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Climate change adaptation strategies among rural communities: Examining indigenous knowledge systems and modern agricultural techniques for sustainable food security

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Abstract

The problem of climate change presents a new challenge to agricultural communities in the rural areas of the world threatening food security and sustainable livelihoods. This is a thorough research paper that investigates how indigenous knowledge systems have been incorporated with other modern forms of agriculture as a form of adaptation among the rural communities. This study evaluates the complement between the traditional weather forecasting methods, practices of crop diversification and community-based resource management systems with the modern advances in agriculture through a comprehensive overview of empirical and theoretical evidence. The research shows that effective adaptation should be achieved by a synergistic approach involving the application of scientific agricultural developments together with ancient indigenous practices. The research is relevant to the current body of knowledge on climate change adaptation because it offers empirical evidence of effective measures that mediate between indigenous wisdom and scientific innovation to provide practical implications to the policymaker, agricultural extension workers, and rural development practitioners as they strive to achieve sustainable food security in the face of global environmental change.

Keywords: Climate Change Adaptation; Indigenous Knowledge Systems; Sustainable Agriculture; Agricultural Innovation; Community-Based Adaptation; Climate Variability

1. Introduction

Climate change is one of the major environmental problems facing humans in the twenty first century with far reaching repercussions on the agricultural productivity and food security of the world population. The rural communities, especially developing ones, are more disproportionately vulnerable to the effects of climate because they rely on rain-fed agriculture, have low adaptability capacity, and restricted access to resources and technologies (Howden et al., 2007). The Intergovernmental panel on climate change has reportedly recorded high evidence of changing rain patterns, rising temperatures, rising instances of droughts and floods which pose a direct threat to the agricultural systems (Intergovernmental panel on climate change, 2001a).

The concept of adaptation to climate change covers a broad scope of alteration in ecological, social, and economic systems due to the real or perceived climatic stimuli and the impact of those stimuli. The process of adaptation may be accomplished in different levels, with individual decisions on farms to community-oriented programs and national policy models (Smit et al., 2006). In the rural farming environment, adaptation methods can be applied in the form of

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changing the pattern of cropping, new varieties of crops, soils and water conservation measures, income diversification, and the use of climate information to make decisions (Bryan et al., 2009).

1.1. Background and Context of Climate Change Impacts on Rural Agriculture

Anthropogenic climate change presents unprecedented challenges to the global agricultural sector and the rural communities in the agricultural sector have been the hardest hit by the consequences of environmental change. The accumulating scientific evidence of the past decades clearly shows that the climate system gets warmed, the average air and ocean temperature rises, extensive melting of snow and ice, and global average sea level is on the rise (Intergovernmental Panel on Climate Change, 2001a). These global scale transformations occur on local and regional scales in the form of changes in precipitation patterns, the frequency and intensity of extreme weather events, changes in the nature of the growing season, and changes in the pest and disease dynamics occurring directly and unavoidably on agricultural productivity (Howden et al., 2007).

The spatial heterogeneity of climate change effects and adaptive capacity further complicates the rural agricultural vulnerability because communities across a comparatively short distance can have significantly different climatic patterns and have different abilities to respond. The differences in the agroecological settings of the soil types, topography, water availability, and vegetation cover present various exposure to climate-related risks despite the apparently homogenous regions (Below et al., 2012). The other dimensions of spatial variation in adaptive capacity are brought about by socioeconomic factors such as wealth distributions, land tenure, access to market and services, and social capital configurations (Adger et al., 2003). Adaptation planning should thus respond to this heterogeneity in the form of adaptable, context-sensitive planning as opposed to standardized prescriptions (Eriksen et al., 2015).

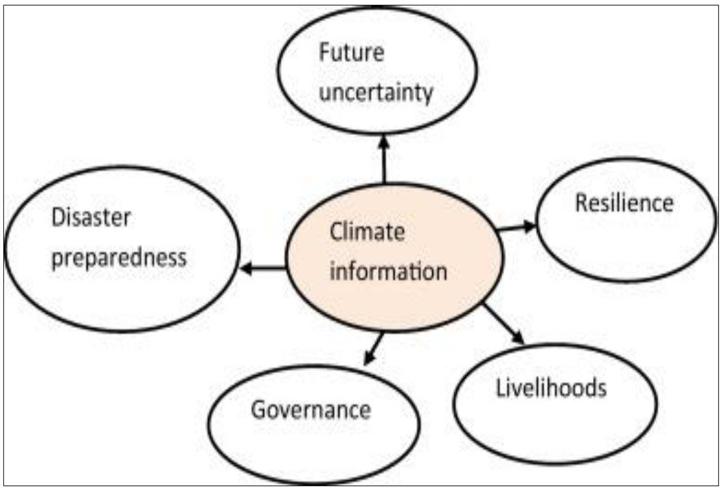

Figure 1 Access and usage of climatic information matters for climate change adaptation

The above figure 1 shows the quantitative data about the major constraints that curb the adaptive action of rural farming households. Information deficiency becomes the largest impediment with around 4% of all the households that were surveyed, which is manifested by poor access to weather predictions, climate estimates, and technical information on adaptation actions (Bryan et al., 2009). The second significant barrier is financial constraints at 33% because most of the adaptation measures have initial investments in inputs, equipment or infrastructure that are beyond the smallholder farmers available resources (Deressa et al., 2009).

1.1.1. Conceptual Framework for Understanding Climate Change Adaptation and Resilience

The conceptual frameworks used in the adaptation to climate change in rural agricultural settings need to be strong enough to explain how vulnerability, adaptive capacity, and resilience interact with different factors that define the outcome of adaptation. Recent adaptation theory is inspired by various disciplinary insights such as hazards and disaster studies, ecological resilience theory, sustainable livelihoods strategies, and political ecology to create combined systems of examining community and system responses to environmental change (Smit et al., 2006).

Vulnerability as a concept offers a background through which to comprehend dissimilar effects of climatic change and adjustment capacity amid communities and households. Vulnerability analysis looks at the extent to which systems or populations are prone to negative influences of climate variability and change relative to the level of exposure to climate risks as well as vulnerability of the agricultural systems to climatic stimuli (Adger et al., 2003). The rural agriculture vulnerability is a consequence of interaction between varied stressors such as climate risks, environmental loss, market instability, health, and political marginalization that respectively weaken livelihood security and livelihood wellbeing (O'Brien et al., 2004).

Adaptive capacity is the capacity of systems, institutions, human beings, and other organisms to adapt to the possible harm, to use opportunities, or to adapt to the effects of climate change. Adaptive capacity elements include resource material and social access, technology and information access, good institutions and governance, resource allocation equity, and human resources properties such as education, health, and skills (Yohe et al., 2002). Studies have found many determinants of adaptive capacity at household, community, and societal levels such as wealth and income, education and knowledge, social networks and institutional support, access of information and technology, and features of local agroecological systems (Smit et al., 2006).

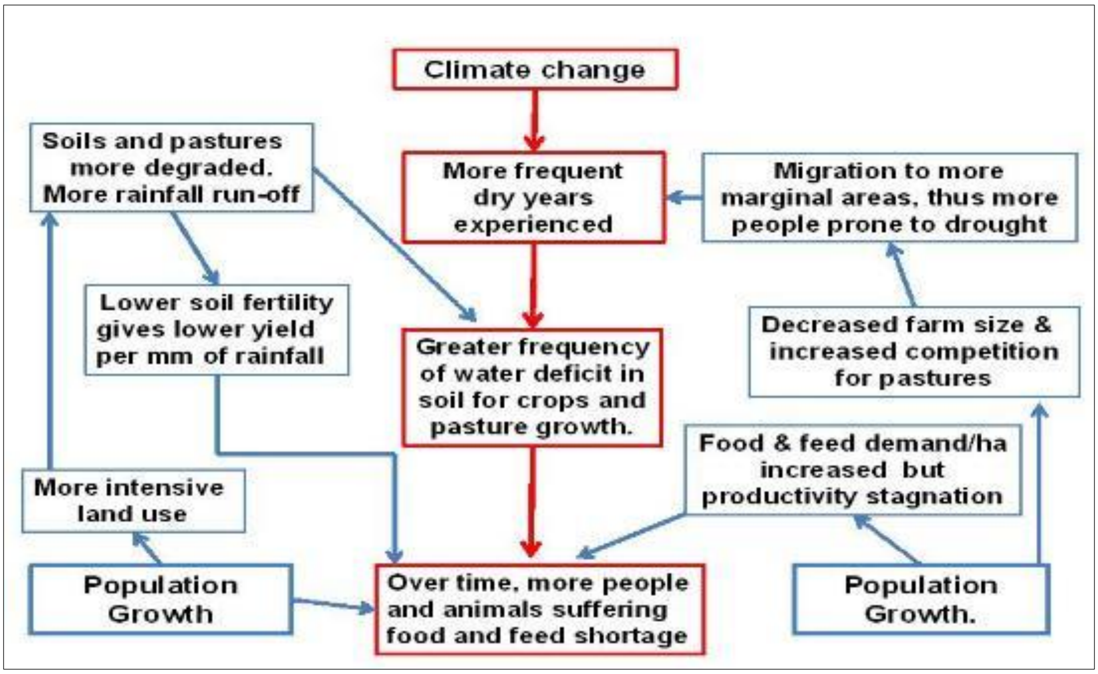

Figure 2 Illustrative impact pathways of climate change (red) and population growth (blue). Source; Cooper et al., (2013)

Complementary views on adaptation are offered by resilience thinking, which seeks to address how systems can take in disturbances without giving up the vital functions and structures. The concept of resilience evolved in the ecological system analysis and has been applied to the social-ecological system such as the agricultural landscape where the human and the natural elements interact dynamically (Folke, 2006). Strong agricultural systems exhibit resilience to climate shocks, can restructure after significant disturbances, and gain experience to increase adaptation ability in the future (Milestad et al., 2003).

1.1.2. Modern Agricultural Technologies and Scientific Approaches to Climate Adaptation

The modern agricultural science has a lot of technological and management innovations that may improve climatic adaptation such as better crop varieties, precision agricultural techniques, sustainable intensification practices, and climate information services. Plant breeding programs have come up with crop varieties that are more tolerant to droughts, heat, salinity, flooding and other climate stresses using traditional selection, marker-assisted breeding, and genetic modification technologies (Tester et al., 2010). These superior types tend to be more stable to unfavorable environmental conditions than the traditional types, although performance gains can be lost in highly marginalized environments or in situations where the stresses of biotic and abiotic factors interact (Cooper et al., 2008).

Another set of contemporary methods of climate adaptation is conservation agriculture practices such as minimum tillage, retention of crop residues, and crop rotation or intercropping. These activities enhance the health of soil, increase the water percolation and storage, decrease soil erosion, store carbon, and moderate the change in soil temperature, which offers several advantages in adapting to water stress and extreme temperatures (Ifejika Speranza et al., 2010). Experience in various agroecological regions indicates that conservation agriculture can not only raise yield stability and decrease the costs of production, but also improve climate variability-resilience, although these benefits are not consistently positive in all settings and it may require several years before the positive attributions truly develop.

Drip irrigation, rainwater harvesting structures and enhanced water storage facilities are some of the water management technologies which provide valuable adaptation opportunities to curb the rising water scarcity as well as rain variation. These technologies have the potential of enhancing efficiency in water use by a significant margin, increasing productive opportunities in dry seasons, and counteracting the effects of droughts (Ngigi, 2003). The infrastructure in water management is however capital intensive such that most smallholder farmers cannot afford without external assistance and this casts a question of fairness and access (Hussain et al., 2004).

1.2. Statement of the Problem

Although there is increasing awareness about the effects of climate change on the rural agricultural systems and food security, there is still much gap in knowledge concerning how effective adaptation mechanisms can be achieved through combining indigenous knowledge with new farming methods. The literature has mainly focused on traditional and modern approaches as independent entities and has not focused on the potential synergies and complementarities, and integrative mechanisms. Moreover, the knowledge about the aspects that affect the adaptation decision of farmers is not well developed, especially in the extent to which socioeconomic attributes, institutional aspects, accessibility of information and resources and local agroecological environment influence the adoption of various adaptation strategies.

The world has a wide variety of adaptation methods being used by the rural people whose methods of adaptation vary widely such as indigenous methods of adaptation that have been passed on by the generation to the new generation, as well as modern methods of adaptation, but there is little systematic analysis to determine the effectiveness of these adaptation methods to ensure food security (Smit and Wandel, 2006). The comparative value of traditional knowledge and modern methods to adaptation success in various situations need to be examined through rigorous means.

1.3. Research Questions

This study addresses the following research questions:

- **RQ1:** What indigenous knowledge systems do rural communities employ for climate change adaptation, and how do these traditional practices contribute to food security?
- **RQ2:** What modern agricultural techniques are available and accessible to rural communities for climate adaptation, and what factors influence their adoption?
- **RQ3:** How do rural communities integrate indigenous knowledge systems with modern agricultural techniques in their adaptation strategies?
- **RQ4:** What are the primary barriers preventing effective climate change adaptation among rural agricultural communities?
- **RQ6:** What policy and institutional interventions can facilitate effective integration of indigenous knowledge and modern agricultural techniques for climate adaptation and food security?

1.4. Research Objectives

The primary objectives of this study are:

- To identify and document indigenous knowledge systems employed by rural communities for climate change adaptation and food security.
- To examine modern agricultural techniques available for climate adaptation and factors influencing their adoption in rural contexts.
- To analyze how rural communities integrate traditional knowledge with contemporary agricultural innovations in adaptation strategies.
- To assess barriers constraining effective climate change adaptation among rural agricultural communities.
- To evaluate impacts of different adaptation strategies on food security outcomes across diverse rural contexts.

Scope of the Survey

This survey explores ways of adaptation to climate change in rural agricultural communities in the special interest of the integration of indigenous knowledge systems and modern agricultural methods to ensure food security. The research will cover a wide geographical setting such as sub-Saharan Africa, South Asia, and other developing areas with a high level of climate change vulnerability by rural communities. The study is dedicated to the smallholder agricultural systems that involve crop production with livestock maintenance as it is the most common agricultural livelihood approach in most rural regions. The temporal scope includes recent decades whereby the effects of climate change on the environment and the adaptation mechanisms have been markedly changing.

2. Related Surveys and Literature Review

2.1. Introduction to Climate Change and Rural Vulnerability

The issue of climate change has developed as a characteristic of the twenty-first century, and its impact has extended effects to agricultural systems and rural livelihoods all over the world (Intergovernmental Panel on Climate Change, 2001b). According to scientific evidence, global temperatures have been on the increase in the last century, and that there are corresponding changes in the amount of precipitation, and the frequency of extreme weather conditions as well as the changes in seasonal cycles and their impacts on agricultural production across the world. Rural people, especially the smallholder farmers in the developing world are subjected to disproportionately greater impacts of such climatic changes because they rely largely on rain-fed agriculture, have poor access to resources of adaption and are also exposed to various stress factors such as poverty, poor infrastructure, and institutional inefficiency (Pelling and High, 2005).

Agricultural systems of production are very sensitive to climate parameters such as temperature, precipitation, extreme weather conditions with major repercussions on the yields of crops, the productivity of livestock and the overall food security (Howden et al., 2007). Increased temperature influences the rate of crop development, evapotranspiration rate causing more water stress, and changes the pest and disease dynamics. The alterations in the precipitation patterns such as decreased total rainfall, augmented rainfall variability, and alterations in the seasonal distribution present uncertainty in production and elevate the chances of crop failure.

2.2. Climate Change Adaptation in Agricultural Systems

Adaptation to climate change refers to changes in ecological, social, and economic systems in reaction to real or predicted climatic stimuli and impacts in the effort to moderate damages or capitalize on exploitative opportunities (Smit and Wandel, 2006). In the agricultural setting, the adaptation strategies can be in terms of incremental changes to the current practices, or transformational changes in production, livelihood, and patterns of settlement. Autonomous adaptation is where farmers adapt basing on their own observations and experiences on climatic variability whereas planned adaptation is where governments, development organizations and other institutional actors actively intervene to enable the process of adaptation and mitigate vulnerability to climatic variability (Below et al., 2012).

Several typologies of agricultural adaptation strategies have been identified such as technological options, management practices, institutional arrangements, and policy interventions (Howden et al., 2007). Some of the technological changes include the use of better crop varieties that have better stress management, water management through irrigation, and precision farming technology to optimize the use of inputs. The adaptations made by the management involve cropping patterns and dates of planting, crop diversification, integrated management of pests and soil conservation. Institutional adaptations can be seen to include better agricultural extension services, climate information system development, agricultural insurance systems, and market infrastructure.

2.3. Indigenous Knowledge Systems and Traditional Adaptation Practices

Indigenous knowledge systems are highly complex stores of knowledge, innovations, and knowledge practices that communities have created through years of experience and intimate contact with their surrounding environments (Berkes et al., 2000). Such knowledge systems include local climatic patterns, ecosystem, farming methods, and management of resources that have been achieved over generations and passed to other generations through cultural processes. Indigenous knowledge proves useful in climate adaptation since communities have already devised a method of coping with climate variability and environmental change in their localities historically.

Traditional weather forecasting is another significant part of the indigenous knowledge systems, whereby observation of biological indicators, atmospheric processes and astronomical cycles are used to forecast the rainfall onset, seasonal features, and extreme weather conditions (Roncoli et al., 2002). Communities monitor the activities of animals, the phenological processes of plants, wind patterns, cloud shapes, and other signs to predict the weather patterns and make suitable decisions concerning agriculture. A wide range of indigenous weather forecasting systems in various locations has been reported such as the observation of bird movements, insect behaviors, flowering of trees, and weather patterns that are used to predict rainfall and seasons (Ifejika Speranza et al., 2010).

2.4. Integration of Indigenous Knowledge and Modern Agricultural Science

There is a growing recognition among researchers and practitioners that successful climate adaptation means integrating and combining the strengths of the indigenous and modern agricultural science with mitigating the weaknesses of either side (Agrawal, 2008). The indigenous knowledge offers specific contextual knowledge of local settings, cost-effective low-cost work, and acceptance within the community due to the cultural acquaintance. Modern science provides capabilities of better prediction, possibility of quick innovation with research and innovative solutions of new challenges. The integration strategies are designed to generate synergies among the knowledge systems by adopting an approach of respectful dialogues, collective research and creation of hybrid practices that would utilize complementary areas of strength.

Recording and legitimatizing the indigenous knowledge will help to popularize it and support it in formal agricultural development initiatives (Nyong et al., 2007). Ethnobotanical researches report on the varieties of crops that were used traditionally, including their traits, which is used to conserve and make use of agricultural varieties. Studies on indigenous weather forecasting confirm the traditional forecasting indicators by comparing them to the meteorological records. The traditional soil and water conservation methods are examined in studies to determine the level of effectiveness and the possibility of broader application. This recording causes the indigenous knowledge to be more transparent and reachable to researchers, policymakers, and development practitioners, but it should be done in a respectful manner, with community approval and benefit-sharing scheme (Salick and Byg, 2007).

2.5. Barriers to Climate Change Adaptation in Rural Communities

Even with the existing variety of adaptation alternatives, rural communities have various constraints that limit practical adaptation to climate change (Below et al., 2012). Limited financial capital, inability to own sufficient land, and lack of work force are some of the major barriers to the implementation of most of the adaptation strategies due to resource constraints. The poverty limits the ability of farmers to acquire better inputs, invest in technology like irrigation system or risk-taking during experimentation. Inability to access credit does not allow financing of capital-intensive adaptations. The lack of land and poor tenure security diminishes the incentives to invest in long term projects in soil conservation, Agro-forestry, and other adaptive land management strategies (Bryan et al., 2009).

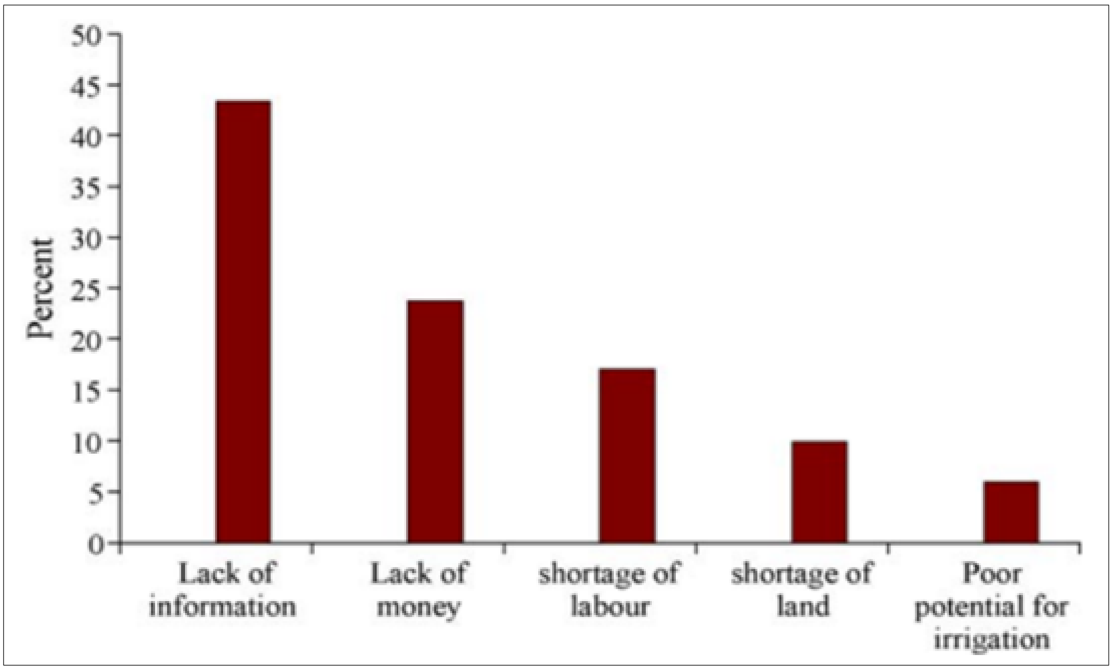

Figure 3 Barriers to Adaptation Among Rural Communities. Source: Adapted from Deressa et al., 2009

This is because information and knowledge gaps restrict adaptation due to poor awareness of climate change, the lack of knowledge about adaptation choices and the lack of access to climate information services (Maddison, 2007). Various rural communities are not exposed to the scientific knowledge on climate change and their estimated effects in their areas. Farmers might not know of the existing adaptation technologies and practices, or have no knowledge about how they are supposed to be applied. The coverage of extension services is usually poor especially in remote rural regions. The provision of climate information services often does not penetrate the rural societies or information is not in forms easily interpreted and utilized by the farmers.

Adaptation is hampered by institutional and policy constraints such as poor governance, poor infrastructure, unfavourable market environment, and inappropriate policies (Eriksen et al., 2015). Lack of a strong property right and tenure insecurity will deter long term investments in adaptive land management. Poor rural infrastructure such as roads, storage facility and market systems limits access of farmers to inputs and selling products. Agricultural policies can encourage a specific group of crops or agricultural systems and discourage diversification and innovation. Inadequate funding towards research and development of agriculture restricts the supply of locally relevant technologies. There can be barriers to adoption of some adaptation strategies or traditional practices due to regulatory barriers.

3. Methodology

3.1. Research Design and Approach

This broad survey is based on the systematic literature review approach and comparative analysis of cases to investigate the strategy of climate change adaptation in rural communities. The study design combines both qualitative and quantitative studies to bring a comprehensive idea on the role of indigenous knowledge systems and new farming technologies in promoting climate adaption and food security. The approach is based on various sources of data such as peer-reviewed scholarly articles, institutional reports, case studies in different geographical backgrounds, and the results of empirical researches on rural agricultural communities in developing and developed countries (Mertz et al., 2009).

Systematic review element is done according to laid down guidelines of identification, screening, and synthesis of pertinent literature on climate change adaptation on rural agricultural settings (Howden et al., 2007). The methodology will assure full coverage of the current knowledge and allow rigor and transparency. The review includes the works that explore the systems of indigenous knowledge, traditional adaptation strategies, recent agricultural technologies, hybrid adaptation strategies, adaptation obstacles, and food security consequences in a variety of geographical and socioeconomic settings.

3.2. Literature Search Strategy and Selection Criteria

The search strategy used in the literature search was a combination of several supplementary measures that were used to guarantee that the relevant studies would be identified in full. Critically designed search strings were performed in the major academic databases such as Scopus, Web of Science and Google Scholar by combining key words associated with climate change adaptation, indigenous knowledge, traditional practices, modern agricultural methods, rural communities, and food security (Thomas et al., 2007). Search strings that included Boolean operators were used (climate change adaptation) AND (indigenous knowledge) AND (agriculture) OR (farming systems) AND (food security). Other searches involved specific adaptation strategies such as drought-resistant varieties, conservation agriculture, traditional weather forecasting, Crop diversification, and water harvesting among others.

Inclusion criteria meant that the studies should discuss the aspects of climate change adaptation or management of climate variability in rural agricultural settings, focus on indigenous knowledge systems or modern agricultural methods or both, and have empirical evidence based on field studies or effective secondary analysis, and implications on food security or agricultural livelihoods. The studies were incorporated irrespective of research methodology used and they included quantitative analysis, qualitative case study, mixed research, and systematic review (Deressa et al., 2009). The exclusion criteria were because the studies about urban settings, less on climate mitigation and more on climate adaptation, papers of solely theoretical basis, and studies that did not address the fact of food security or agricultural aspects explicitly were eliminated.

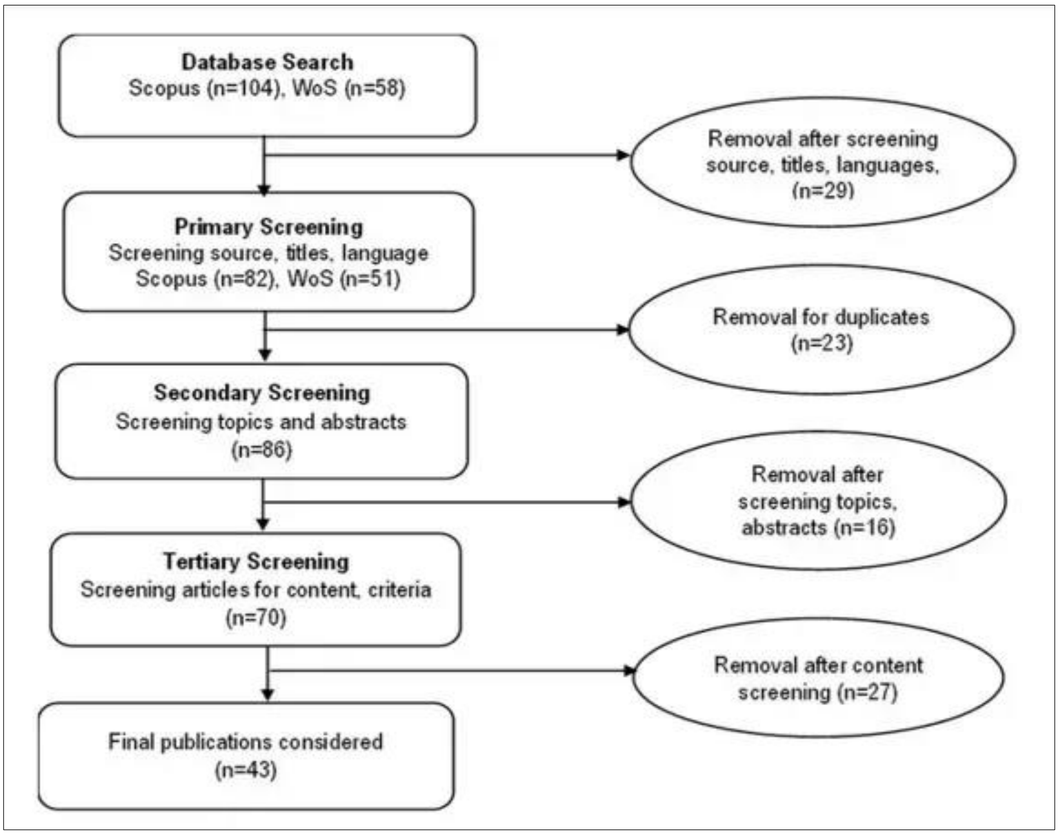

Figure 4 Literature Selection Process Following PRISMA Framework

The selection was done using a multi-stage screening strategy according to the PRISMA model (Moher et al., 2009). The preliminary database search has identified a total of 194 potentially useful publications on the platforms of Scopus and Web of Science. Having eliminated duplicates, 143 distinct data were subjected to primary screening (based on titles and abstracts) to determine possible relevance. This preliminary screening removed 29 articles which were evidently not meeting inclusion criteria depending on topic, geographical area, or scope. The rest 114 publications underwent the secondary screening process which included the review of full texts to determine whether they were sufficient to address the research questions and were of good quality (Below et al., 2012). This critical review has eliminated 44 studies because of the lack of empirical support, poor coverage of the adaptation strategies, or lack of relevance to food security outcomes. After tertiary screening of the contents in terms of quality and methodological rigor, 43 publications were retained in this review to analyze and synthesize in detail.

3.3. Data Extraction and Analytical Framework

Information retrieval of selected publications used specific protocols to extract pertinent information in answering research questions. In both studies which have been included, the extraction process included bibliographic data, geographical and agroecological setting, methodology used in the research, population, specific adaptation strategies, dynamics affecting adaptation choices, challenges to adaptation, and food security outcomes (Pelling and High, 2005). The research focused on the indigenous knowledge systems was given special consideration in terms of documentation of the traditional practices, processes of knowledge transmission, assimilation with the modern methods and authentication of the traditional knowledge.

The synthesis of findings implements both the narrative and quantitative methodology fitting the heterogeneous evidence base. Narrative synthesis determines patterns, themes, and relationships among studies without ignoring the contextual differences and limitations in the studies (Smit and Wandel, 2006). When several studies are available that give quantitative information on relationships, including determinants of adaptation decisions, meta-analytic methods are used to estimate the overall effect sizes and determine whether the results are consistent across contexts. Comparative analysis investigates the differences in the processes and results of adaptation in various geographical, agroecological, socioeconomic settings, and agricultural systems.

3.4. Conceptual Framework for Analysing Climate Adaptation

The theoretical framework that is used to steer this analysis combines several theoretical approaches to climate adaptation, vulnerability, and food security. Based on the vulnerability framework of the Intergovernmental Panel on Climate Change, adaptation can be viewed as an interaction among three interacting elements which are; exposure to climate hazards, sensitivity of agricultural systems and livelihood to climate stresses and adaptive capacity of households and communities to respond well (Intergovernmental Panel on Climate Change, 2001b). In this framework, vulnerability is not only caused by the biophysical climate factors but also predetermined by the socioeconomic factors, institutional frameworks, and the accessibility to resources defining adaptive capacity (Adger et al., 2003).

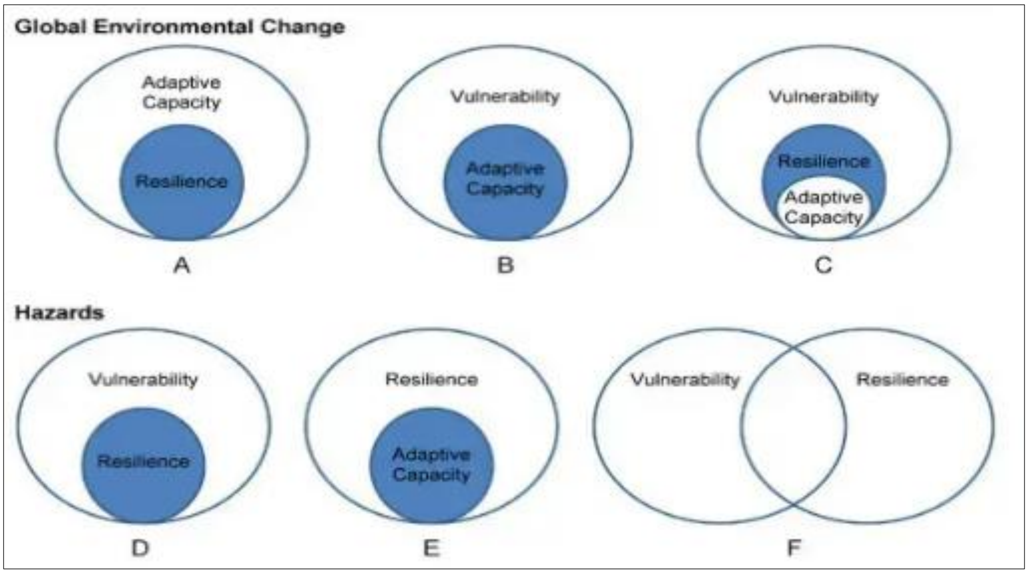

Figure 5 Conceptual Linkages Between Vulnerability, Resilience, and Adaptive Capacity

The model integrates the ideas of the resilience theory that involves the fact that successful adaptation creates the ability of systems to absorb disruptions, restructure as they change, and preserve fundamental functions and feedbacks (Milestad and Darnhofer, 2003). Strong agricultural systems are seen to exhibit resilience to climate shocks (due to redundancy and diversity), adapt gradually (due to learning and innovation) as well as change radically (when the conditions surpass adaptive limits). Integration of indigenous knowledge and modern methods may bring resilience in a variety of ways, including preserving diversity of practices and genetic resources, complementary benefits of various approaches, facilitating innovations through the sharing of knowledge, and developing social capital through participatory procedures (Berkes et al., 2000).

The sustainable livelihoods framework also offers further analytical prism of the rural households utilizing various capital assets such as natural, physical, human, financial and social capital to assemble livelihood tactics and attain the required results (Yohe and Tol, 2002). Through many mechanisms, climate change has impacted these capital assets: by weakening natural capital through soil erosion and water shortage, demolishing physical capital through extreme events, compromising human capital through health effects and migration, weakening financial capital through losses in production and destabilizing social capital through conflict and displacement.

4. Climate change challenges facing rural agricultural communities

4.1. Observed and Projected Climate Change Impacts on Agriculture

The global rural agricultural communities are faced with an ever-increasing severe climatic change effects that are threatening the production systems, livelihoods, and food security. Some of the changes that have been observed over the past decades include increase in average temperatures, changes in precipitation patterns with increased variability and unpredictability, increased prevalence, and intensity of extreme weather events such as droughts and floods, and even changes in seasonality in agricultural calendars (Intergovernmental Panel on Climate Change, 2001a). Increase in temperature has been registered in all agricultural areas and more so in tropical and subtropical areas which many vulnerable and rural communities live in.

Change in water availability due to changes in precipitation and evapotranspiration directly affects the rain-fed agriculture that is the leading one in most of the rural regions in the developing nations. A decrease in total precipitation decreases the amount of moisture crops can use, leading to more drought stress (Thomas et al., 2007). The greater variability of rainfall also brings about uncertainties regarding the timing of planting and an increase in the risks of dry periods in the important growth periods in places where the overall amount of rainfall may be sufficient. An increase in the precipitations can lead to increased intense rainfall events which may surpass soil infiltration capacity and cause the run off and soil erosion instead of providing the plant-available soil moisture.

4.2. Vulnerability Factors Amplifying Climate Risks for Rural Communities

The susceptibility of rural agricultural communities to the impact of climate change is not restricted to direct climate exposure but covers the underlying socioeconomic factors, resource limitations and institutional failures and inefficiencies, which suppress adaptation (Adger et al., 2003). Poverty is also one of the underlying vulnerabilities issues that limit households in investing in adaptation strategies, holding asset buffers in response to shocks, and recovering losses related to climate. In the households, lack of financial savings tends to affect poor households and they are unable to buy inputs, invest in irrigation or other technologies or even survive during production breakdowns. Ownership of limited assets such as land, livestock and equipment limits the choice of production and income generation.

The adaptation options and productive capacity are constrained by land limitation factors such as limited size of farm land, lack of tenure security and land degradation. Most of the smallholder farmers in developing areas have farms of two hectares or less with most farmers having less than one hectare which severely restricts production and income potential (Maddison, 2007). The small size of the farm restricts the possibilities to diversify crops, to switch land and introduce fallows to restore soil fertility, as well as to introduce some land-intensive adaptations such as Agroforestry. Uncertain land tenure, be it under customary tenure systems, under rental systems or under claims, decreases incentives to make long term investments in soil conservation, trees planting and other adaptive land developments (Bryan et al., 2009).

4.3. Food Security Challenges Under Climate Change

The climate change is a challenge to food security in all four dimensions availability, access, utilization, and stability by affecting the production systems, market forces, health, and livelihood stability (Harvey et al., 2014). The problem of food availability is based on the diminished yield of climate, the high level of variability of production, and the worsenment of natural resources available in the agriculture sphere. According to studies on global crop modelling, it is projected that by mid-century, climate change will lower the yields of major cereals by five to twenty percent or more in most areas, with the highest effects experienced in tropical and subtropical regions where most of the vulnerable populations are located (Kurukulasuriya and Mendelsohn, 2008).

Climate influences the food usage in the following ways, it threatens food quality, water quality and availability, and disease trends. As per the research, increased carbon dioxide concentration in the air diminishes the protein levels and various micronutrients in wheat, rice, and other staple food resulting in the aggravation of already existing nutritional deficiencies (Harvey et al., 2014). The stress of heat in grain filling does not only impact yields only, but also parameters of grain quality. The lack of water and water pollution undermine food preparation and sanitation and health as well as the nutrient absorption and needs.

The disaster resilience framework shown in the above figure 10 shows how the rural agricultural communities are exposed to climate hazards in such complex pathways that lead them to recovery or to the long-lasting vulnerability. This framework focuses on the understanding that the resilience outcomes are not solely determined by the severity of the climate hazards but resolutely by antecedent conditions that cover the levels of exposure, the sensitivity of the system as well as the resilience capabilities that exist (Nyong et al., 2007). Societies that have a greater adaptive capacity, high levels of social capital and access to resources exhibit the ability to absorb shocks and continue with their vital processes during times of stress and the ability to recover faster after climate events.

5. Indigenous Knowledge Systems for Climate Change Adaptation

5.1. Traditional Weather Forecasting and Climate Prediction

The indigenous weather forecast systems are highly developed systems of observational knowledge based on close interrelationship between the local environments of an area and conveyed by means of cultural processes over generations (Roncoli et al., 2002). In the context of a wide variety of geographical situations, rural population always worked out the sophisticated systems of the weather conditions and seasonal specifics prediction based on biological indicators, atmospheric observations, and astronomical patterns. These neotraditional forecasting systems allow farmers to forecast the onset of rainfall, the amount and distribution of rainfall seasonally, and extreme events which provide important information in making agronomical decisions on whether to plant, the type of crops to grow, and how to use the resources (Ifejika Speranza et al., 2010).

The biological indicators form one of the main groups of traditional weather forecasting with communities monitoring plant phenology, animal behaviors, and insect activities as one of the indicators of the future weather situation (Nyong et al., 2007). Environmental signals such as timing and strength of flowering, leafing, and fruiting of native trees and bushes are used as plant indicators. East African studies record farmers depending on flowering of specific tree species to signal the imminent occurrence of rainfall with various tree species serving as predictors at different scales such as weeks and months before it falls (Ifejika Speranza et al., 2010).

Traditional forecasting systems have their strengths and limitations as far as their use in climate adaptation is concerned (Nyong et al., 2007). These are the local-specific relevance to local geographical contexts and Agro-ecosystems, access to communities where no formal weather services are available, cultural embeddedness which facilitates knowledge transfer and application, and rich integration of several indicators which provide redundancy. The studies comparing the predictive power of traditional forecasting techniques to the meteorological records show that some indicators have statistically significant predictive skill especially in short term weather and rainfall onset, and that the predictive power of these techniques differs widely across indicators, regions, and time scales (Roncoli et al., 2002).

5.2. Traditional Crop Management and Agricultural Biodiversity

Agroecosystems of indigenous people retain high crop diversity by growing many species and varieties of species and have a key adaptation advantage by spreading risks, dietary diversity, and genetic resource in future breeding (Altieri and Nicholls, 2017). The traditional systems of farming often have many species that are intercropped with complementary traits such as different periods of maturity, different depths of roots, different nutrient needs, and different levels of stress tolerance to provide diversified production systems that counter-shock to changing conditions. In West Africa, studies record smallholder farms which typically cultivate between ten and twenty species of crops at once comprising of cereals, legumes, root crops, vegetables, and fruits in complicated spatial and temporal configurations (Berkes et al., 2000).

Landraces or indigenous varieties of crops preserved by traditional seed systems have desirable adaptive characteristics that have been acquired over generations of selection in the local environmental conditions such as climatic stresses (Salick and Byg, 2007). These old varieties tend to be drought and heat, waterlogging, poor soils, pests, and disease tolerant, and most importantly they represent genetic diversity that is mostly lacking in the modern improved varieties that are bred under good experimental environments. Studies of traditional varieties of crops show the tremendous diversity with each community having dozens of varieties of individual crop species that are distinguished by the maturity date, resistance to stress, taste, cooking quality, and ritual value.

5.3. Community-Based Natural Resource Management

Traditional resource governance systems regulate access to and use of common property resources including grazing lands, forests, water sources, and wild resources through community-based institutions and customary rules (Berkes et al., 2000). These governance systems evolved over generations to prevent overexploitation, ensure sustainable use levels, maintain resource productivity, and mediate conflicts among resource users. Indigenous resource management incorporates detailed ecological knowledge about resource dynamics, regeneration requirements, and sustainable harvest levels transmitted through oral traditions, customary practices, and institutional rules. Research documents diverse traditional resource management systems across continents demonstrating sophisticated understanding of ecosystem processes and social mechanisms for collective action, though effectiveness varies depending on institutional strength, external pressures, and changing contexts (Agrawal, 2008).

Pastoral communities in semi-arid regions of Africa and Asia have developed elaborate common property range management systems governing access to grazing areas, regulating herd movements, maintaining strategic water points, and coordinating seasonal migrations (Nyong et al., 2007). These systems typically involve customary authorities allocating grazing rights, enforcing restrictions on use during vulnerable periods such as early growing season, managing access to dry season grazing reserves, and negotiating access across group territories. Traditional range management incorporates practices including controlled burning to manage vegetation, protection of key grazing areas during growing season, strategic movement of livestock following rainfall and forage availability, and maintenance of genetic diversity in livestock breeds adapted to harsh conditions (Berkes et al., 2000).

6. Conclusion

In conclusion, his extensive survey of climate change adaptation planning in rural people indicates that adaptations can only be effective when there is synergistic combination of indigenous knowledge system and modern agricultural methods and not by depending on either of the two systems. Indigenous knowledge is context-based knowledge about the local environments, practices that are low-cost, and culturally based models of explaining changes in the environment. The contemporary science of agriculture has increased predictability using climate models, improved innovation in plant breeding and technology, and the potential of revolutionary change in the form of drought-tolerant varieties and precision agriculture. There are various factors that determine the adaptation decisions of farmers, including education, gender, access to information and extension services, credit accessibility, and farm income are revealed to be consistent predictors of adaptation decisions in a variety of contexts.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict-of-interest to be disclosed.

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