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Agriculture and community adaptation: A review on food production and climate resilience of the population in Southern Africa, Mozambique

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Abstract
Production systems have their own peculiarities when it comes to agricultural practices, and everything centres around the objective of production. Farming practices dictate the success or failure of the production of a certain crop and in many cases can be linked to climate change. This review looks at the current situation regarding food production and the resilience of communities in southern Africa in the face of food insecurity. Resilience has been linked to intelligent agricultural production practices due to the ease with which these production factors can be monitored in the midst of many uncertainties in the context of rainfall for irrigating agricultural fields. Although there are many approaches, research shows that there is much to be done in terms of finding better strategies for disseminating the most suitable practices to communities, new methodologies for seeking information about the real situation of food insecurity, resilient agricultural practices, maintaining soil fertility and community resilience. There is another paradigm that suggests looking for mechanisms to favour crops that can easily be preserved for a long time by naturally occurring methods and conditions. Overall, it can be seen that climate-smart food farming practices are the main act of community resilience aimed at producing resilient food with productive success.

Keywords: Food availability, climate, Adaptability

Introduction

Climate change has brought many challenges to the global population. Floods, prolonged droughts, tornadoes and severe storms are just a few examples of disasters that have occurred in various places, leaving major devastation, which suggests the adaptability or resilience of communities in the face of these climate impacts (Queiroga *et al.* 2022) [39].

Reflections on theories of the occurrence of climatic events in subsistence agriculture and the resilience of communities have intensified, covering the chronological variation of their occurrence in order to find better theoretical or methodological bases for identifying, predicting oscillations and pulsation. Food production in sub-Saharan Africa has been highlighted by researchers, who predict changes in the average yield of crops such as wheat (17%), maize (5%), sorghum (15%) and millet (10%) due to the impacts of climate change directly affecting the agricultural sector of food production (Tanure *et al.* 2023) [44].

Recent studies show that new trends in climate change include rising global temperatures, rising sea levels, changes in precipitation patterns as well as drought and flooding, which have negative effects on agricultural and food production, especially in underdeveloped countries such as Mozambique (Turyasingura *et al.* 2023) [45]. The impacts of climate change are not only visible in the area of food production, but also have negative consequences for the economies of developing countries, since they have fewer properties for production, low use of technology and unskilled labour (Santos *et al.* 2022) [41].

Several studies on the impacts of climate change on food productivity in the global context are based on the application of three methodological approaches: the Ricardino, agronomic and agro-geological zoning models (Tanure *et al.* 2024) [44]. These models mentioned above bring an approach of adaptability or resilience of rural communities mainly, since for the success of the yield of various crops it is necessary to reconcile factors such as: biological, effect on the variety of the crop, agronomic management, changes in climate, soil conditions, natural resources mainly in semi-arid areas (Hu *et al.* 2023) [24].

Recent approaches show that climate change is developing at an accelerated pace, resulting in an intensification of natural disasters and extreme weather events, and this suggests a rapid adaptability of communities in search of solutions to ensure survival, including the adoption of resilient agricultural practices that do not suffer too much from the impacts of climate change (Kraetzig *et al.*, 2024) [27]. The search for production and productivity alternatives amidst the occurrence of various climate-related events in Mozambique is limited due to the unavailability of incentives for income generation (Ziegler *et al.* 2022) [49].

Agricultural practices

The success of agricultural practices and the resilience of communities in the face of the impacts of climate change on food production depends on the adoption of effective strategies to mitigate these impacts, and recently climate-smart agriculture has been adapted to circumvent its effects on crops grown (Akinsemolu *et al.* 2024) [1]. Climate-smart agricultural practices are a resilient approach providing actions to transform and reorient food production systems, effectively and sustainably supporting development and food security in a changing climate (Kombat *et al.*, 2021) [26].

A report released by the UN on the "State of Food Security and Nutrition in the World 2022" reveals that hunger affected 828 million people in 2021, equivalent to 9.8 per cent of the world's population, and future projections estimate that 8 per cent of the world's population, around 670 million people within 6 years, will be affected by hunger, even considering a global economic recovery (Oliveira & Moser, 2024) [35]. Against this backdrop Akinsemolu *et al*., (2024) [1], emphasises that the main components of climate-smart agricultural practices should be proposed in response to certain gaps in agriculture's contribution to food security and its strength in capturing synergies between resilience and mitigation within the framework of global climate policies.

According to Turyasingura *et al*., 2023) [45], in Africa agricultural practice is dominated by small farmers, who are very susceptible to climate impacts and need more robust production systems. The Mozambican reality brings a different approach to food security, where attention is drawn to government involvement in drawing up strategies aimed at healthy eating and reducing the risk of obesity (Spain, 2022) [19]. In the midst of climate uncertainty, analysing drought variability is a very important tool for planning and managing water resources and food security around the world, and Mozambique is no stranger to this phenomenon and must quickly find better mechanisms to improve the dissemination of climate impacts (Yang *et al*., 2024) [48].

Climate change is causing distortions in human, agricultural and ecological systems. SubSaharan Africa (SSA) is classified as one of the regions most vulnerable to rising temperatures and unpredictable rainfall (Gershoni, 2023) [22]. The livestock sector in sub-Saharan Africa (SSA) is under increasing pressure to define its role in addressing food security and climate change. Livestock provide critical sources of protein and micronutrients for SSA's growing population, account for 20-50 per cent of agricultural Gross Domestic Product in the subcontinent and generate key income streams and assets in some of the world's harshest environments (Germer *et al.,* 2023) [21].

The climatic variability estimated that nine major droughts in Africa during the period 1981-2000 caused livestock losses of 40 per cent on average and up to 90 per cent in some regions in conjunction with production factors and natural biological processes (Germer *et al*., 2023) [21]. To overcome soil degradation and potentially restore soil properties, conservation agriculture (CA) has been increasingly recommended. According to the FAO (2022) [20], "CA is a concept of resource-saving agricultural production that strives to achieve acceptable profits together with high and sustained production levels. In order to analyse the current situation regarding food production and the resilience of communities in southern Africa, a review was proposed focusing on food production systems and the climate resilience of southern African communities in the face of food insecurity in Mozambique.

Methodology

Using the methodology proposed by Queiroga *et al.* (2022) [39], we proceeded with a review approach, where we searched for scientific articles published in the following engines: Google Scholar, Tayor & Francis, DOAJ, Scielo, Science Driect and the virtual library of the Higher Polytechnic Institute of Gaza, followed by a synthesis of the articles looking for the relevant aspects and findings of the various researchers in relation to the subject under analysis.

Diversification of production units

According to Rodrigues & Medeiros (2023) [40], it is suggested that results be sought on the main typologies of peasant family production units, which can be poorly diversified, diversified or highly diversified. In order to find these results, a semi-structured interview was first carried out with the farmers, where they were asked to list the main types of food production units and then determine the relative frequency (%) of each type listed by them (Rodrigues & Medeiros, 2023) [40]. The following equation is used to determine the relative frequency:

$$TIP = Ti * 100/Tg \quad (1)$$

So: TIP: Typology; Ti= individual total; Tg: Grand total; The TIP scales for the main socio-productive activities were determined in ascending order, as follows: Little Diversified: with TIP between 01 and 33%, which corresponds to Ti of 01 to 13 socio-productive activities; Diversified: with TIP between 34 and 66 per cent, which corresponds to Ti from 14 to 27 socio-productive activities; Highly Diversified: with TIP between 67 and 100 per cent, which corresponds to Ti of 28 to 41 socio-productive activities;

Agricultural practice models with more emphasis on Mozambique

According to Santos *et al*. (2022) [41]. agricultural models and practices for food production play a fundamental role in mitigating the impacts of climate change by seeking the resilience or adaptability of Mozambican communities, and it is proposed to determine the relative frequency of the practices adopted by households, which makes it possible to verify the efficiency of food production as well as the resilience of these communities. Generally, the frequency is determined using the following equation:

$$Fr(\%) = \frac{NA}{N} * 100 \quad (2)$$

Where: Fr - Relative frequency; N- Universe of each region; NA - Number of households that mentioned the practice.

The determination of the yield of the food harvest produced by them must be equated due to the impacts of climate change on crop yields, and the strategy defined by the World Bank (2010) (Santos *et al*. 2022) [41], is proposed, which considers the area of agricultural production and agricultural yield as key variables mainly in rural areas with resource limitations, and so the following equation is proposed:

$$RC = \frac{QPC}{AC} \quad (3)$$

Being: CR- harvest yield; QPC - Quantities of harvested product e; AC - cultivation area.

According to Bento *et al*. (2023) [4], determining indicators in order to find information on the state of food and nutrition security in Mozambique involves checking the level of schooling, family income, family consumption, access to food and availability of food for consumption.

Assessment of the food security situation

According to Anjos & Caldas, (2023) [3], the assessment of the food security situation, unlike the aforementioned authors, requires a deep and exhaustive immersion in the reality of the community in question. This involves an investigation based on an empirical inventory of the food insecure population, poverty indicators, incidence of obesity, number of meals, legal records and current legislation on food. Once this is done, data is collected in the context of the subject of the research, using a semi-structured questionnaire with closed and open questions. A table drawn up for this purpose gives a comprehensive view of the diversity of conditions of the interviewees who took part in the research into the situation of food security (Spain 2022; bryngelsson *et al*. 2022) [19, [7].

Climate-smart agricultural practices

To mitigate the impact of climate change on agriculture, farmers need to develop or transform their farming and livestock systems by changing processes, practices and structures. One way of doing this is by adopting climate-smart farming practices (Akinsemolu *et al.* 2024) [1]. According to Carmelo (2023) [8], climate-smart agriculture is an attempt to respond to extreme weather events that put pressure on food production and food security. As such, Bosetti (2023) [5] advocates the introduction of urban agricultural spaces that absorb rainwater, reducing heat islands and mitigating flooding from a resilience perspective.

According to Manoel *et al*. (2023) [30] & Carmelo (2023) [8], there is another strategy for mitigating climate impacts that involves the introduction of agricultural spaces that act as green sponges in an urban environment, guaranteeing its cohesion. This climate-smart agriculture can therefore create agricultural spaces, more cohesive communities and shared gardens between neighbours. However, there is the economic factor that limits the application of this mechanism in rural areas, which suggests looking for very practical methods and techniques in these communities, where they can be strongly combined with crop intercropping and technical assistance (Souza *et al*, 2022; Palha *et al*, 2022) [43];[37].

Food production systems and community resilience

To mitigate the impact of climate change on agriculture, farmers have to develop or transform their farming and livestock systems by changing processes, practices and structures. One way to do this is by adopting resilient farming practices for communities (Ogisi & Begho, 2023) [34]. Climate change has brought several challenges to the global population. Floods, prolonged droughts, tornadoes and severe storms are just a few examples of disasters that have struck many places, leaving great devastation (Queiroga *et al.* 2022) [39]. Since then, climate change has been shown to have negative effects on FNS (food and nutrition security), exacerbated by poverty and social inequality (Anjo & Caldas, 2022) [3]. Self-sufficiency in food production then came to be seen as a national security policy, in which the training of "strategic conservatives" would be a fundamental premise of a sovereign country. The farmers need to transform their farming systems and livestock and adopt climate-smart agricultural practices (Akinsemolu *et al*., 2024; Ogisi & Begho, 2023) [1, 34].

Livestock management strategies

The agrarian systems of a region call for the analysis, explanation and study of their evolutionary dynamics by looking at the time and relationships that this system maintains with the rest of the ecosystem in its different stages of evolution. Extensive ruminant grazing systems in SSA (sub-Saharan Africa) are dependent on natural pasture, which most of the time is not of the desired quality, leading producers to exploit other pasture areas to improve the quality of the diet, and this scenario favours deforestation, which results in offsetting objectives aimed at mitigating and conserving habitat during land use changes (Germer *et al.*, 2023) [21].

Some reported scenarios of poor animal development are associated with climate impacts such as changes in temperature and rainfall frequency in communities in developing countries. These communities are known as subsistence farmers or small-scale farmers, and have a certain vulnerability to climate events from a socio-economic, demographic and political adaptation point of view (Vinholis *et al.* 2022) [47]. The large volume of feed imports is associated with significant fossil fuel emissions from feed production and transport that may not be accounted for in farm-level emissions assessments (Gershoni, 2023) [22].

In all livestock systems, the urgent need for intervention to increase animal productivity is to improve feed conversion efficiency. This interaction will express a ratio between the food production factors (for example, the dry matter content of the food) and the production results (Gershoni, 2023) [22].

The use of climate-resilient feed varieties, as well as the storage of feed and water and the determination of production costs in rainy and dry periods, are therefore common interventions to maintain production during seasonal changes and adapt to the changes caused by climate change in the timing and duration of feeding (Ogisi & Begho, 2023) [35]. Specialised and intensive systems that rely heavily on feed imports can also benefit from flexibility, where they have access to multiple feed import sources; through feed imports, these systems have the ability to free themselves from local food resource constraints, especially when feed is easily transported and stored for long periods of time (Queiroga *et al.*, 2022) [39].

Agricultural management strategies

It is estimated that agriculture is around 10,000 years old and has undergone several changes over time due to environmental factors and the way society has related to nature. Disasters related to natural phenomena have been jeopardising the agricultural sector. When extreme events hit agricultural areas, they cause damage to crops, the economy and food availability and access, interfering with food and nutritional security (Queiroga *et al.* 2022) [39].

Climate-smart agriculture is an integrated approach to agricultural management that aims to sustainably increase agricultural productivity and yields, while reducing greenhouse gas emissions and building resilience or adaptive capacity to climate change, through a combination of mostly long-standing practices such as conservation agriculture, cover crops, integrated crop and livestock production management, improved nutrient management and better water management, among others (Ogisi & Begho, 2023) [34].

There is a certain perception that only agricultural intensification and the use of inorganic compounds (agrochemicals) can generate success in terms of yield, but what has come to be realised is that these also have adverse effects on health such as genetic mutation, reproductive system, hormonal disorders and cancer Agriculture is part of the origin of human society and is intrinsically linked to the social, economic and cultural model of life in society (Bryant *et al.* 2022; Lopes *et al.* 2023) [6];[29].

This strategy is all the more emphatic given that the large-scale use of pesticides has led to higher rates of hearing loss, gestational problems, neurological diseases, neoplasms, acute poisoning and consumption of contaminated water (De Sene & Bacha, 2024) [19]. It's about making today's society aware of their needs without jeopardising future generations. Agroecological production is a comprehensive framework for the sustainable use of biodiversity that also supports productivity and economic resilience, reduced dependence on agricultural inputs (Marcos *et al.* 2022) [31].

Crop management systems

Conservation agriculture (CA) or organic agriculture is an agricultural system that can prevent losses of arable land while regenerating degraded land, and promotes minimal soil disturbance, the maintenance of a permanent soil cover and the diversification of plant species, increases biodiversity and natural biological processes above and below the soil surface, which contributes to increasing the efficiency of water and nutrient use and to improving and maintaining agricultural production (Muatendauafa *et al.* 2023) [32].

Among the various alternatives to existing management systems, which include the introduction of new crop varieties, crop rotation, intercropping, the use of index-based insurance, minimum/zero tillage, mulching, agroforestry systems, half-moon pits and Zaï, stone/soil/vegetation barriers, use of mineral fertilisers and/or manure, water storage or collection, irrigation and livestock management, the most frequently mentioned strategy is the introduction of new crop varieties, while the least mentioned strategy is half-moons and Zaï wells (Akinsemolu *et al*. 2023) [1].

In research and development efforts spanning more than a decade, a team of interdisciplinary scientists in East Africa has developed a stimulant-dissuasive pest control approach specific to lepidopteran species, known as 'push-pull' technology (PPT). In this system, plant chemicals, including primary and secondary metabolites that mediate plant-insect interactions and therefore effectively control pests, are deployed through polycultivation (Alexandridis *et al.,* 2023) [2].

Land management systems

The distortion of the norms of communal use and possession of land in Africa has been explained as a way of maintaining production and ensuring labour, supporting wage workers. Furthermore, the control of land by traditional authorities is to ensure a "decentralised despotism" of the same land (Pereira, 2023) [38]. Implementing these strategies requires an integrated and adaptive approach, taking into account the specific needs of the local environment as well as the cultural and economic practices of the region (Alexandridis *et al.,* 2023) [2].

Livestock management strategies

According to CEPEA (Centre for Advanced Studies in Applied Economics) (2023) [9], it works as an area of application of tools, techniques and software that make it possible to produce results in productive and economic terms to increase a country's gross domestic product (GDP).

Extensive ruminant grazing systems in SSA (sub-Saharan Africa) often rely on natural pastures that are generally of poor quality, leading producers to expand grazing areas to improve diet quality (Germer *et al.* 2023) [21]. Non-grazing systems that rely on imported animal feed also cause habitat loss and emissions methane gas, nitrogen oxides, VOCs and PM due to the change in land use associated with the expansion of forage crop areas - whether located nearby or around the world - into forest and other natural areas (Gershoni, 2023) [22].

In all livestock systems, a key intervention to increase animal productivity is to improve feed conversion efficiency, usually expressed as a ratio between feed inputs (e.g. dry matter content of feed) and outputs (e.g. milk, meat, eggs or protein). According to the United States Agency for International Development (USAID) (2023) [46] and the Food and Agriculture Organisation of the United Nations (FAO) (2022) [20], this can be achieved by improving the diet's nutrient content, digestibility and rationing, which can increase production quickly (for example, during a lactation or growth period). The selection of animals with high feed conversion efficiency for reproduction within the herd, as well as the introduction of breeds with inherently high feed conversion efficiencies, will also increase productivity, albeit after one or more years, depending on the fertility rate and the length of the reproductive cycle of the animal herd (Gershoni, 2023) [22].

Climate resilience in the context of livestock farming

According to (Ogisi & Begho, 2023) [34], the use of climate-resilient feed varieties, as well as the storage of water between rainy and dry periods, should not be common interventions to maintain production during seasonal changes and adapt to the changes caused by climate change in the timing and duration of feeding. In the Mozambican context, it is important to apply this strategy, since the behaviour of rainfall and warming has taken an alarming toll on livestock production yields, and resilience is the key component for better adaptation and management of available water resources in relation to this phenomenon (Silva, 2024) [42].

Agricultural management strategies

Climate-smart agriculture is an integrated approach to agricultural management that aims to sustainably increase agricultural productivity and yields while reducing greenhouse gas emissions and building resilience or adaptive capacity to climate change (Ogisi & Begho, 2023) [34]. According to Hygor *et al*. (2022) [25], climate instability is one of the components that has led to the intensification of the search for agricultural management strategies, which are based on an approach that maximises the sustainability of agricultural production, without neglecting the anthropogenic factor, since man has carried out various actions that culminate in the improvement and/or negative results of these actions or agricultural practices in regions with a marked variation in climate, compromising socio-economic issues and the adaptability of populations.

Crop management systems

Among the various alternative management systems, we find the introduction of new crop varieties, crop rotation, intercropping, minimum/zero tillage, mulching, agroforestry systems, half-moon pits and stone barriers, soil, vegetation, the use of mineral fertilisers and/or manure, water storage or collection, irrigation and livestock management (Germer *et al*. 2023) [21]. Ecological intensification through agricultural diversification, where additional crops are grown over space and time, and greater provision of ecosystem services, such as enhanced soil fertility and natural pest and weed control, have been advocated as a sustainable approach to reducing yield gaps (Alexandridis *et al.*, 2023) [1].

Soil/land management systems

Resilient soil/land management in relation to climate change is essential for maintaining agricultural productivity, conserving natural resources and mitigating environmental impacts. These systems focus on sustainability, biodiversity and adaptability, seeking to reduce greenhouse gas emissions and increase the soil's capacity to withstand extreme climatic conditions (Alexandridis *et al.* 2023) [1]. These systems bring with them the challenge of implementing strategies that are suitable for Mozambican communities, especially when combined with climate impacts and human activities that have adverse effects such as methane gas emissions, nitrogen oxides, VOCs and PM, soil degradation, changes in topography, deforestation and reduction of tree and non-tree species and deposition/acid rain. Implementing these strategies requires an integrated and adaptive approach, taking into account the specific needs of the local environment as well as the cultural and economic practices of the region (Alexandridis *et al.*, 2023) [1].

There is an experience in Brazil that involves the rational use of water resources, since they are becoming scarce, especially in hot and dry areas such as Mozambique and sub-Saharan Africa in general, which is being exacerbated by climate change. Where, according to Yang *et al*. (2024) [48], the combination of these factors drastically favours low crop yields, especially those that are less resistant to climatic variations and, also looking at the approach of Silva *et al.* (2024) [42], we have to incorporate the practice of irrigating fields as a fundamental element in generating this yield because the type of irrigation will dictate the yield of agricultural production.

Agricultural mechanisation

Agricultural mechanisation has played a significant role in the implementation of MCA (Minimum Compatible Area) on large commercial farms that use heavy tractors and large-scale machinery (especially seeders). The limited adoption of CA in developing countries, especially by small-scale farmers, is therefore mainly associated with the absence of appropriate smallscale equipment at an affordable price (Lolaso *et al.*, 2024) [28]. According to Heinz *et al.* (2024) [23], small farmers in SSA (Sub-Saharan Africa) who adopt direct or minimum tillage systems rely mostly on manual or animal traction, with few using mechanised direct seeders.

Crop management systems

Among the various alternatives to existing management systems, which include the introduction of new crop varieties, crop rotation, intercropping, the use of index-based insurance, minimum/zero tillage, mulching, agroforestry systems, half-moon pits and Zaï, stone/soil/vegetation barriers, use of mineral fertilisers and/or manure, water storage or collection, irrigation and livestock management, the most frequently mentioned strategy is the introduction of new crop varieties, while the least mentioned strategy is half-moons and Zaï wells (Tamure *et al*. 2023) [44].

Ecological intensification through agricultural diversification, where additional crops are grown over space and time, and greater provision of ecosystem services, such as enhanced soil fertility and natural pest and weed control, have been advocated as a sustainable approach to reducing yield gaps (Alexandridis *et al.* 2023) [2].

Soil/land management strategies resilient to climate change

Ercin *et al.* (2024) [18] presents some key strategies for achieving a soil/land management system that is resilient to climate change, one of which is regenerative agriculture, which promotes practices that guarantee soil regeneration, improving its structure, fertility and water retention capacity, and which must be accompanied by techniques such as soil cover, crop rotation, polycultivation and the use of compost. Another perspective is addressed by Munn *et al.* (2022) [33], which encompasses Agroecology that integrates ecological principles of agricultural practices that may be traditional, creating more diversified and resilient systems, guided by the balance of the ecosystem in the use of resources in countries like Mozambique.

Tanure *et al*. (2023) [44] integrates the agroforestry component, crop rotation and the use of cover crops as practices that can help maintain soil quality insofar as the combination of trees and agricultural crops promotes species diversity, which promotes carbon retention and protection against erosion in Mozambique (Osman *et al*. 2023) [36].

Water management systems

Long-term analyses have shown that food and water shortages in many parts of sub-Saharan Africa are due to climate change, and that livestock productivity may increasingly depend on water use efficiency, which varies significantly between species and systems (Lolaso *et al.*, 2024) [28]. This scenario has taken on alarming proportions in the context of food security and income from agricultural production, which in part creates pressure on the ecosystem insofar as few areas may be favourable for agricultural practices due to the availability of water and environmental resources (Alexandridis *et al.*, 2023) [2].

Final considerations

The aim of this study was to provide a review of food production systems and the climate resilience of communities in southern Africa in the face of food insecurity. Climate change not only affects the agricultural component, but also the economic component, considering that most of these communities practise subsistence farming for consumption and some for income generation. Resilience brings with it a number of advantages in the production context, as it can be seen to provide better production yields, conservation of natural resources and preservation of the ecosystem. Mitigating these impacts requires the implementation of strategies that require an integrated and adaptive approach, taking into account the specific needs of the local environment, as well as the cultural and economic practices of the region. Research shows that there are a number of solutions to these dilemmas:

1. Determining the important factors involved in intelligent agricultural production practices;
2. Determining new methodologies for finding solutions to mitigate food insecurity in communities;
3. Use of resilient cultures in the Mozambican context to adapt to new trends in other countries;
4. Massification of agricola practices with a higher yield rate for countries with a tropical climate.

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