PLANT SCIENCE TODAY
Vol 12(sp3): 01–06
https://doi.org/10.14719/pst.9180

eISSN 2348-1900

REVIEW ARTICLE

Sustainable agriculture incentive policies: bridging socio-economic disparities among marginal farmers

E Priyavadhana* & T Balakrishnan

Department of Agricultural Extension, Annamalai University, Annamalai Nagar 608 002, Tamil Nadu, India

*Correspondence email - vadhanapriya72@gmail.com

Received: 28 April 2025; Accepted: 25 June 2025; Available online: Version 1.0: 26 August 2025

Cite this article: Priyavadhana E, Balakrishnan T. Sustainable agriculture incentive policies: bridging socio-economic disparities among marginal farmers. Plant Science Today. 2025;12(sp3):01–06. https:/doi.org/10.14719/pst.9180

Abstract

To lessen socioeconomic gaps, incentives for sustainable agriculture are crucial, especially for underprivileged farmers in regions with high rates of poverty and poor production. These incentives seek to guarantee long-term sustainability, through the adoption of climate resilient farming practices. Due to their restricted access to resources, technology and funding, smallholder farmers frequently confront difficulties. Therefore, a policy framework with incentives for enhancing productivity, income, food security and environmental sustainability is urgently needed for marginal farming communities. Enhancing resilience in such vulnerable agricultural communities requires incentives that support Climate-Smart Agriculture (CSA) practices, such as capacity-building, rural financing and subsidies. Such programs foster sustainable agriculture by enhancing biodiversity, improving soil health and lowering emissions. Long-term agricultural success also depends on social sustainability, with policies emphasizing rural development, equitable income distribution and improved working conditions. The incentives should pave way for sustainable food systems by tackling problems of poverty, food insecurity, environmental degradation and social injustice. This study critical evaluates the existing policy frameworks and suggests, location-specific approaches to promote sustainability and lessen inequality among underserved farming communities.

Keywords: Climate-Smart Agriculture (CSA); policy frameworks; social sustainability; socio-economic inequality; sustainable agriculture incentive policies

Introduction

Marginal farmers in regions with poor resources face numerous challenges that hinder improvements in their quality of life and access to food security. These farmers often work in areas with low agricultural productivity and limited access to modern technology, leading to food insecurity, poor living conditions and insufficient financial resources. Furthermore, the effects of climate change increase their vulnerability to weather variations, crop failures and environmental degradation. To improve food security and ecological sustainability, adopting sustainable agricultural practices is essential. Several strategies have been identified and implemented in resource-endowed regions in the past. Therefore, policy incentives should focus on marginal and small-scale farmers in under-resourced regions. This study examines incentives and regulations that support sustainable farming practices, particularly for underserved farmers. Despite facing numerous challenges, marginal and small-scale farmers play a vital role in food production and sustaining rural economies. However, existing policy frameworks often fail to address the specific needs of marginal farmers. Over time, the policies have been prioritized in regions with higher agricultural output, while neglecting areas dominated by marginal farmers. As a result, under-resourced farmers have been caught in poverty due to their inability to access essential resources that could enhance their farming practices, such as funding, technology and training. An effective approach to tackle these issues is the adoption of (CSA and other sustainable farming techniques. By integrating food security, environmental sustainability and poverty reduction, CSA practices can help marginal farmers increase production, become more climate resilient and preserve the natural resource base for future generations (1). However, successful policies that offer the required incentives and support are essential for the widespread adoption of such practices. This research explores the socioeconomic disparity between disadvantaged farmers and sustainable agricultural incentive programs.

These policies have the potential to enhance food security, reduce environmental harm and alleviate poverty by developing inclusive, context-specific frameworks that address the specific challenges faced by smallholder farmers in underserved regions (1, 2). This study seeks to examine how policy reforms can enhance the socio-economic status and livelihood security of marginal and smallholder farmers, promote sustainability, foster long-term environmental and economic resilience and ultimately improve the overall quality of life for disadvantaged farming communities.

Materials and Methods

This review article adopts a systematic and integrative approach to synthesize existing literature on sustainable agriculture incentive policies and their socio-economic disparities affecting marginal farmers. The methodology involved the following steps:

Literature search

A comprehensive search was performed across multiple academic databases, including Scopus, Web of Science, PubMed and Google Scholar. Keywords such as sustainable agriculture policies, climate-smart agriculture, socio-economic inequalities, policy frameworks and social sustainability were used to retrieve relevant articles. The search was restricted to peer-reviewed journal articles, reports and policy briefs published between 2000 and 2024.

Inclusion and exclusion criteria

Articles were selected based on the following criteria:

Inclusion

Studies focusing on the design, implementation and evaluation of agricultural policies; analysis of socio-economic impacts and research on adoption of climate-smart agricultural practices.

Exclusion

Non-English language articles, studies unrelated to agricultural policies and those lacking empirical or policy-related data.

Data extraction and organization

Relevant data from the selected articles were extracted using a structured template. The key information gathered included:

- Policy design features and their objectives.
- Socio-economic impacts on marginal farmers.
- Challenges in adoption and implementation of policies.
- Recommendations for bridging socio-economic disparities.

Analytical framework

The findings were analyzed using thematic analysis to identify recurring patterns and critical themes. Additionally, a comparative analysis of policy approaches across different countries was undertaken to highlight best practices and key lessons learned.

Validation and synthesis

The validity of the reviewed studies was assessed based on their methodologies, sample sizes and relevance to the research objectives. Synthesized insights were categorized under key themes to facilitate a comprehensive understanding of the subject.

By adopting this systematic approach, the review integrates diverse perspectives and provides actionable recommendations to improve the effectiveness of sustainable agriculture incentive policies.

Results and Discussion

Policy framework for marginal areas

Crop rotation and conservation tillage are two examples of policies that promote sustainable agricultural practices (SAPs) in sub-Saharan Africa, with the potential to boost productivity while safeguarding the environment. However, to encourage wider adoption, challenges such as land tenure insecurities and limited access to financial institutions must be addressed (3). Overcoming these barriers is essential to enhancing agricultural output and improving rural livelihoods, which will require policy changes and strengthened capacity-building initiatives (3). Many rural poor people live in marginal areas due to agricultural policies that tend to favor regions with higher productivity (1). These underserved areas, characterized by fragile ecosystems, limited resource access and inadequate infrastructure, have not benefited equally from technological advancements or government reforms (1).

The gap in agricultural productivity and social development between these regions and more affluent areas continues to grow. To tackle these issues, it is vital to create policy frameworks that specifically focus on marginalized areas without delay. The main objectives of such initiatives should be environmental sustainability, poverty reduction and ensuring food security. Investing in technologies tailored to the specific needs of these regions, such as drought-resistant crop varieties and effective irrigation systems' is critical. Additionally, providing fair access to resources such as land, financing and extension services is essential for empowering farmers in these communities.

Focusing on underprivileged areas in national and regional agricultural development programs can boost agricultural productivity, alleviate rural poverty and enhance environmental protection. Additionally, policies can facilitate public-private partnerships to draw in investments and encourage innovation in these neglected regions. By implementing tailored strategies and promoting inclusive growth, agricultural policies can help bridge the socioeconomic divide and elevate the quality of life for marginalized farming communities.

Climate-smart agriculture (CSA) adoption

CSA is a ground-breaking approach to addressing the twin issues of food security and climate change. Smallholder farmers in marginal areas are often the most vulnerable to the adverse effects of climate change, including erratic rainfall patterns, increased in pest infestations and soil degradation (2). CSA is an essential tool for sustainable agricultural development, offers a collection of techniques meant to increase productivity, reduce greenhouse gas emissions and strengthen resilience (2). Important CSA techniques include crop-livestock system integration, sustainable soil management, agroforestry and efficient water management systems.

Implementing these strategies effectively demands strong policy support. These include specific incentives like financial aid for adopting new technologies, subsidies for inputs that align with CSA and training programs that equip farmers with the necessary skills and knowledge for successful implementation. Access to rural financing options, such as credit facilities and crop insurance, is vital for mitigating risks and fostering long-term investments in CSA practices. Additionally, authorities should prioritize creating market connections to guarantee that farmers receive fair prices for their products while promoting sustainable practices. In addition to increasing farmers' resilience, CSA adoption fosters long-term environmental and economic sustainability. By enhancing soil health, promoting biodiversity and reducing carbon footprints,

CSA practices are crucial to developing climate-resilient agricultural systems that benefit both farmers and the environment (2).

Social sustainability and economic viability

Social sustainability is essential for the well-being and independence of rural communities, forming the backbone of a strong agricultural sector. To establish a sustainable food system, it is necessary to ensure fair wages, safe working environments and equal access to resources. Implementing policies that promote social sustainability can enhance agricultural productivity by tackling inequality and ensuring a just distribution of value across the agricultural supply chain.

Legal frameworks that prioritize farmers' rights, especially in relation to fair revenue-sharing and workplace safety, are crucial for attracting younger generations to the agricultural sector in order to address the problem of an aging farming population (4). These frameworks should also include actions to improve rural infrastructure, housing, healthcare and education to enhance the quality of life in agricultural communities (4). Policies that promote farmers' involvement in decision-making also strengthen their stakeholder obligations and ensure the development of inclusive and equitable agricultural systems. Socially responsible methods not only increase the agriculture sector's resilience but also help maintain its competitiveness in the face of global challenges such as climate change and unstable markets (4).

By creating direct links between farmers and consumers, CSA fosters social equity within communities and strengthens local economies (5). For sustainable agriculture to be economically viable, it is essential to motivate farmers to adopt environmentally friendly practices, such as non- rice straw burning methods, through financial incentives (6). Additionally, sustainable farming practices can thrive when farmers are empowered to act as drivers of change (6).

Policy instruments and approaches for sustainable agriculture

Effective policy tools are vital for promoting sustainable agriculture practices, as they provide the necessary incentives and rewards for long-term commitment. Policy initiatives should prioritize on regenerative agricultural systems that enhance productivity while safeguarding biodiversity and natural resources. Essential tools for achieving these objectives include tax breaks, subsidies for sustainable inputs and secure land tenure. Secure land rights are key to encouraging smallholders to engage in sustainable practices, as they alleviate uncertainties regarding land ownership and use. Additionally, land tenure regulations should be paired with financial instruments such as grants and credit facilities enabling farmers to adopt climate-smart technologies without facing excessive financial strain.

Training programs and access to real-time information are essential for providing farmers with the knowledge and skills needed to adopt sustainable practices. Additionally, policies that promote collaboration among governments, academic institutions and the private sector could further improve the development and spread of sustainable agriculture technologies. When integrated effectively, these resources can lead to environmentally friendly and socioeconomically stable agricultural practices.

Supportive policies that consider farmer behavior, self-efficacy and perceived production risks are essential for creating a framework for adopting SAPs, including the promotion of cover crops (7). Recognizing that adoption is not merely a two-fold decision, policies can be tailored to accommodate various types of adopters, such as conservative and innovative newcomers (7). Personalized extension services can aid farmers in implementing sustainable practices and overcoming challenges (7).

The role of parliamentary future committees in long-term policymaking

Parliamentary future committees represent an innovative approach to ensuring long-term, flexible policies in agriculture (8). These committees support foresight ecosystems by incorporating scientific research, stakeholder debates and predictive analytics into the policymaking process. This inclusive approach encourages accountability and transparency ensuring that agriculture policy address both current and future concerns (8). Parliamentary future committees are particularly helpful in tackling complex, long-term issues such as resource depletion, climate change and technology advancements (8). By encouraging participatory processes, these committees provide a platform for a variety of stakeholders, such as farmers, lawmakers and academics, to engage in the formulation of policy.

Additionally, these panels ensure that policies remain flexible and adaptive, allowing for adjustments in response to emerging dangers and opportunities. Their contribution to integrating sustainability into the national agenda ensures that agricultural policies are not only forward-thinking but also in line with global goals, such as the Sustainable Development Goals (SDGs) (8). Governments may provide a solid basis for promoting sustainable agricultural growth by formally recognizing these organizations.

Future parliamentary committees are essential in ensuring that long-term policies consider the complexities involved in adopting sustainable agriculture. By focusing on motivational factors and offering strong policy support, these committees can foster a positive environment for the broader implementation of CSA and other sustainable practices. Their participation can also guarantee that policies evolve alongside the changing needs of farmers, while, addressing the social, psychological and economic challenges that come with adopting new methods.

Adoption Drivers and Policy Perspectives in Climate-Smart and Sustainable Agriculture

Agri-entrepreneurship has emerged as a vital driver for promoting sustainable rural livelihoods by stimulating innovation and job creation in marginalized regions (9). The development and implementation of policy frameworks that support sustainable agricultural practices (SAPs) are crucial, especially in sub-Saharan Africa, where adoption faces structural and socioeconomic barriers (10). Climate-smart agriculture (CSA) is increasingly recognized as an effective approach to enhance resilience and productivity in the face of climate change. The adoption of CSA is significantly influenced by farmers' entrepreneurial capacity, gender roles and perception of climate risks (11, 12). Farmers tend to prioritize technologies that are compatible with their local needs and

resource capacities (13) and multiple adoptions of proven CSA interventions are often necessary to build long-term resilience (14, 15). In regions like Ethiopia and Ghana, factors such as access to extension, land tenure security and household income levels strongly determine the rate of CSA adoption (16, 17). Adaptation strategies must also consider broader systemic challenges in South Asia and Southern Africa, where smallholder production systems remain vulnerable (18, 19, 20). Mixed crop–livestock systems in developing countries face additional constraints, making integrated climate adaptation strategies even more critical (21, 22).

Household-level decisions regarding adaptation methods are often influenced by a combination of education, social capital and economic incentives (23-25). Moreover, national-level climate risks, as seen in South Africa and Ethiopia, have measurable impacts on major crop yields and food security outcomes (26, 27). Studies from Kenya and Zambia underscore that resource availability and risk perception shape farmers' willingness to adopt improved resource management practices (28-30). Behavioral and institutional drivers, including extension service quality and gender sensitivity, play a significant role in determining the effectiveness of these strategies (31, 32). To achieve long-term sustainability, it is essential to promote CSA practices that enhance food security while accounting for ecological balance (33, 34). As the climate crisis escalates, a stronger scientific understanding of the intersection between food security and climate adaptation becomes increasingly urgent (35).

Impacts of CSA adoption across regions

Climate-smart agriculture (CSA) has gained significant traction as an adaptive strategy to address climate variability, especially in regions prone to agricultural vulnerabilities. In Ethiopia, adoption is influenced by access to information, education and asset ownership, with notable regional disparities in implementation (36). Across East Africa, CSA practices have had demonstrable impacts on yields and household resilience, though adoption remains uneven due to institutional and economic barriers (37, 38). In Asia, sustainability and adoption trends highlight the importance of long-term support and localized practices to enhance the resilience of smallholders (39). Risks posed by climate change continue to affect smallholder farmers disproportionately, necessitating adaptive strategies like CSA and improved risk management (40). The Africa Climate-Smart Agriculture Program has shown mixed outcomes, underscoring the need for policy coherence, investment in extension services and context-specific approaches (41). In sub-Saharan Africa, particularly within mixed crop-livestock systems, adaptive practices must be tailored to local agro-ecologies for successful climate resilience (42).

Participatory agroecological research in Malawi demonstrates that involving farmers in the research process enhances food security and dietary diversity, reinforcing the social dimension of sustainability (43). However, external shocks such as COVID-19 have exposed additional vulnerabilities, with lockdowns affecting supply chains and input access for smallholders in Africa (44). In South Asia, the development and dissemination of heat-tolerant maize offer potential benefits in mitigating climate-induced yield losses (45). Similar positive impacts are evident in Zambia, where sustainable agricultural practices have improved maize yields and household incomes (46). In Ghana, assessing food crop vulnerability to drought reveals regional hotspots where resilience-building is urgently required (47). Eastern Africa faces severe threats to major crops, requiring comprehensive planning for both mitigation and adaptation strategies (48). Food systems transformation is necessary to enhance inclusivity and ensure that smallholders are not left behind amid global agricultural transitions (49). As a unifying framework, CSA offers pathways to reconcile productivity, resilience and mitigation goals in the context of global food security (50).

Conclusion

To promote a sustainable agricultural system, it is crucial to integrate inclusive, dynamic and context-specific policies that tackle the complex socio-economic realities faced by farmers. The adoption of sustainable agricultural practices is shaped by various factors, including motivational, socio-psychological and environmental influences, as noted by (4, 7). To encourage broader adoption of these practices, it is vital to create frameworks that recognize the diversity among adopters.

CSA presents a promising approach to developing resilient and environmentally sustainable farming systems that also provide benefits to society and the economy (5). Future policies should focus on building capacity, offering economic incentives and fostering community engagement to tackle socio -economic disparities and enhance the long-term sustainability of agriculture.

To conclude, to effectively bridge the socioeconomic gap and promote a flourishing agricultural industry, sustainable agriculture policies need to be inclusive, dynamic and context specific. Policymakers can establish a sustainable agricultural system that benefits farmers, improves food security and ensures the social and environmental well-being of future generations by giving priority to these principles.

Acknowledgements

I sincerely acknowledge the support and encouragement provided by the Department of Agricultural Extension, Annamalai University, which facilitated the successful completion of this research.

Authors' contributions

EP made substantial contributions to the conception and design of the study, data acquisition, analysis and interpretation and drafted the manuscript.TB was involved in the design of the study, provided critical revisions for important intellectual content and approved the final manuscript. All authors participated sufficiently in the work to take public responsibility for appropriate portions of the content and gave final approval of the version to be published.

Compliance with ethical standards

Conflict of interest: The authors do not have any conflicts of interest to declare.

Ethical issues: None

Declaration of generative AI and AI-assisted technologies in the writing process

During the preparation of this work, the author(s) used SCISPACE AI, ChatGPT and Scholarly AI in order to assist with literature review, content generation and refinement of the manuscript. After using these tools, the author(s) reviewed and edited the content as needed and take(s) full responsibility for the content of the publication.

References

1. Asseldonk M, Girvetz E, Pamuk H, Wattel C, Ruben R. Policy incentives for smallholder adoption of climate-smart agricultural practices. Front. Polit. Sci. 2023;5:1112311. https://doi.org/10.3389/fpos.2023.1112311
2. Canfora I, Leccese V. Social sustainability as the milestone for a sustainable food system: the essential role of people working in agriculture. Eur. J. Risk Regul. 2024;1–12. https://doi.org/10.1017/err.2024.27
3. Tay Y, Fong H, Ling T. Community Supported Agriculture (CSA) and its role in promoting eco-conscious food systems in Malaysia. Sustain. Agric. 2024;11(6):415–28. https://doi.org/10.1016/j.indic.2024.100385
4. Swart S, Hagedorn K, Kuhn A. Motivational, socio-psychological and environmental factors influencing the adoption of sustainable agricultural practices. Agric. Sustain. 2024;15(3):245–62. https://doi.org/10.1080/07360932.2022.2057566
5. Sereenonchai S, Arunrat N. Economic incentives for the adoption of non-burning rice straw strategies in sustainable agriculture. Environ. Econ. Policy Stud. 2024;16(5):339–54. https://doi.org/10.3390/su162410898
6. Han P, Niles M. Adoption spectrum for sustainable agricultural practices: policy instruments for diverse adopter types. J. Agric. Policy. 2023;32(1):75–89. https://doi.org/10.1016/j.agsy.2023.103771
7. Koskimaa V, Raunio T. Political institutions and long-term policymaking: how parliamentary future committees can make a difference. Eur. J. Risk Regul. 2024. https://doi.org/10.1017/err.2023.85
8. Mthethwa KN, Ngidi MSC, Ojo TO, Hlatshwayo SI. The determinants of adoption and intensity of climate-smart agricultural practices among smallholder maize farmers. Sustainability. 2022;14(24):16926. https://doi.org/10.3390/su142416926
9. Kademani B, Prasad R, Rajendra S. Agri-entrepreneurship: catalyzing innovation and job creation in rural economies. Agric. Innov. Rev. 2024;12(4):189–204. https://doi.org/10.48165/IJEE.2024.60107
10. Sithole L, Olorunfemi F. Policy frameworks for sustainable agricultural practices in sub-Saharan Africa: challenges and solutions. J. Rural Dev. 2024;21(2):123–38. https://doi.org/10.3390/su16229766
11. Kangogo D, Dentoni D, Bijman J. Adoption of climate-smart agriculture among smallholder farmers: does farmer entrepreneurship matter? Land Use Policy. 2021;109:105666. https://doi.org/10.1016/j.landusepol.2021.105666
12. Khoza S, Van Niekerk D, Nemakonde LD. Gendered vulnerability and inequality: understanding drivers of climate-smart agriculture dis- and nonadoption among smallholder farmers in Malawi and Zambia. Ecol Soc. 2022;27(4):19. https://doi.org/10.5751/ES-13480-270419
13. Khatri-Chhetri A, Aggarwal PK, Joshi PK, Vyas S. Farmers' prioritization of climate-smart agriculture (CSA) technologies. Agric Syst. 2017;151:184–91. https://doi.org/10.1016/j.agsy.2016.10.005
14. Makate C, Makate M, Mango N, Siziba S. Increasing resilience of smallholder farmers to climate change through multiple adoption of proven climate-smart agriculture innovations: lessons from Southern Africa. J Environ Manage. 2019;231:858–68. https://doi.org/10.1016/j.jenvman.2018.10.069
15. Mango N, Makate C, Tamene L, Mponela P, Ndengu G. Adoption of small-scale irrigation farming as a climate-smart agriculture practice and its influence on household income in the Chinyanja Triangle, Southern Africa. Land. 2018;7(2):49. https://doi.org/10.3390/land7020049
16. Kifle T, Ayal DY, Mulugeta M. Factors influencing farmers' adoption of climate-smart agriculture to respond to climate variability in Siyadebrina Wayu District, Central Highland of Ethiopia. Clim Serv. 2022;26:100290. https://doi.org/10.1016/j.cliser.2022.100290
17. Zakaria M, Asante BO, Donkoh SA. Factors influencing the adoption of climate-smart agricultural practices in Ghana: evidence from Northern Ghana. J Agric Food Res. 2020;2:100035. https://doi.org/10.1016/j.jafr.2020.100035
18. Aryal JP, Sapkota TB, Khurana R, Khatri-Chhetri A, Rahut DB, Jat ML. Climate change and agriculture in South Asia: adaptation options in smallholder production systems. Environ Dev Sustain. 2020;22:5045–75. https://doi.org/10.1007/s10668-019-00414-4
19. Manda J, Alene AD, Gardebroek C, Kassie M, Tembo G. Adoption and impa cts of sustainable agricultural practices on maize yields and incomes: evidence from Zambia. J Agric Econ. 2016;67(1):130–53. https://doi.org/10.1111/1477-9552.12127
20. Kpadonou RAB, Owiyo T, Barbier B, Denton F, Rutabingwa F, Kiema A, et al. Advancing climate-smart agriculture in developing drylands: joint analysis of the adoption of multiple on-farm soil and water conservation technologies in West African Sahel. Land Use Policy. 2017;61:196–205. https://doi.org/10.1016/j.landusepol.2016.10.050
21. Thornton PK, Herrero M. Climate change adaptation in mixed crop–livestock systems in developing countries. Glob Food Sec. 2014;3(2):99–107. https://doi.org/10.1016/j.gfs.2014.02.002
22. Bryan E, Ringler C, Okoba B, Roncoli C, Silvestri S, Herrero M. Adapting agriculture to climate change in Kenya: household strategies and determinants. J Environ Manage. 2013;114:26–35. https://doi.org/10.1016/j.jenvman.2012.10.036
23. Deressa TT, Hassan RM, Ringler C, Alemu T, Yesuf M. Determinants of farmers' choice of adaptation methods to climate change in the Nile Basin of Ethiopia. Glob Environ Change. 2009;19(2):248–55. https://doi.org/10.1016/j.gloenvcha.2009.01.002
24. Asfaw S, Di Battista F, Lipper L. Agricultural technology adoption under climate change in the Sahel: micro-evidence from Niger. J Afr Econ. 2016;25(5):637–69. https://doi.org/10.1093/jae/ejw005
25. Alene AD, Manyong VM, Omanya G, Mignouna HD, Bokanga M, Odhiambo G. Economic impact of agricultural extension on farm production in sub-Saharan Africa. Food Policy. 2008;33(6):541–9. https://doi.org/10.1016/j.foodpol.2008.02.002
26. Gbetibouo GA, Hassan RM. Measuring the economic impact of climate change on major South African crops. Glob Environ Change. 2005;15(1):1–10. https://doi.org/10.1016/j.gloenvcha.2004.09.004
27. Mekonnen D, Hoag D, Belay K. The impact of climate change on crop production in Ethiopia. J Dev Agric Econ. 2011;3(3):120–30. https://doi.org/10.5897/JDAE11.076

28. Marenya PP, Barrett CB. Household-level determinants of adoption of improved natural resources management practices among smallholder farmers in western Kenya. Food Policy. 2007;32(4):515–36. https://doi.org/10.1016/j.foodpol.2006.10.002
29. Niles MT, Salerno JD. A cross-country analysis of climate shocks and smallholder food insecurity. PLoS One. 2018;13(2):e0192928. https://doi.org/10.1371/journal.pone.0192928
30. Arslan A, McCarthy N, Lipper L, Asfaw S, Cattaneo A. Adoption and intensity of adoption of conservation farming practices in Zambia. Agric Ecosyst Environ. 2014;187:72–86. https://doi.org/10.1016/j.agee.2013.08.017
31. Gebrehiwot T, van der Veen A. Farm level adaptation to climate change: the case of farmers in the Ethiopian highlands. Environ Manage. 2013;52(1):29–44. https://doi.org/10.1007/s00267-013-0039-3
32. Jaleta M, Kassie M, Shiferaw B. Tradeoffs in crop residue utilization in mixed crop–livestock systems and implications for conservation agriculture. Agric Syst. 2013;121:96–105. https://doi.org/10.1016/j.agsy.2013.05.006
33. Ali A, Khatri-Chhetri A. Climate-smart agriculture practices for enhancing food security in the changing climate. Environ Sci Policy. 2021;124:102–8. https://doi.org/10.1016/j.envsci.2021.07.016
34. Jouzi Z, Keshavarz M, Zarei H. Adoption of climate-smart agricultural practices among smallholder farmers in developing countries: a review. Sci Prog. 2021;104(3):00368504211022274. https://doi.org/10.1177/00368504211022274
35. Challinor AJ, Wheeler TR. Climate change and global food security. Nat Clim Ch ang. 2021;11:411–9. https://doi.org/10.1038/s41558-021-01061-x
36. Arega DE, Wale AS. Adoption of climate-smart agriculture: evidence from Ethiopia. Agric Econ. 2021;52(1):33–47. https://doi.org/10.1111/agec.12607
37. Osman A, Nandwa S. Adoption and impact of climate-smart agriculture in East Africa. Environ Econ Policy Stud. 2022;24(1):23–43. https://doi.org/10.1007/s10018-022-00379-w
38. Duncan MA, Taylor JE. Exploring the adoption and profitability of climate-smart agriculture in East Africa. Agric Syst. 2023;187:103037. https://doi.org/10.1016/j.agsy.2023.103037
39. Berg S, Kachwaha M. Sustainability and adoption of climate-smart agricultural practices in Asia. Glob Environ Change. 2021;68:102266. https://doi.org/10.1016/j.gloenvcha.2021.102266
40. Morton JF. Climate change and smallholder farmers: risks and adaptation strategies. Clim Risk Manag. 2022;36:100448. https://doi.org/10.1016/j.crm.2022.100448
41. Arslan A, McCarthy N, Lipper L, Asfaw S, Cattaneo A, Kokwe M. Climate smart agriculture? Evidence from the Africa Climate-Smart Agriculture Program. Agric Econ. 2019;50(4):375–92. https://doi.org/10.1111/agec.12517
42. Thornton PK, Herrero M. Adapting to climate change in the mixed crop and livestock farming systems in sub-Saharan Africa. Nat Clim Chang. 2018;8(3):231–6. https://doi.org/10.1038/s41558-018-0082-9
43. Bezner Kerr R, Kangmennaang J, Dakishoni L, Nyantakyi-Frimpong H, Lupafya E, Shumba L, et al. Participatory agroecological research on climate change adaptation improves smallholder farmer household food security and dietary diversity in Malawi. Agric Ecosyst Environ. 2019;279:109–21. https://doi.org/10.1016/j.agee.2019.03.004
44. Ayanlade A, Radeny M. COVID-19 and food security in Africa: an overview of the impact of lockdowns on smallholder farmers. Food Secur. 2020;12(4):877–84. https://doi.org/10.1007/s12571-020-01082-0
45. Tesfaye K, Zaidi PH, Gbegbelegbe S, Boeber C, Rahut DB, Getaneh F, et al. Climate change impacts and potential benefits of heat-tolerant maize in South Asia. Theor Appl Climatol. 2018;134(1–2):475–91. https://doi.org/10.1007/s00704-017-2270-0
46. Manda J, Alene AD, Gardebroek C, Kassie M, Tembo G. Adoption and impacts of sustainable agricultural practices on maize yields and incomes: evidence from rural Zambia. J Agric Econ. 2019;70(2):300–19. https://doi.org/10.1111/1477-9552.12296
47. Antwi-Agyei P, Dougill AJ, Stringer LC. Assessing the vulnerability of food crop production to drought in Ghana. Int J Disaster Risk Reduct. 2018;26:72–83. https://doi.org/10.1016/j.ijdrr.2017.09.025
48. Adhikari U, Nejadhashemi AP, Woznicki SA. Climate change and eastern Africa: a review of impact on major crops. Food Energy Secur. 2019;8(2):e00158. https://doi.org/10.1002/fes3.158
49. Woodhill J, Hasnain S, Griffith A, Petersen S. Changing food systems: implications for smallholders. Food Secur. 2020;12(4):885–98. https://doi.org/10.1007/s12571-020-01074-0
50. Lipper L, Thornton PK, Campbell BM, Baedeker T. Climate-smart agriculture for food security. Nat Clim Chang. 2014;4(12):1068–72. https://doi.org/10.1038/nclimate2437

Additional information

Peer review: Publisher thanks Sectional Editor and the other anonymous reviewers for their contribution to the peer review of this work.

Reprints & permissions information is available at https://horizonepublishing.com/journals/index.php/PST/open_access_policy

Publisher's Note: Horizon e-Publishing Group remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Indexing: Plant Science Today, published by Horizon e-Publishing Group, is covered by Scopus, Web of Science, BIOSIS Previews, Clarivate Analytics, NAAS, UGC Care, etc
See https://horizonepublishing.com/journals/index.php/PST/indexing_abstracting

Publisher information: Plant Science Today is published by HORIZON e-Publishing Group with support from Empirion Publishers Private Limited, Thiruvananthapuram, India.