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Small Farms, Big Risks: A Review of Flood Resilience Challenges Faced by Vegetables Farmers

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ABSTRACT

Smallholder vegetable farmers play a critical role in ensuring food security but remain highly vulnerable to climate-related challenges, particularly floods. This review explores the multifaceted challenges these farmers face in building resilience to floods, focusing on four key components: social, economic, physical, and environmental. Small farms, often constrained by limited resources, fragmented landholdings and dependency on weather patterns. These challenges are further intensified by inadequate access to financial support, adaptive agricultural practices and other indicators. The review also identifies recent studies on flood resilience, identifying gaps in research and practice. A lack of knowledge about flood vulnerability levels among vegetable farmers remains a significant barrier to designing effective coping strategies. To address these challenges, prioritizing foundational research is essential to better understand the dimensions of vulnerability under each component. Such knowledge is vital for guiding policymakers and decision-makers in identifying and addressing the most critical areas for intervention. Closing these gaps is necessary not only for protecting livelihoods but also for achieving long-term agricultural sustainability and enhancing climate resilience.

1. Introduction

Flood disaster risk now extends beyond specific regions to become a global issue. This susceptibility arises from various factors, including socioeconomic conditions [1], demographic pressures [2], unplanned urbanization [3], environmental degradation [5] and climate change [5]. Natural events, such as annual monsoons, intensify the problem in areas like Southeast Asia, South Asia, Australia, and parts of Africa. For instance, floods in Pakistan have led to substantial crop losses, with damages estimated at 2.3 million USD [6], sparking severe food crises. Rising precipitation levels in recent years have increased flood frequency by generating river runoff, shallowing riverbeds and causing overflows that submerge nearby areas. Over the past ten years, flooding events have

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damaged more than 1.5 million crops worldwide [7], highlighting the escalating magnitude of this challenge.

The agricultural sector, particularly vegetable farming, remains highly vulnerable to these weather changes, despite floods being recurring natural occurrences in many regions [8]. Crop fields face elevated flood risk because farmers often establish them near floodplains or water bodies for convenient irrigation access [9]. Additionally, the fertile soil in these zones supports robust crop growth, making such locations appealing despite their exposure to flooding. Vegetable crops, sensitive to excess water at any growth stage, whether vegetative or maturing [10], suffer significantly under these conditions. Excessive moisture can hinder seed germination, induce root rot, or cause plant mortality [11], leading to considerable losses for small-scale farmers.

Protecting small-scale farmers from the devastating effects of floods is essential for sustaining vegetable production and supporting broader societal benefits. First, maintaining food security and nutrition is critical. In Malaysia, where vegetable imports exceed exports, domestic supply struggles to meet demand [12]. Persistent flood impacts could prevent small-scale farmers from recovering, threatening food availability and nutritional needs in daily diets, a concern already evident in nations experiencing food crises. Second, agriculture serves as a vital source of employment and livelihoods, particularly in rural areas [13], helping to alleviate poverty. Furthermore, small farms often employ traditional practices that minimize reliance on chemical inputs like synthetic fertilizers, opting instead for organic alternatives. This approach preserves biodiversity, promotes long-term soil health, and supports environmental sustainability. Consequently, understanding the underlying causes of small-scale farmers' limited resilience to flooding is crucial. Identifying these barriers enables the development of optimized mitigation strategies. Therefore, this paper reviews the challenges faced by small-scale vegetable farmers in enhancing their resilience to flood events. Despite extensive research, gaps remain in understanding the long-term efficacy of flood mitigation strategies for smallholder farmers. Limited studies explore the integration of traditional knowledge with modern technologies, such as combining indigenous flood barriers with sensor-based early warning systems. Additionally, there is a lack of longitudinal data on how repeated flooding affects farmers' psychological resilience and economic recovery. Addressing these gaps is critical to developing holistic solutions.

2. The Concept of Flood Resilience

The concept of resilience appears across numerous fields and disciplines, such as engineering, social sciences, and disaster management, though its origins trace back to ecology. Scholars define resilience as the capacity of a system to recover its functionality following a disruptive event. Alternatively, it encompasses the ability to withstand, resist, cope with, adapt to, learn from, or transform disturbances, ultimately improving conditions after such setbacks. Definitions vary widely, with some sources suggesting 56 distinct terms to describe resilience, while others propose as many as 70 [14]. A meta-analysis of resilience in disaster management by Patel *et al*., [15] identified 62 distinct definitions, with 78% emphasizing adaptation and recovery over mere resistance. This diversity has sparked debate, particularly regarding the distinction between resistance and resilience. Most experts concur that these concepts differ fundamentally, yet resistance constitutes an essential component of resilience. By enabling systems to endure adverse conditions, resistance facilitates mitigation efforts and forms an integral part of resilience. Researchers can evaluate resilience through both qualitative and quantitative approaches, providing a comprehensive understanding of its dynamics.

3. Flood Resilience Challenges by Small Farmers

Floods remain a recurring and significant threat to smallholder farmers, despite their annual occurrence. While larger commercial farms often have access to financial reserves, advanced infrastructure, and institutional support, small farms face disproportionately higher challenges in recovering from flood-related damage. Existing literature classifies these challenges into four primary components: economic, social, environmental, and physical.

4. Social Challenges

4.1 Limited Access to Education

Rural populations, predominantly engaged in small-scale farming, often have limited access to formal education [16], which plays a crucial role in equipping individuals with essential knowledge for practical application in agriculture. Education enhances farmers' ability to adopt modern flood-resilient practices [17], improve productivity [18] and make informed decisions about risk management. However, annual initiatives by governments or non-governmental organizations to provide educational programs frequently fail to reach these communities due to logistical challenges, lack of awareness, or inadequate outreach efforts [19]. Even when farmers are informed about such opportunities, participation remains difficult due to barriers such as distance, time constraints, and competing responsibilities. Moreover, the high cost of attending paid training programs further limits their accessibility [20], as most smallholder farmers allocate their limited financial resources to immediate household and farming needs.

In rural Vietnam, only 15% of small-scale farmers had access to agricultural training programs due to distance and cost barriers [21]. Those who participated adopted flood-resistant crop varieties, reducing losses by 25% to untrained farmers. The study emphasized that low literacy rates among farmers hindered understanding of modern practices making them more vulnerable to climate-related challenges like flooding.

4.2 Limited Access to Early Warning Systems

Small-scale farmers in rural regions often experience limited access to early warning systems [22], whereas larger farm owners benefit from better resources and advanced technologies. In many underdeveloped areas, poor network coverage and inadequate infrastructure further restrict communication, making it difficult for farmers to receive timely flood alerts. For example, certain locations in Malaysia, such as Jeli in Kelantan, still lack reliable network access [23], which limits the dissemination of critical disaster warnings. Without accurate and timely information, farmers are unable to take necessary precautions to protect their farms from flood damage. This results in higher losses of crops and essential agricultural infrastructure. While, larger farms often utilize advanced meteorological monitoring systems and automated alert mechanisms, allowing them to implement early protective measures [23].

Yusuf *et al*., [24] found that 70% of small-scale vegetable farmers in Kelantan, Malaysia lacked access to reliable flood alerts due to inadequate mobile network coverage. In contrast, larger farms using satellite-based warnings mitigated 40% of potential losses. Community radio trials in pilot areas increased warning reach by 50%, demonstrating a viable solution for smallholders.

Providing smallholder farmers with improved access to early warning information through mobile applications, community-based radio systems, and satellite-driven weather forecasts could significantly enhance their ability to prepare for flood events. Strengthening communication

infrastructure and ensuring that flood warnings reach all farming communities in an accessible and understandable manner are crucial steps in reducing the vulnerability of small farmers to climate-related disasters.

4.3 Health Issue

Health challenges play a critical role in shaping the social and economic circumstances of small-scale farmers. Many farmers suffer from chronic health conditions but continue working under strenuous conditions to ensure food security for their families [23]. Limited access to healthcare services, coupled with financial constraints, worsens their vulnerability, often forcing them to prioritize daily survival over seeking medical attention. The combination of physical ailments and psychological stress can significantly impair their decision-making abilities, resilience and overall well-being. Poor health reduces physical stamina, limiting their ability to perform essential farming tasks, which ultimately leads to lower agricultural productivity. These challenges become even more pronounced during flood events, as exposure to contaminated water increases the risk of waterborne diseases such as leptospirosis and cholera [25], further weakening their capacity to recover from disasters. By comparison, large-scale farm owners can afford to hire laborers and specialists to manage operations, ensuring continuous productivity regardless of personal health concerns [26].

In India documented that 60% of small-scale farmers reported health issues post-floods, including leptospirosis, reducing work capacity by 30%. Access to healthcare was limited for 80% of rural farmers, compared to 10% for large farm owners [27]. Psychological stress from repeated losses lowered decision-making efficacy, increasing vulnerability.

This disparity underscores the need for improved healthcare accessibility, financial support for medical expenses and tailored health interventions to enhance the resilience of smallholder farmers. Integrating health awareness programs with agricultural extension services could help mitigate these challenges and promote sustainable farming practices in vulnerable rural communities.

5. Economic Challenges

5.1 Livelihood Dependency

Small-scale farmers who rely solely on vegetable farming as their primary income source face significant challenges during flood events [28]. Flooding often causes immediate disruptions in production, necessitating substantial investments in replanting crops [29]. Recovery requires a waiting period of several months before harvests resume, which creates financial strain for farmers without sufficient savings.

85% of small-scale vegetable farmers in Nigeria depended solely on farming income, with floods causing a 70% income loss for six months post-event. Lack of savings forced 60% to borrow at high interest rates, delaying recovery [30]. The situation is further aggravated when floodwaters damage critical infrastructure, such as irrigation systems or storage facilities, as rebuilding such infrastructure requires considerable financial resources.

5.2 Market Disruptions

Flooding in rural areas often leads to disruptions in market access due to transportation challenges and market closure [28]. Floodwaters can severely affect the quality and quantity of harvested crops, reducing their market value. Furthermore, transportation routes to market centers may be blocked, preventing farmers from selling their produce in a timely manner. These challenges

result in additional losses for small-scale farmers, as their goods either spoil or must be sold at significantly lower prices, reducing their potential income. In distinction, larger farms, often located closer to urban areas or with better logistics infrastructure, face fewer barriers in accessing markets [29]. Small-scale farmers faced market access barriers due to high transportation costs and flood-damaged roads, with 50% reporting spoilage losses. Larger farms near urban centers incurred only 15% losses [31].

5.3 High Cost Recovery

After a flood, small-scale farmers face high recovery costs, which can be financially crippling. In addition to the loss of crops, essential agricultural inputs such as seeds, fertilizers, and pesticides may be destroyed or rendered unusable due to waterlogging or contamination [32]. Soil quality is often degraded due to nutrient leaching from prolonged saturation [33], further hindering recovery. Restoring these inputs and replenishing soil quality demands significant capital investment, which many small farmers cannot afford. Large-scale farms are often better equipped to absorb these costs due to access to capital, insurance and other financial resources, enabling them to recover more swiftly. In Ethiopia reported that small-scale farmers spent 80% of annual income on post-flood recovery (seeds, fertilizers), with 70% unable to restore soil fertility [34]. Large farms accessed insurance covering 50% of costs, enabling faster recovery.

5.4 Limited Access to Financial Aid

Access to financial support remains a major barrier for smallholder farmers. Many farmers, especially those from older generations, may not be aware of available disaster relief programs or may lack the technical skills to navigate application processes [35]. Even when such programs are accessible, the administrative delays often result in relief arriving well after the event, forcing farmers to endure extended periods of hardship. Furthermore, loans or grants may have restrictive terms or come with high-interest rates, which many small farmers cannot afford to repay. Larger farming operations often have established relationships with financial institutions and can more easily secure the funding needed to recover from flood-related losses. Recent study supports findings that 20% of small-scale farmers accessed government flood relief due to complex application processes; 60% faced high-interest loans in Philippines [36]. Large farms secured grants within weeks, recovering 40% faster.

6. Environmental Challenges

6.1 High Precipitation

The frequency and intensity of precipitation events have increased significantly due to climate change [37], leading to elevated water levels and more frequent, severe flooding [38]. In many regions, these extreme weather events disrupt agricultural productivity, especially for small-scale farmers who are highly dependent on consistent weather patterns for crop growth. The rise in unpredictable and prolonged flooding has broader implications, affecting residential areas, infrastructure, and local economies. Without coordinated global action to mitigate climate change and reduce greenhouse gas emissions, the long-term stability of farming systems, especially in vulnerable regions, remains uncertain. IPCC [39] report confirmed a 20% increase in extreme precipitation events globally since 2000, with small-scale farms in South Asia losing 30% of yields annually to floods. Adaptation measures like raised beds reduced losses by 15%.

6.2 Pest and Disease Outbreaks

Flooding creates favorable conditions for pest and disease outbreaks, which significantly impact crop health [40]. Excess moisture from flooding leads to conditions such as root rot, fungal infections, and other plant diseases, which can quickly spread across vegetable crops, decimating yields. Prolonged waterlogging weakens the plants' natural defense mechanisms, making them more susceptible to pathogens [41]. Fungal growth thrives in wet environments, also attracts additional pests, further compounding the negative effects on crop health [42]. Beyond vegetables, these conditions extend to other crops, including cash crops and plantations, severely impacting agricultural productivity [43]. Small-scale farmers, who often lack access to pest control resources, are particularly vulnerable to these outbreaks, which threaten their ability to recover after flood events.

6.3 Soil Degradation

Soil degradation is a significant consequence of flooding, particularly in regions with low soil porosity [44]. Flooding reduces the soil's ability to retain essential nutrients and water, leading to diminished fertility and reduced agricultural productivity. Waterlogged soils suffer from the leaching of essential minerals and nutrients [45], which directly affect crop growth and quality. For small-scale farmers, this presents a particularly dire challenge, as they often rely on traditional cultivation methods such as seed beds or open-field farming. The lack of access to alternative agricultural practices, such as hanging cultivation systems, further exacerbates the issue, leaving their lands vulnerable to erosion and nutrient depletion. Floods reduced soil nitrogen levels by 35% in smallholder farms, lowering yields by 25% [46]. Farmers lacked resources for soil restoration, unlike large farms using mechanized techniques.

7. Physical Challenges

7.1 Poor Drainage Systems

Effective drainage systems are essential for mitigating waterlogging and maintaining crop health [47], yet many small-scale farmers lack the resources to implement adequate drainage infrastructure. Waterlogged conditions, caused by inadequate drainage, not only delay crop recovery but also increase the risk of soil erosion, nutrient leaching, and further flooding. When floodwaters carry debris and silt into drainage systems, they often become blocked, exacerbating waterlogging and crop damage. A well-maintained drainage system would significantly reduce the negative impacts of flooding, yet for many smallholder farmers, the cost of installation and maintenance is prohibitively high [48]. 80% of small-scale farms lacked drainage systems, increasing flood losses by 60%. Pilot drainage projects reduced waterlogging by 40%, improving yields [49].

7.2 Storage Facilities

Storage facilities are critical for preserving harvested crops, yet many small-scale farmers rely on basic [50], ground-level structures that are highly vulnerable to flood damage. When floodwaters breach these storage areas, valuable resources, such as harvested vegetables, seeds, and fertilizers, are damaged or lost. The limited financial resources of small farmers often prevent them from constructing more resilient storage systems, such as elevated or multi-level structures, which could provide better protection against floodwaters. This lack of storage capacity further hampers recovery

efforts, as it prolongs the period before crops can be properly stored or marketed, leading to increased post-flood losses.

8. Conclusions

Floods pose an escalating threat to small-scale vegetable farmers worldwide, undermining their livelihoods and the broader systems they support. This review highlights the multifaceted challenges these farmers face in building resilience, spanning economic, social, environmental, and physical domains. Economically, dependence on farming, market disruptions, high recovery costs, and limited financial aid constrain their capacity to rebound from flood events. Socially, restricted access to education, early warning systems, and healthcare exacerbates their vulnerability, reducing their ability to adapt or recover. Environmentally, rising precipitation, pest outbreaks, and soil degradation intensify agricultural losses, while physically, poor drainage and inadequate storage facilities compound the damage. These interconnected barriers disproportionately affect small farmers compared to larger operations, which benefit from greater resources and infrastructure.

For future research, several avenues warrant exploration. Studies should investigate cost-effective, scalable solutions tailored to small farmers, such as affordable drainage systems or community-based early warning networks. Research into flood-tolerant vegetable varieties and sustainable soil management practices could mitigate environmental challenges, enhancing long-term productivity. Additionally, examining the efficacy of localized financial aid programs and health support initiatives would inform policies to alleviate economic and social burdens. Integrating qualitative insights from farmers with quantitative data on flood impacts could further refine resilience strategies. By pursuing these directions, future efforts can empower small-scale farmers to withstand floods, ensuring their vital contributions endure in an increasingly unpredictable climate.

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