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REVIEW ARTICLE Agricultural Reviews

Indicators, Theory of Change and Impact Pathways in Climate-smart Agriculture for Sustainable Development: A Systematic Review

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10.18805/ag.RF-261

ABSTRACT

Climate change is among the pressing global challenges affecting sustainable development, especially in the rain-fed-based agriculture of developing countries. Climate-smart agriculture (CSA) approach answers this question by ensuring high productivity, creating an improved adaptive capacity and reducing GHG emissions. This systematic literature review aims to provide an overview of the indicators, theory of change and impact pathways of CSA that lead to sustainable development. Using a systematic research method, four stages of PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-analysis) namely, identification, eligibility, screening and included were used for selecting the articles reviewed. A total of 37 articles were then used for this study. CSA interventions measured by the behavioral changes resulting from different stakeholders (producers, consumers, extension workers, policymakers and institutions, civil society and the private sector) can play a significant role in sustainable development.

Key words: Climate-smart agriculture, Impact pathways, Indicators, Sustainable development, Theory of change.

Agriculture accounts for 70 per cent of freshwater resources and 40 per cent of the terrestrial land used by human beings and 24 per cent of greenhouse gas emissions induced by humans. It also employs about 2.6 billion people globally (World Bank, 2016). In the developing world of largely agriculture-based economies where the largest proportion of poor people live in rural areas and are associated with the highest poverty rates, the significance of agriculture is the greatest (Dinesh *et al*., 2018; Kirina *et al*., 2022; World Bank, 2016). Agricultural production can be affected by climate change in different ways. Precipitation and temperature patterns, surface water runoff, extreme climate events, CO_2 concentration and soil moisture are some of the factors that can greatly affect agricultural development (Kirina *et al*., 2022). Climate-smart agriculture (CSA) approach is currently proposed as the best fix in feeding the rising food demands and creating climate change adaptive communities with mitigation co-benefits in low-income countries (Musafiri *et al*., 2022).

In its broadest sense, CSA indicates three fundamental elements of the worldwide agenda. The primary element is to maximize agricultural productivity and satisfy the rising demands while maintaining the sustainability of soil and water resources. Climate change adaptation is the second element that refers to producing a resilient production system that is better able to withstand climate shocks and weather variabilities. Mitigation is the third element that plays a role in reducing greenhouse gas emissions from agriculture and promoting carbon sequestration in plants and agricultural soils (Phiri *et al*., 2021; Rajala *et al*., 2021). The effects of these elements simultaneously to yield benefits in all is referred to as ‘‘triple wins’’.

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How to cite this article: Girma, G.T. and Petros, W.W. (2024). Indicators, Theory of Change and Impact Pathways in Climate-smart Agriculture for Sustainable Development: A Systematic Review. Agricultural Reviews. doi: 10.18805/ag.RF-261.

Submitted: 18-02-2023 **Accepted:** 10-01-2024 **Online:** 20-02-2024

Transformations at various scales, governance levels and time horizons are required to achieve climate-smart agricultural outcomes (Fig 1). A range of indicators is available currently to measure the performance of agriculture, climate change, natural resource management and different variables associated with nutrition and food security. Trends and facts on global, regional, national and local scales are reflected by these indicators (Dinesh *et al*., 2021; Newell *et al*., 2019). An encompassing CSA impact pathway is used for the development of CSA indicators that identify how project outputs can produce project outcomes (behavioral change). Behavioral change is key in CSA interventions because it is only when certain stakeholders show a change in behavior in using CSA that the approach can be termed sustainable (Collins-Sowah, 2018; Dinesh *et al*., 2021; Vernooy and Bouroncle, 2019).

On the other hand, impact pathways are theoretical frameworks that assist in guiding program planning, management and evaluation (Collins-Sowah, 2018). These impact pathways give a conceptual framework for evaluating a set of indicators that enable measuring the change in behavior, project outputs and conditions of the enabling institutional and policy environment that could be important to aid the CSA intervention and subsequently attain development outcomes in the long term. Few of the project outcomes are regarded as approximate behavioral change measures.

The systematic literature review research method is applied to this study. In selecting the articles, the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analysis) method was used, which constitutes 4 stages: identification, eligibility, screening and included (Moher *et al*., 2016). The following databases were used for searching the articles: Scopus, Science Direct and Web of Science. The keywords used for the search were Climate-smart (with and without hyphen between climate and smart) agriculture, indicators, impact pathways and sustainable development.

In descending order, 28 relevant articles were selected in the Web of Science database, 12 in the Scopus database and 11 in the Science Direct database. Then, the manual selection was used for the 90 items on the first 10 pages. During the process, book chapters, working papers, books, conference proceedings and newspaper articles were excluded. This resulted in 60 additional articles.

In the phase of identification, 37+60 items were identified. Screening was then followed to remove duplication (Fig 2). This resulted in 77 identified articles. Then, a review of the abstracts of these articles was made

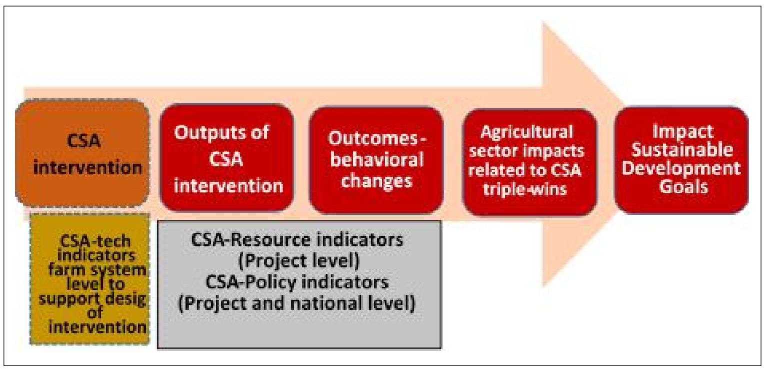

Fig 1: CSA intervention impact pathways and relation to CSA indicators (Source: World Bank Report, 2016).

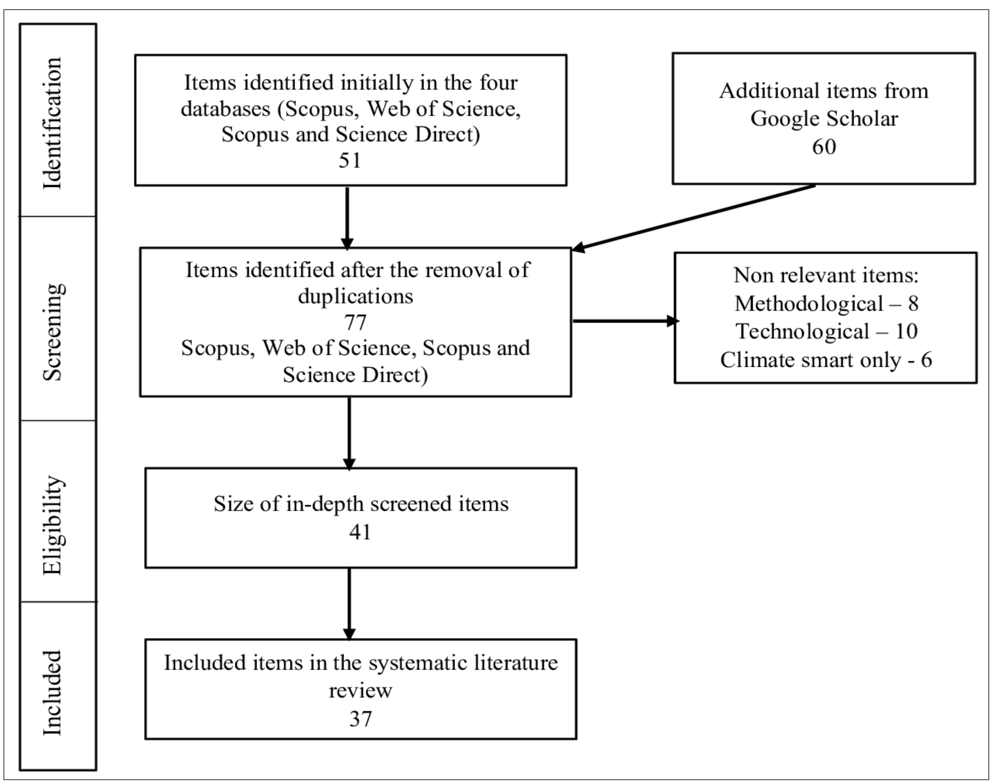

Fig 2: PRISMA article screening method.

and verifying whether they deal with climate-smart agriculture, indicators, impact pathways and sustainable development nexus was conducted. The majority of the excluded articles dealt purely with methodological, empirical and technology issues. Eventually, the systematic literature review was based on 37 articles. This study was conducted in the years 2020-2022 at Addis Ababa University during my PhD study.

Impacts on the agricultural sector

The long-term outcomes aimed to be achieved by CSA are discussed in this section. Various stakeholder groups' behavioral changes that lead to long-term outcomes are elaborated.

Productivity increase

The dedicated goal of CSA is increasing productivity. For example, in a number of African nations, the level of the yield of many commodities is under the world average yet (Brandt *et al*., 2017). The reduced level of productivity is attributed to the use of low levels of improved seeds, knowledge gaps on agricultural practices, inadequate irrigation, low level of synthetic fertilizer use and absence of strong policies and institutions (Dinesh *et al*., 2021; (Steenwerth *et al*., 2014; Thornton *et al*., 2018). Various studies showed that an increase in productivity increases the availability of food, access, as well as household incomes (Beuchelt and Badstue, 2013; Neufeldt *et al*., 2015; Zougmoré *et al*., 2019). From enhancing agricultural productivity, three basic benefits can be gained: i) food and nutrition security, ii) economic growth and poverty reduction and iii) environmental sustainability (Thornton *et al*., 2017). Likewise, literature confirmed that agricultural growth is twice as effective in poverty reduction as compared to growth emerging from other sectors (Christiaensen and Martin, 2018). Growth in agricultural productivity creates employment and income and generates rural goods demands. This stimulates other rural good demands. On the other hand, productivity determines food prices that again govern competitiveness and tradable sectors (Thornton *et al*., 2017).

Sustainable productivity is knowledge-intensive, such that intellectual capital investment, is mainly acquired through the dissemination of agricultural technologies and management practices, research and development that require training, education and extension services that are relevant to achieving sustainable climate-smart agriculture (Masikati *et al*., 2019). A study conducted in Tamil Nadu, India also confirmed the use of organic manure significantly improves soil fertility, productivity and enhance ecological status (Vanathi *et al*., 2023). The World Development published in 2008 suggested various activities that can enhance agricultural productivity are price incentive improvement and quality and quantity of public investment increase, producer market function improvement, financial services access improvement, producer organizations performance enhancement, promoting of technology and science innovation and making agriculture a provider of environmental services and sustainable (World Bank, 2008). These efforts require a broader strategic framework and policy that includes agribusiness and agro-industrial services along with farming.

Resilience enhancement

The increasing volatility of food prices and uncertainties associated with global market development and the increasing occurrence of extreme and erratic weather events induce negative food security impacts and consumers' agricultural incomes, farmers and entire nations. Smallholder farmers are the majority climate-dependent groups of the population that were expected to play a significant role in food and nutrition security but in reality, they possess the weakest capacity to adapt to the increasingly volatile world. Targeted institutions, policies and investments strengthen their resilience (Negera *et al*., 2022). The crucial goal of CSA intervention is to promote resilience, at every scale and from social, environmental and economic perspectives.

One major intervention is the use of best-performing crop cultivars that enhance food security (Al-Ragam *et al*., 2023). The definition of resilience takes several forms. One of the most cited definitions is the one given by the International Panel on Climate Change (IPCC) (2014) states resilience is ‘‘the capacity of environmental, economic and social systems to cope with hazardous events, disturbance, or trend, or responding in ways essential functions, structure and identity are maintained while also maintaining the capacity of learning, transformation and adaptation’’ (Neufeldt *et al*., 2015). Resilience is then a dynamic process as economic, social and environmental landscapes change. Resilience may refer to the capacity of communities to withstand and recover from environmental, economic, or social stress in social systems. These systems can plan based on perceived or real changes, thus minimizing losses, avoiding damages and taking advantage of opportunities (Cleves *et al*., 2022; Denton *et al*., 2015). For natural systems, it may refer to the amount of disturbance an ecosystem can absorb without shifting to a different qualitative state. The relation, interdependence and complexities of both systems must be taken into consideration during resilience building to changes in climate (Jarraud and Steiner, 2012).

To enhance smallholder farmers' resilience, it is important to facilitate their use and access to productive assets, such as water, land and production inputs. Water and land rights strengthening can encourage farmers to diversify, invest and build assets (Aguilar *et al*., 2022; Mottram *et al*., 2017). Access to water enhancement through water harvesting on-farm, on-farm water retention, moisture holding capacity of the soil enhancement and more systematic access to supplementary irrigation or groundwater can have a complementary effect on household resilience (Maia *et al*., 2021). Further investment in both political and technological innovation may be necessary. This includes research, replacement of inefficient subsidies, development and dissemination of drought-tolerant varieties of seeds, bio-fortified crops, prevention response, recovery and response activities in response to climate change and shock events, social safety nets, risk management tools that aid social preparedness and livelihood strategies (Meybeck *et al*., 2012). Resilience enhancement also means mechanisms such as sustainable forest management improvement. This strategy not only improves the resilience of the forest but also contributes to soil protection from soil erosion, improving water management and agrobiodiversity conservation (McCabe, 2013).

The extreme vulnerability of agriculture intensifies the challenge. The negative impact of climate change is already being felt, in the form of weather variability, increasing temperatures, invasive crops and pests, shifting agroecosystem boundaries and more frequent extreme weather events. Climate change reduces crop yield, major cereals' nutritional quality and lowers livestock productivity. To meet the increasing demand for maintaining current yields to achieve food quality and production, substantial adaptation investments will be required (Masikati *et al*., 2019).

Greenhouse gas (GHG) emission reduction

One of the most important aims of practicing CSA is greenhouse gas emission reduction from agriculture. Any CSA intervention needs to lead toward a sustainable reduction of GHG emissions. Globally, forestry, agriculture and other land use sectors are responsible for 25 per cent of anthropogenic GHG emissions mainly from livestock and poor soil and nutrient management and deforestation (Anuga *et al*., 2020). Opportunities for mitigation may include both demand and supply-side strategies. Strategies on the demand side include changes in diet, food waste and loss and wood consumption reduction, whereas, the supply side strategies are GHG emission reduction through livestock and land management improvements. Increased levels of terrestrial carbon stock through carbon sequestration in biomass and soils (Sain *et al*., 2017).

As population growth continues to spike globally, agricultural production especially in the developing world is expected to increase. By decoupling production growth from emission growth, improving efficiency, as well as by elevating carbon sinks, the contribution of agriculture to mitigation *i.e*. changes in climate food security, which is the primary objective, can be enhanced (Rafik *et al*., 2022).

One of the most effective strategies for reducing emissions can be increasing nitrogen-use efficiency. This should be coupled with the decarbonization of fertilizer synthesis. Using the available technologies currently, GHG emissions of fertilizers could be decreased by approximately one-fifth of the present levels by 2050 (Zougmoré, 2019).

Outcomes

Behavioral change

Sustainable achievement of aspired impacts of CSA can be realized when interventions bring about behavioral changes. This portion highlights the six key stakeholder groups to achieve the desired impacts of behavioral changes: I) producers; II) extension workers; III) civil society; IV) consumers; V) policymakers and institutions; VI) the private sector (World Bank, 2016).

Producers

In producers, the following observable behavioral changes are induced by CSA intervention and projects (Vernooy and Bouroncle 2019):

a) Producers adopt the right CSA practices and inputs such as fertilizer, seed, risk management tools and pesticides. The outcome shows that producers have taken up specific CSA outputs in their day-to-day practices.
b) Produces ensure that they gain knowledge on trade-offs of adopting CSA, costs and benefits. Producers' knowledge and capacity need to be developed to ensure sustainable adoption of CSA technologies. This backs up productivity as well as the resilience of farming systems.
c) If the desired impacts are to be achieved, producers need to engage themselves with extension services because their decision-making capacity can be empowered.
d) Access to improved financial instruments and services and income diversification strategies of income improvement strategies of producers can be improved.
e) Integration of farmers with new markets and value chains is possible. Market access is important for smallholder farmers to improve food security, generate income and ensure sustainable livelihoods.

Extension workers

Extension workers need to take part in multilateral service and knowledge sharing and strive to get updated on CSA latest knowledge from different sources including the farmers themselves. One of the key channels through which information on new practices and technologies can be disseminated and importantly supporting CSA services are extension services (Musafiri *et al*., 2022).

Civil society

Civil society support helps achieve the CSA-related sectoral goals and activities of improved productivity, resilience and enhanced sustainability and minimizing GHG emissions. Civil society plays an important role in CSA mainstreaming for achieving desired impacts. Civil society institutions have considerable potential to influence decision-making processes and readily foster bottom-up engagements, for instance, demanding services and measures and becoming vocal about local concerns (Aggarwal *et al*., 2018). International and local level societal engagements can exist and they have a considerable capacity to help achieve the aspired impacts.

Consumers

Consumers contribute to CSA practices in consumption decisions. Consumers determine the value by buying products whereby they benefit other stakeholders in the value chain. Particularly consumers have a large degree of power in developed countries. The behavior of consumers needs to reflect improved awareness towards the reduction, recycling and reuse of food that is still healthy for human and animal consumption (van Wijk *et al*., 2020). Increased demand for goods that are rooted in integrated and sustainable value chains built on CSA practices should also be reflected in their behavior. Sustainable production by farmers and the value chain can be promoted through their demand.

Policymakers and institutions

According to Zougmoré (2019) Institutions and policymakers' behavioral changes that are aimed to be induced by CSA interventions and projects are:

a) Policymakers oversee and monitor compliance with CSA. The institutional support and commitment support of policymakers is detrimental to ensuring the sustainable CSA adoption and application is not limited to the farm level but to the landscape and country level.

b) There is cooperation in developing and disseminating information by institutions. Implementation of CSA demands cooperation across various sectors and CSA requires a landscape approach. Decision-makers from various research institutes and ministries with different thematic areas need to work together to collect and provide relevant and timely information. This behavioral change in institutions and policymakers aims to facilitate future data and information availability on CSA under the landscape approach.

c) Policymakers use a multitude of information, instruments and inputs from stakeholders for building capacity and creating incentives for producers for CSA implementation in an intersectoral manner and across different stakeholders including research, technical and extension staff, as well as international partners and nongovernmental stakeholders.

d) Institutional framework, legal and regulatory frameworks for the implementation and mainstreaming of CSA are established by policymakers.

e) Government agencies enforce, implement, monitor and evaluate policies related to CSA. It is, then, important for policymakers to oversee and monitor the compliance of CSA across various institutions and sectors.

f) The commitment given by governments to abide by global and regional agreements and mechanisms in supporting climate change adaptation and mitigation is the crucial outcome of mitigating agriculture-caused GHG.

The private sector

The fundamental objectives of CSA implementation; improved productivity, enhanced sustainability and reduced GHG emissions must be supported by the private sector. The basic private sectors may include farmers themselves, national and international agribusinesses, producer cooperatives credit and saving institutions and commercial consultancies and banks. Actors of the private sector provide education, development, research and extension. Though private sectors are aiming at making profits and public perception, appropriate behavioral change may include an increased interest in supporting CSA-related activities. As market engagements and markets of smallholder farmers become more relevant, it is important to provide outputs that alter the private sector's behavior to support CSA (Mottram *et al*., 2017).

Literature gap

Generally, this review research provides valuable insights into the potential effects of climate-smart agriculture on sustainable development. However, the question of how climate change will interact with other anthropogenic stressors to affect the adaptive capacity and resilience of smallholder farmers remains unanswered, highlighting the need for further research.

CONCLUSION AND RECOMMENDATIONS

Within the development community, there is now a substantial consensus over the need for further climate-smart agriculture, which constitutes three defining priorities: sustainably increasing agricultural production, enhancing agricultural resilience to climate change and reducing agricultural greenhouse emissions. Our ability to measure production resilience and emissions makes climate-smart agriculture operational in a way that decision-makers are informed about technologies, policies and practices that promote each effectively. Besides the immediate results of improved practice or activity, longer-term outcomes may lead to fundamental changes in the way that consumers, producers, investors and others behave and what they base their consumption, production and investment decisions on. The indicators described in this article were discussed for this purpose.

The application of indicators to analyze the performance of agriculture in various nations reveals a number of correlates associated with legal frameworks, institutions and the relationship between agriculture and other sectors like energy and water. Implementing them in projects makes sure that the crucial advantages of approaches that employ the right technologies and that include broader, landscape-based approaches that appreciate and allow for competing demands for water and land resources.

The empirical practical evidence of the highly practical type that can be amassed by monitoring these indicators will play a pivotal role in agriculture's large ecological footprint mitigation, capitalizing on its potential to provide services of environmental benefits and in guiding intensification forms lead to substantially higher and more sustainable production and thereby ensure sustainable development.

Conflict of interest

The authors declare that there is no conflict of interest.

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