et al*., 2024). Evidence from digital agriculture studies suggests that advisory services are more effective when messages are simplified, locally contextualized, and delivered through trusted intermediaries, such as lead farmers or cooperatives (Mavhura *et al*., 2022; Mohammadi Mehr *et al*., 2025). Therefore, designing communication strategies that account for cognitive processing limits and belief systems is essential for strengthening climate-smart adoption and productivity outcomes.

4.1.2. Cultural Beliefs and Traditional Knowledge

Traditional ecological knowledge forms the foundation for decision-making in many small-holder systems. Research has demonstrated that indigenous soil and crop management practices often enhance resilience in marginal environments (Occelli *et al*., 2021). However, tension can arise when externally promoted climate-smart innovations contradict culturally embedded norms or ancestral practices. Deeply rooted belief systems linked to identity, spirituality, and community cohesion may create resistance to externally introduced technologies (Reyes-García *et al*., 2013).

Empirical evidence from northern Ghana suggests that farmers' preference for indigenous practices significantly influences their evaluation of climate-smart agriculture, particularly when innovations are perceived as incompatible with traditional systems (File and Nhamo, 2023) [29]. Rather than considering traditional knowledge as an impediment, integrative approaches that align scientific recommendations with local epistemologies have proven to be more effective. Designing with respect for cultural values makes projects more accepted, reduces resistance, and helps create lasting changes. This research highlights that smallholder farmers' continued reliance on traditional methods—shaped by factors such as accessibility, cultural beliefs, and perceptions of risk and complexity—affects their assessment and frequent hesitance to adopt climate-smart agricultural innovations that are deemed incompatible with their established systems.

4.1.3. Psychological Stress and Climate Anxiety in Smallholder Agriculture

Climate change heightens uncertainty, increases the risk of crop failure, and threatens livelihoods across sub-Saharan Africa, where smallholder farming systems are particularly susceptible to climatic variations and environmental disturbances (Berhanu *et al*., 2024; Jaison, 2024). Persistent droughts, erratic rainfall patterns, flooding, and rising temperatures adversely affect agricultural outputs and household resilience. Beyond the physical consequences, frequent exposure to climate-related stressors induces psychological strain, climate anxiety, and uncertainty regarding future food and income security. Studies suggest that chronic stress impairs cognitive function, restricts long-term planning, and favors short-term survival strategies over adaptive investments (Lewins, 2025; Pienaah, 2025).

Empirical research indicates that repeated climate shocks often compel farmers to resort to immediate survival measures, such as selling assets under duress, diversifying income into low-return ventures, or engaging in temporary wage labor, rather than implementing sustainable land and soil management practices (Berhanu *et al*., 2024). Emotional responses to anticipated losses further intensify anxiety and risk aversion, reinforcing defensive adaptive behaviors. Thus, climate vulnerability operates through both economic and psychological pathways that influence decision making under uncertainty. Addressing these challenges requires interventions that integrate psychosocial support and technical adaptation strategies. Strengthening peer networks, building confidence through extension services, and ensuring access to reliable climate information can enhance farmers' adaptive capacity. Policies that incorporate mental resilience, social support systems, and investments in climate-smart agriculture are vital for enabling long-term, transformative adaptation.

4.2. Enablers in the Psychology of Smallholder Agriculture for Sustainability

4.2.1. Participatory Learning and Extension

Participatory extension approaches represent one of the most powerful psychological enablers of sustainable adoption. Unlike hierarchical knowledge transfer models, participatory learning engages farmers in co-creation, experimentation, and shared reflection (Orlando *et al*., 2020; Sahu *et al*., 2023). This approach builds psychological ownership, enhances perceived behavioral control, and strengthens self-efficacy, concepts rooted in the work of Albert Bandura.

Recent studies have shown that farmer field schools and community-based learning groups significantly increase the adoption of soil fertility management, agroforestry, and water harvesting practices in Uganda and Ethiopia (Prajapati *et al*., 2025). Peer-to-peer demonstrations reduce uncertainty and normalize innovations within social networks. By aligning scientific guidance with farmers' experiential knowledge, participatory extension strengthens both productivity and resilience.

4.2.2. Social Capital and Collective Action

Social capital, characterized by trust, reciprocity, and shared norms, facilitates collective adaptation and productivity gains in smallholder systems (Pretty & Ward, 2001). Strong farmer associations and cooperatives enable shared irrigation systems, watershed management, and bulk-input procurement. Collective efficacy enhances individual confidence in experimenting with new practices, thereby reducing perceived risks.

Empirical evidence from Kenya and Ghana indicates that communities with active farmer groups exhibit higher adoption rates of drought-tolerant crops and climate-smart irrigation technologies because of peer reinforcement and collaborative problem-solving (Gao *et al*., 2020; Sangali *et al*., 2024). Therefore, leveraging social capital offers a scalable pathway for mainstreaming sustainable innovations across rural landscapes.

4.2.3. Behavioral Interventions

Behaviorally informed interventions, often termed "nudges "can complement financial and technical support mechanisms. Drawing on insights popularized by Richard Thaler and Cass Sunstein (2008) [41], subtle framing and choice architecture adjustments can influence decision-making without coercion or manipulation. For example, framing soil conservation as protecting "family livelihoods" rather than abstract environmental goals, increases perceived immediacy and relevance.

Recent applications demonstrate that incremental demonstrations, default enrollment in farmer groups, and peer comparison feedback mechanisms significantly enhance the adoption of agroforestry and drought-resilient practices (Mohammadi Mehr *et al*., 2025; Shankar *et al*., 2025). Such interventions reduce psychological resistance, address loss aversion, and align innovation with intrinsic motivation. When integrated with participatory extension and supportive policy frameworks, behavioral strategies can substantially improve productivity and sustainability outcomes in smallholder farming systems in SSA.

Collectively, addressing behavioral barriers while strengthening psychological enablers provides a comprehensive pathway for improving agricultural productivity and climate resilience in smallholder farming systems. Integrating cognitive, cultural, emotional, and social dimensions into policy design ensures that climate-smart agriculture is not only technically viable, but also behaviorally achievable.

5. Intersection with Socio-Economic and Cultural Contexts

Psychological processes in smallholder agriculture do not operate in isolation; rather, they are embedded within broader socioeconomic, institutional, and cultural systems that shape access to resources, exposure to information, and decision-making authority. Therefore, cognition, motivation, and behavioral intention are influenced not only by individual factors but also by structural inequalities and cultural norms. Understanding these intersections is essential for promoting the equitable and context-sensitive adoption of climate-smart agricultural practices across both crop and livestock systems in sub-Saharan Africa (SSA).

5.1. Gender Dynamics

In sub-Saharan Africa, examining climate change adaptation through the lens of gender is essential. The region's climate patterns underscore existing inequalities, where gender roles and differences in resource access shape vulnerability to risks and the ability to adapt to them (Assan, N., & Moyo, 2025) [7]. Psychological processes in smallholder farming are deeply intertwined with gendered socioeconomic structures. Women farmers frequently face greater resource constraints, limited access to extension services, and social norms that restrict their participation in household and community decision-making. These structural barriers shape perceptions of risk, self-efficacy, and behavioral intentions regarding climate adaptation (Mersha *et al*., 2018) [31]. In Ethiopia, gender differences play a crucial role in shaping risk perception and adaptive capacity development within crop production systems. Research indicates that women farmers often express greater concerns about issues such as drought stress, declining soil fertility and pest infestations. This heightened awareness is due to their primary involvement in food crop production and responsibility for ensuring household food security.

Despite increased awareness of climate challenges, women frequently encounter structural obstacles that hinder effective adaptation. These barriers include insecure land ownership, limited access to improved seed varieties, restricted involvement in irrigation programs, and inadequate access to formal credit and extension services. Such institutional limitations impede their ability to convert risk awareness into tangible climate adaptation measures, thereby perpetuating vulnerability gaps in smallholder systems (Doss, 2018; Ragasa, 2014; Ragasa, 2021) [17].

The mismatch between perceived risk and adaptive capacity can reduce the agency and weaken behavioral follow-through. In livestock systems, women commonly manage small ruminants or poultry but have limited access to veterinary services, extension advice, or vaccination programs, which constrains their ability to respond effectively to disease outbreaks or climate-induced feed shortages. Consequently, women's adaptation strategies, such as intercropping, using drought-tolerant seeds, household-level poultry management, or informal savings groups, often reflect both practical constraints and socially defined roles. Addressing these gendered disparities requires interventions that enhance women's access to information, financial resources, land rights, and participatory decision-making. Therefore, behaviorally informed climate-smart initiatives must incorporate gender-sensitive designs to strengthen self-efficacy, agency, and equitable productivity outcomes.

5.2. Education and Literacy

Education and literacy significantly influence how smallholder farmers process climate information, evaluate risks, and translate knowledge into action (Shani *et al* 2024; Nhemachena *et al*. 2019) [33, 37]. Farmers with higher levels of formal education or agricultural training are generally better equipped to interpret seasonal forecasts, understand soil and water conservation principles, and assess the long-term benefits of adopting improved crop varieties and livestock management practices (Radeny, *et al* 2022; Makate *et al* 2019) [30,34].

A study on climate-smart crop varieties and resilient livestock breeds among smallholder farmers in Kenya revealed that households led by individuals with higher levels of education were more likely to benefit from adopting stress-tolerant crop varieties and resilient livestock breeds, including improved livestock. The effectiveness of these technologies in improving dietary diversity was stronger where household heads had higher education (Mutisya *et al* 2022). In their study conducted in Western Kenya, Musafiri *et al* (2022) [32] highlighted the education level of the household head as a crucial socio-economic determinant influencing the adoption of climate-smart agricultural (CSA) practices. These practices aim to enhance the productivity of both crops and livestock through integrated methods. A study examining the factors influencing smallholder farmers' adoption of climate-smart agricultural practices in eastern Malawi (Zomba) highlights education as a crucial socioeconomic factor in shaping adoption choices. However, it also highlights the importance of other contextual factors, such as the compatibility and simplicity of practices. Enhanced cognitive skills, such as information evaluation, probabilistic reasoning, and future-oriented thinking, support more strategic adaptation decisions. Studies on the adoption of better poultry breeds are rare. In Kenya, research has shown that knowledge of these breeds and access to information helps small farmers use them. This is often linked to education and contact with the extension services.

In Kenya and Malawi, smallholder farmers with higher education levels are more likely to adopt drought-resistant crop varieties and resilient livestock technologies and gain greater advantages from them. Education enhances access to information, comprehension of benefits, and decision-making abilities, all of which are crucial for adopting climate-smart innovations. In Kenya, the adoption of improved poultry breeds is affected by awareness and socio-psychological factors, which are connected to education and exposure to information. However, unequal access to education across rural SSA, particularly among women, constrains their adaptive capacity. Lower literacy levels can limit the comprehension of technical extension materials, reduce engagement with digital advisory platforms, and increase dependence on informal information networks. This disparity not only slows the adoption of agroforestry, soil fertility innovations, and vaccination programs for small ruminants but also perpetuates gender and productivity gaps. Therefore, expanding inclusive education, adult literacy programs, and context-adapted extension materials is critical for strengthening behavioral capacity across diverse farming systems.

5.3. Cultural Worldviews

Cultural worldviews, including beliefs about the relationship between humans, nature, and spiritual forces, profoundly influence how smallholder farmers interpret climate variability and respond to environmental risks (Eriksen *et al*., 2015) [19]. These worldviews shape causal attributes, perceived control, and preferred coping strategies of individuals. In communities where climate variability is attributed to spiritual or ancestral forces, adaptation responses may emphasize rituals, ceremonies, or the traditional timing of agricultural activities rather than technical interventions. In northern Ghana, farmers frequently depend on culturally ingrained ceremonial planting calendars and traditional seasonal indicators to make agricultural decisions. These traditional systems are sometimes favored over adopting drought-resistant crop varieties, especially when external innovations clash with local beliefs (Antwi-Agyei and Nyantakyi-Frimpong, 2021) [21]. Similarly, pastoral communities in Ethiopia often make livestock management decisions based on indigenous strategies for risk mitigation, mobility customs, and culturally rooted livestock protection practices. These practices can hinder the immediate adoption of improved feed formulations or water management technologies promoted by formal extension systems (Alhassan *et al*., 2025) [5].

While these traditional methods strengthen social cohesion and local adaptive knowledge, they also influence the pathways of technology adoption by affecting how innovations are perceived, trusted, and incorporated into existing livelihood systems (Never & Moyo 2025). Gender roles further mediate these dynamics. Women are often more involved in ritualized crop-related practices, whereas men typically oversee decisions regarding livestock mobility, grazing patterns, and asset allocation (Assan, 2015). These divisions influence access to climate-smart technologies and shape the differential adoption patterns across crop and livestock systems. Recognizing the influence of cultural worldviews does not imply a rejection of scientific innovation; rather, it highlights the importance of culturally sensitive engagement in addressing health concerns. Climate-smart interventions that respect local belief systems, incorporate traditional ecological knowledge, and involve community leaders are more likely to gain trust, enhance perceived legitimacy, and stimulate sustained behavioral change.

6. Case Studies and Empirical Evidence in Sub-Saharan Africa

Empirical evidence from Sub-Saharan Africa (SSA) demonstrates that psychological and behavioral factors significantly influence the adoption of climate-smart agricultural practices in the region. The following case studies illustrate how risk perception, trust, social learning, intrinsic motivation, and gender dynamics interact with structural conditions to shape adaptation outcomes in crop and livestock systems.

6.1. Ethiopia: Soil and Water Conservation

In eastern Ethiopia, smallholder farmers' perceptions of soil erosion severity significantly influenced their adoption of soil and water conservation measures, in some cases, outweighing the influence of formal economic incentives (Awulachew *et al*., 2018). Farmers who perceived erosion as a direct threat to future harvests were more willing to invest in labor and resources for terracing, contour bunding, and other soil retention practices.

Psychological variables, including risk awareness, perceived vulnerability, self-efficacy, and prior experience with land degradation, shaped both the initiation and sustained maintenance of conservation efforts. Farmers with strong beliefs in their ability to mitigate erosion were more consistent in maintaining their structures over time. Participation in community-based learning groups further reinforces adoption. When farmers observe their peers successfully implementing conservation strategies, it greatly influences their behavioral choices by providing social validation, reducing perceived risks, and enhancing collective confidence. Smallholders who witness neighboring farmers adopting and benefiting from sustainable practices are more inclined to view these innovations as practical and socially acceptable in their local environment, thus increasing their willingness to try them out (BenYishay & Davis, 1999; BenYishay & Mobarak, 2019) [10].

People change their actions based on what they think others expect and what they see others doing. This can make these actions spread faster or slower (Schultz *et al*., 2007) [36]. Additionally, self-efficacy theory posits that seeing similar individuals successfully implement these practices boosts confidence in one's own ability to replicate them under similar conditions, thereby enhancing adaptive capacity and promoting long-term sustainability (Bandura, 1997; Krishnan & Patnam, 2014) [9, 28]. This case illustrates that effective soil and water conservation strategies depend not only on technical recommendations but also on aligning interventions with farmers' perceptions, experiential knowledge, and social networks to ensure their adoption.

6.2. Ghana: Climate Information Services

In northern Ghana, SMS-based weather forecasting services have improved smallholder farmers' decisions regarding planting dates and crop management, thereby enhancing their adaptive capacity (Angelucci *et al*., 2019). However, the effectiveness of these climate information services depends heavily on trust, perceived accuracy, and cognitive accessibility of the information. Farmers are more likely to use climate forecasts when the information aligns with their local agricultural timelines, reflects observable environmental patterns, and is delivered through trusted sources, such as extension officers, community leaders, or other farmers. The trustworthiness and perceived value of forecast data for making decisions in uncertain situations are strengthened when scientific recommendations are consistent with Indigenous knowledge systems (Antwi-Agyei & Kirshen, 2009; Antwi-Agyei & Nyantakyi-Frimpong, 2021) [6].

When digital weather forecasts and traditional signs do not match, people may become doubtful. This can make them trust outside information less and slow down changes in behavior. Research on risk perception shows that when information conflicts with personal experience or culturally ingrained knowledge, individuals often resort to familiar shortcuts, which can obstruct the adoption of new advisory systems (Slovic, 1992; Van der Linden, 2015) [38]. Therefore, effective climate communication strategies should integrate local knowledge with scientific forecasts to foster trust, reduce uncertainty, and promote adaptive action.

Gender disparities significantly influence access to and use of climate information and advisory services in smallholder farming systems. Research shows that men typically have better access to mobile phones, digital platforms, and extension networks, which allows them to more easily receive and utilize SMS-based weather advisories to manage field crops. In contrast, women, who frequently manage vegetable gardens, small animals, and food production for their households, tend to rely more on community knowledge networks and traditional environmental cues when making decisions. (Doss *et al*., 2018; Nhemachena *et al*., 2019) [17, 33].

Structural barriers, such as limited phone ownership, lower levels of digital literacy, restricted land tenure rights, and unequal access to extension services, further hinder women's engagement with formal climate information systems, diminishing their ability to fully benefit from technological advancements. This underscores the importance of climate services that are comprehensible, socially reliable, and attentive to gender considerations. By integrating local indicators with scientific forecasts, facilitating peer discussion forums, and providing information through inclusive dissemination channels, the credibility and accessibility of these services can be improved, thereby increasing the likelihood of sustained behavioral change in crop and livestock production systems (Mersha & Van Laerhoven, 2018; Wossen *et al*., 2024) [31, 46].

6.3. Kenya: Drought Tolerance and Social Learning

In Kenya's arid and semi-arid lands (ASALs), farmers who participate in community-based learning groups and field demonstrations have shown significantly higher adoption rates of drought-tolerant crops (Gao *et al*., 2020). These outcomes highlight the influence of social norms, observational learning, and peer reinforcement in shaping adaptive decision-making. Farmers became more inclined to try resilient crop varieties after seeing respected members of their community successfully implement them in their fields. This change reduced perceived risks, bolstered confidence, and helped normalize innovation within the community. Social learning mechanisms have shifted adaptation from an individual risk to a collective effort, particularly where peer demonstrations, farmer field schools, and community-based experimentation platforms are effectively utilized (Berhanu *et al*., 2024; Jankowska *et al*., 2024) [24].

Evidence suggests that visible success among peers significantly enhances the adoption of climate-smart technologies by reducing uncertainty and increasing perceived feasibility among farmers. Similar patterns have been identified in livestock productions. Initiatives such as cooperative feed management, shared water resources, and joint drought contingency planning enhance herd resilience while distributing risks among the households. Recent research suggests that collective action improves access to scarce resources during climate shocks and augments adaptive capacity in pastoral and mixed crop–livestock systems (Pienaah 2025; Lewins 2025). These collaborative frameworks mitigate vulnerability by pooling labor, feed resources, and water infrastructure while reinforcing community risk-sharing mechanisms.

Research has shown that men and women participate differently in climate adaptation activities. Women often join small animal and poultry farming groups. Men usually participate in larger crop trials or pastoral groups. This is due to land ownership, resource control, and cultural norms (Jaison, 2024). These differences highlight the need for gender-sensitive approaches to ensure fair participation and benefits. Programs that consider gender differences help include everyone and make projects last longer. This case demonstrates that combining technical innovations with socially embedded learning platforms substantially enhances the adoption and sustainability of climate-smart agricultural practices. Integrating social learning, collective action, and gender-responsive strategies strengthens resilience outcomes while improving technology uptake and livelihood security in vulnerable farming systems is recommended.

6.4. Nigeria: Behavioral Drivers of Tree Planting

In northern Nigeria, smallholder adoption of tree planting and agroforestry practices is strongly influenced by intrinsic motivation (Ajibade & Gandu, 2021) [1]. Farmers who perceive tree planting as directly contributing to soil fertility, household welfare, shade provision, and long-term livelihood security exhibit more sustained engagement than those motivated primarily by external subsidies or short-term incentives are more engaged. Psychological factors significantly influence farmers' dedication to sustainable farming methods, particularly through elements such as perceived self-efficacy, alignment with social norms, and awareness of long-term benefits for future generations. When farmers are confident in their ability to successfully implement agroforestry techniques, their confidence in managing associated risks increases, which in turn enhances their willingness to adopt these methods (Bandura, 1997; Ajzen, 1991) [3, 9].Likewise, behavioral changes are more probable when new methods align with existing community norms and are supported by peer approval, which diminishes uncertainty and fosters collective acceptance (Schultz *et al*., 2007; Valente & Davis 1999) [36, 44].

When agroforestry projects align with farmers' cultural values and goals, such as improving soil, providing wood, and helping future generations, farmers are more likely to adopt them independently. This increases the likelihood of these projects lasting a long time (Griskevicius *et al*., 2012; Thornton *et al*., 2019) [42]. In systems that combine crop and livestock farming, incorporating trees for fodder production, enhancing soil fertility, providing shade for poultry, and regulating the microclimate for small ruminants boost the perceived multifunctionality and practical importance of climate-smart strategies. When farmers notice direct benefits to their livelihoods, such as better feed availability, less heat stress for animals, increased crop yields, and more diverse income sources, these practices are integrated into existing production systems rather than being seen as externally imposed innovations (Thornton *et al*., 2019; Wossen *et al*., 2024) [42. 46].

When a project seamlessly aligns with existing functions, it significantly enhances intrinsic motivation and virtually eliminates the risk of abandonment once project support or external funding ceases to exist. This alignment is not merely beneficial; it is essential because it ensures that adoption is driven by undeniable advantages for households and seamless integration at the system level. By embedding projects within existing frameworks, we guarantee their sustainability and long-term success, making them indispensable to the communities they serve. Research shows that people are more likely to stick with climate-smart practices if they are linked to food security, family well-being, risk reduction, and cultural values. This approach is more effective than simply offering short-term economic benefits (Ajzen, 1991; Griskevicius *et al*., 2012) [3, 22].

7. Policy and Extension Implications for Smallholder Farming

Integrating psychological and behavioral insights into agricultural policy and extension systems can significantly improve the adoption and sustained use of climate-smart practices among smallholder farmers in sub-Saharan Africa (SSA). Climate adaptation is not solely a technical or economic challenge; it is fundamentally a behavioral one. Policies that recognize cognitive biases, risk perceptions, social norms, gender dynamics, and motivational drivers are more likely to generate durable improvements in productivity and resilience to climate change.

7.1. Behaviorally Informed Extension

In sub-Saharan Africa, extension systems are increasingly being urged to shift from traditional, hierarchical technology transfer models to more behaviorally informed approaches that are sensitive to local contexts. Conventional models often assume that a lack of information is the main obstacle to adoption. However, research has shown that farmers' choices are influenced by cognitive biases, perceptions of risk, trust networks, and socioeconomic limitations. Studies indicate that when extension advice is aligned with farmers' experiential knowledge, belief systems, and local agroecological conditions, the adoption and continued use of innovations improves significantly. For example, evidence compiled by the Food and Agriculture Organization of the United Nations (2022) underscores that participatory and farmer-focused advisory services are more effective than prescriptive models in advancing climate-smart agriculture among African smallholder farmers. Similarly, research published in Agricultural Systems revealed that the adoption of sustainable intensification practices is more successful when extension strategies address behavioral and contextual factors rather than simply providing technical recommendations (Schut *et al*., 2020; FAO, 2022).

Methods such as farmer field schools, community demo plots, peer helpers, and local leaders help reduce farmers' fears and doubts. When farmers observe these methods being effective in their communities, they feel more confident. This makes them more likely to start and continue using practices such as drought-resistant crops, better soil management, conservation farming, and improved livestock care. A recent review published in World Development corroborates that peer learning and the involvement of locally trusted intermediaries substantially enhance credibility and facilitate sustained behavioral change within agricultural innovation systems (BenYishay & Mobarak, 2019; Krishnan & Patnam, 2014) [10, 28]. The integration of behavioral diagnostics, such as the systematic identification of perceived barriers, trust gaps, and motivational constraints, into extension planning further customize interventions to align with local decision-making contexts, thereby leading to measurable improvements in the adoption of resilience-oriented practices (FAO, 2022; Schut *et al*., 2020).

7.2. Climate Information Framing

The manner in which climate information is presented significantly influences the reactions of small-holder farmers. When communication focuses on abstract climate metrics or distant environmental advantages, it often fails to inspire action, especially in situations where farmers are more concerned with immediate livelihood needs than with long-term objectives. Recent studies from sub-Saharan Africa indicate that farmers are more receptive to adaptation messages that highlight concrete and short-term benefits such as enhanced household food security, reduced labor, stable income, and safeguarding productive resources (Jankowska *et al*., 2024; Kassie *et al*., 2024) [24, 27]. Research in behavioral economics also shows that preferences for immediate rewards and risk aversion decrease the likelihood of responding to distant or uncertain benefits, making framing emphasizes benefits and loss prevention more effective in encouraging the adoption of climate-smart practices by farmers. For instance, SMS-based weather forecasts and seasonal advisories are more impactful when combined with specific actionable advice, such as the best times for planting, recommendations for fertilizer application, or adjustments in livestock feeding, rather than just general rainfall forecasts (Berhanu *et al*., 2024).

Presenting climate-smart practices as strategies to protect family welfare, ensure income continuity, and build intergenerational resilience increases their perceived importance and urgency, especially when communicated through trusted local networks (Wossen *et al*. 2024) [46]. Communication strategies informed by behavioral insights must also consider literacy levels, local languages, gender roles, and culturally ingrained knowledge systems to ensure that they are clear, trustworthy, and usable in various farming contexts. Customizing climate information to align with social and cognitive realities enhances its adoption, improves decision-making quality, and boosts adaptive capacity in the face of climate uncertainty.

7.3. Gender-Sensitive Interventions

For the successful adoption of climate-smart policies, it is vital to overcome the structural and psychological challenges that restrict women's engagement and influence in smallholder farming. In sub-Saharan Africa, gender norms continue to dictate unequal access to land ownership, agricultural loans, extension services, climate data, and decision-making power within households, thereby affecting women’s ability to adapt and be resilient (Wossen *et al*., 2024; Jaison, 2024) [46]. Research indicates that women farmers are less likely than their male counterparts to receive timely climate advice or benefit from input subsidy programs, which hinders their capacity to adopt climate-smart practices on a large scale.

Beyond material limitations, limited participation in producer organizations and local governance diminishes women's bargaining power and collective voice in adaptation planning. Therefore, addressing these interconnected structural and social barriers is vital to achieving equitable climate resilience. Initiatives such as women-led learning groups, targeted communication channels, mentorship networks, and participatory planning platforms have proven effective in enhancing women's self-efficacy, negotiation skills, and confidence in adopting innovative agricultural practices (Kassie *et al*., 2024) [27]. Organizations that focus on gender and social learning help farmers obtain better seeds, animal care, vaccines, and money. This leads to better crop and livestock production and helps to close adaptation gaps (Pienaah, 2025; Wossen *et al*., 2024) [46]. Policies that consider gender can rectify inequalities and strengthen families and communities. Including gender fairness in climate-smart farming is important for fairness and improving productivity.

7.4. Social Network Strengthening

Strengthening social networks and collective action mechanisms is critical for accelerating the diffusion of climate-smart innovations. Peer learning platforms, cooperative associations, savings groups, and producer organizations create enabling environments in which observational learning, normative influence, and shared risk-taking can flourish (Jankowska *et al*., 2024; Wossen *et al*., 2024) [24, 46]. Empirical evidence from Sub-Saharan Africa demonstrates that farmers embedded in strong social networks are significantly more likely to adopt climate-smart practices due to reduced uncertainty and enhanced trust in locally validated knowledge (Kassie *et al*., 2024) [27].

Providing opportunities for early adopters to demonstrate successful agroforestry systems, soil conservation structures, improved livestock feeding regimes, and vaccination programs reinforces social proof and legitimizes innovation within communities (Berhanu *et al*., 2024). Visible demonstration effects increase perceived feasibility and strengthen collective efficacy, particularly where climate risks create hesitation among more risk-averse farmers. In livestock systems, shared management practices and cooperative adaptation strategies further enhance resilience while distributing exposure to climatic shocks across households (Pienaah, 2025).

Policies that invest in social infrastructure—such as producer organizations, community-based learning platforms, and inclusive farmer associations—rather than solely physical or technological inputs, can generate multiplier effects that enable climate-smart practices to scale organically within smallholder communities (Wossen *et al*., 2024; Kassie *et al*., 2024) [27, 46]. Such socially embedded approaches enhance sustained adoption, improve risk-sharing capacity, and strengthen long-term adaptive resilience under conditions of climatic uncertainty.

8. Research Gaps and Future Directions

Although scholarship on the psychology of smallholder agriculture in sub-Saharan Africa (SSA) is expanding, substantial empirical and methodological gaps remain. Addressing these gaps is essential for advancing behaviorally informed climate-smart agricultural policies and interventions in the future. A major research gap concerns the psychological impact of chronic climate stressors on smallholder farmers' mental health. Limited evidence exists on how repeated exposure to droughts, erratic rainfall, crop failures, livestock mortality, and market disruptions affect cognitive functioning, mental health, risk tolerance, and long-term planning capacity. Climate-related stress and anxiety may reduce decision-making quality and adaptive motivation; however, these dimensions remain underexplored in agricultural research. Future studies should integrate environmental psychology and agricultural economics to examine how mental health intersects with resilience, productivity and adaptation outcomes. Such research is critical for designing interventions that support both psychological well-being and sustainable agriculture.

Methodologically, most existing studies in SSA rely on cross-sectional data that capture perceptions and behaviors at a single point in time. While valuable, these designs limit our understanding of the dynamics of behavioral change. Longitudinal research is needed to track how attitudes, beliefs, risk perceptions, and adaptation strategies evolve across seasons in response to climate variability, policy shifts, and social influence. Panel data approaches would provide stronger causal insights into the drivers of the sustained adoption of climate-smart practices in crop and livestock systems.

Another significant gap is the limited experimental testing of behavioral interventions in smallholder contexts. Although concepts such as nudges, framing effects, social norm messaging, and participatory learning have been widely discussed, relatively few randomized controlled trials or field experiments have rigorously evaluated their effectiveness in SSA agriculture. Future research should implement experimental designs to test which psychological strategies most effectively enhance the adoption, productivity, and resilience of employees. Comparative studies across agro-ecological zones would further clarify the contextual differences in intervention performance.

Future investigations should also examine the interactions between psychological determinants and structural constraints, including land tenure security, gender inequality, market access, institutional trust, and resource availability. These factors operate simultaneously and shape behavioral outcomes in complex ways. Mixed-methods research combining quantitative modeling with qualitative inquiry can better capture these interactions and reveal how cognitive processes are embedded within broader socio-economic systems.

Addressing these research gaps will strengthen the theoretical development in agricultural behavioral science and improve the design of evidence-based, context-specific policies. By integrating psychological insights with structural analyses, future studies can contribute to more effective, equitable, and sustainable climate adaptation strategies for smallholder farming systems across SSA.

9. Synthesis, Recommendations, and Conclusion

The choices made by smallholder farmers in Sub-Saharan Africa (SSA) are shaped by a complex mix of environmental challenges, socio-economic limitations, and psychological factors. Elements such as risk perception, beliefs, social norms, motivation, self-efficacy, and cognitive biases all play a role in how these farmers understand climate data and react to opportunities to adapt their crop and livestock farming systems. Research from countries such as Ethiopia, Ghana, Kenya, and Nigeria show that behavioral factors interact dynamically with structural conditions, cultural perspectives, and gender-based power dynamics. Consequently, achieving sustainable agricultural transformation necessitates strategies that combine psychological insights with technical and institutional strategies.

Key Synthesis

Perceptions and Risk Awareness

Farmers' recognition of climate risks significantly influences their willingness to adopt adaptation strategies, such as soil and water conservation, drought-tolerant crop varieties, improved livestock management, and agroforestry systems. Higher perceived vulnerability combined with a perceived adaptive capacity increases proactive behavior. However, misinterpretation of climate variability or limited access to reliable information may reduce the responsiveness to risk signals.

Cognitive and Behavioral Factors:

In smallholder farming, decision-making is influenced by heuristics and biases, such as loss aversion, present bias, and status-quo bias. These mental shortcuts help simplify complex choices but can also deter the adoption of new technology. In contrast, factors such as intrinsic motivation, perceived self-efficacy, and positive framing can encourage the uptake of innovations. Behavioral interventions, including nudges, social norm messaging, demonstration plots, and participatory learning, can effectively harness these psychological tendencies to promote sustainable practices.

Socio-Cultural and Gender Dimensions

Gender roles, cultural beliefs, and social networks significantly mediate access to resources, information, and collective learning processes. Women often face structural constraints but play a central role in household food security and in small livestock management. Therefore, strengthening women's agency is critical for enhancing resilience at both the household and community levels. Social norms and peer influence further shape behavioral outcomes, underscoring the importance of collective approaches to the diffusion of innovation.

Policy and Extension Implications:

Incorporating behavioral insights into policy frameworks and extension systems can enhance the trustworthiness, relevance, and impact of climate-smart agricultural strategies. By integrating psychological factors into climate information services, advisory initiatives, and rural development policies, farmer participation and the sustainable adoption of practices have been bolstered.

Recommendations

The following strategic measures are suggested to put these insights into practice.

- Design behaviorally informed interventions that align with smallholders' cognitive processes, cultural values and intrinsic motivations.
- Promote inclusive and gender-sensitive extension programs that enhance women's access to resources, information, and decision-making.

- Strengthening social networks, cooperatives, and peer-learning platforms to leverage normative influence and collective action for climate adaptation.
- Integrate psychological determinants with structural factors such as land tenure security, market access, financial services, and institutional support to address adoption barriers, holistically.
- Support longitudinal and experimental research to evaluate how beliefs, attitudes, and behavioral interventions evolve under changing climatic and socioeconomic conditions.

10. Conclusion

Examining the psychological dimensions of smallholder farmers offers a valuable perspective for promoting sustainable and climate-resilient agricultural systems in sub-Saharan Africa (SSA). By acknowledging the interaction between cognitive processes, emotional responses, social contexts, gender dynamics, and environmental conditions, policymakers and development practitioners can formulate interventions that align with farmers' experiences and mitigate behavioral obstacles to innovation. Ultimately, incorporating psychological, socioeconomic, and cultural aspects into climate-smart agriculture strategies is crucial for developing resilient, productive, and equitable smallholder farming systems that can adapt to a rapidly changing climate. This integrated approach transcends purely technical solutions and places human behavior at the core of sustainable agricultural transformation.

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