RUFORUM Working Document Series (ISSN 1607-9345), 2023 No. 22:472-483.

Available from http://repository.ruforum.org

Research Application Summary

Climate smart agriculture through passive and active strategies to counter climate-change and climate variation in order to boost small-scale farming systems in Cameroon

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Abstract

Serious threats from climate change and variability on the agricultural sector throughout the world are eminent. The resources needed to combat the negative effects of climate change are wanting in Cameroon and other Sub-Saharan Africa (SSA) nations due to their lower capacity to adapt to the climate change and variation and high dependence on rain-fed agriculture. There exist varied passive and active approaches that can be easily handled by small-scale farmers in Cameroon and other nations in SSA to boost the agricultural sector. Applied Agricultural Climatology and Meteorology knowledge are favourable tools for passive interventions while transformational agricultural practices such as agroforestry are favourable active Climate Smart Agriculture strategies to counter climate change and variation in order to boost small-scale farming systems.

Keywords: Cameroon, Climate smart Agriculture, Passive and Active strategies, Small-scale farmers

Résumé

Les menaces sérieuses liées au changement et à la variabilité climatiques sont évidentes sur le secteur agricole à travers le monde. Les ressources nécessaires pour lutter contre les effets négatifs du changement climatique font défaut au Cameroun et dans d'autres pays d'Afrique subsaharienne (ASS) en raison de leur faible capacité d'adaptation au changement et aux variations climatiques et de leur forte dépendance de l'agriculture pluviale. Il existe diverses approches passives et actives qui peuvent être facilement mises en œuvre par les petits agriculteurs du Cameroun et d'autres pays d'ASS pour améliorer le secteur agricole. Les connaissances appliquées en climatologie agricole et en météorologie agricole sont des outils favorables aux interventions passives, tandis que les pratiques agricoles transformationnelles telles que l'agroforesterie sont des stratégies actives d'agriculture intelligente face aux changements et les variations climatiques afin d'améliorer les systèmes agricoles à petite échelle.

Mots clés : Agriculture intelligente, Cameroon, Stratégies passives et actives, petits agriculteurs

Introduction

Climate change and variation are causing distortions in agricultural production systems in Cameroon and Sub-Saharan Africa (SSA) in general which is classified as one of the most vulnerable regions to increased temperature and unpredictable rainfall (Field *et al*., 2014) due to the lower capacity of the populations and systems to quickly adapt to the climate change and variation and high dependence on rain-fed agriculture (Kiboi *et al*., 2017).

The problem is more devastating in the Central and Eastern Africa regions due to the increased frequencies of El Nino episodes (Williams *et al*., 2018). Due to a growing concern about the effects of climate change and variation, future policies in conservation should rely on affordable and sustainable preservation strategies. Hence, resilience of agricultural systems needs to exploit sustainable preservation strategies. In some studies, the distinction between climate change and variation are not taken care of . Müller *et al*. (2010) proposed sowing dates change each year based overall on the same technique. This attitude is therefore more an adaptation to inter-annual climate variation than to climate change proper.

Climate-smart agriculture techniques can help farmers adapt to and prepare for impacts in order to preserve and improve their livelihoods. Climate-smart agriculture (CSA) is one of the sustainable methods to tackle the specific climate challenges of a specific farming community. The objectives of climate smart agriculture are to be adapted to climate change and mitigate it, while sustainably contributing to food security. Different CSA practices exist and integrate its objectives differently. Climate smart programs aim to: improve farmer productivity, hence, livelihoods; make farms more resilient to negative climate impacts; and curb greenhouse gas emissions.

The notion of active and passive methods used in this article is based on methodologies. Passive methods generally refer to the use of fundamental knowledge in the field of Agrometeorology and Agricultural climatology to provide solutions to unfavourable climatic conditions for agricultural production; a passive method generally does not need an outside source of energy or cost to proceed. Active methods use an external energy source and or cost to provide solutions to unfavourable agro-climatic conditions. Agroecological practices aiming for a permanent soil cover, either with trees or crops, are among the most common active CSA practices. The presence of various landforms and large latitudinal extension in Cameroon results in a diversity of micro-climates and ecosystems that can provide passive CSA approaches to face climate change effects in the country.

Agriculture is the mainstay of Cameroon's economy. The agricultural sector employs a high proportion of the population and over 90 percent of some rural populations (Tume *et al*., 2018). Cameroon is commonly referred to as "Africa in miniature because Cameroon's geography is quite diverse with low-lying coastal plains rising inland to high plateaus, and mountain ranges stretching along its northwestern border with Nigeria. This variationaffords Cameroon with three main climatic regions: southern equatorial forests, central grasslands, and the northern semi-arid, Sahelian region. Cameroon has one main rainy reason that lasts from May-November when the West African Monsoon brings moist air over the country from the Atlantic Ocean. The peak rainy months correspond with the lowest average temperatures of the year. The Southern Plateaus experience two shorter rainy seasons during May-June and October-November. Cameroon's dry season lasts from December-April and corresponds with the highest average temperatures of the year during the latter part of the season in the months of February-April. There exist two main groups where the southern part of the country with a bimodal rainfall pattern, is characterized as humid and equatorial with temperatures ranging from 20-25°C (depending on altitude) and the wettest regions receiving more than 400 mm of rainfall per month. Debundscha village, found in this part of the country is the second rainiest place in the world with over 10,299 millimeters of annual rainfall. The tropical climate characterized by a monomodal rainfall pattern (one rainy and one dry season) occupies the rest of the country. Northern Cameroon (north of 6°) is semi-arid and dry with temperatures ranging from 25-30°C (Fig. 1). This portion of the country receives less than 100 mm of rainfall per month (World Bank Group, 2022).

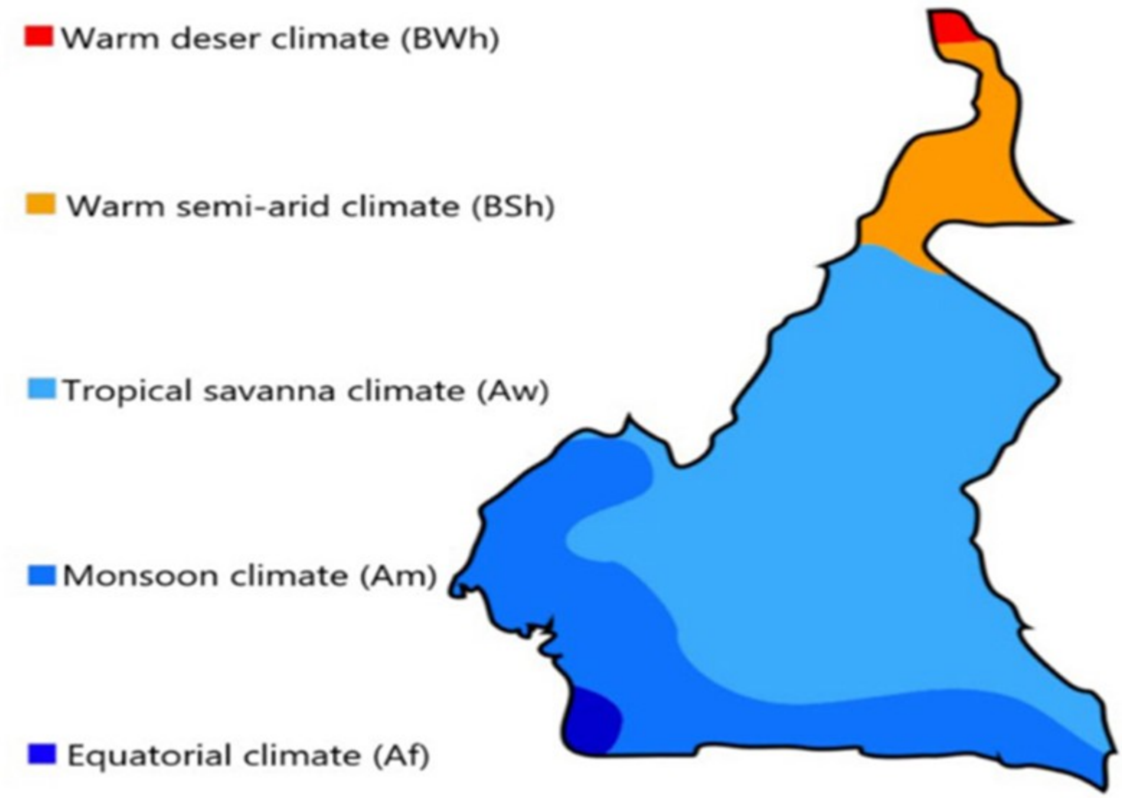

Figure. 1. Climatic classification of Cameroon. Source: Beck *et al*. (2018).

The effects of climate change and variation in the country have been reported in various disciplines. Flooding during the rainy season (August–September) throughout the country have been documented, with losses estimated at several billion CFA francs (Tanessong *et al*., 2021). The West Region of Cameroon, recently experienced landslide disaster associated with extreme rainfall that caused the death of over 50,000 people, hundreds of animals, and destroyed 155 houses, numerous shops, factories and hundreds of hectares of landscape and farms (Aretouyap *et al*., 2021). In many parts of Cameroon, dry spells in the past decade has been experienced during the first growing season (March to August) especially in the months of April and May, with devastating effects on crop production. There is thus a dire need to provide sustainable approaches to face climate change and variation in Cameroon. This article aims to identify sustainable passive and active CSA methods that can be used to mitigate climate change and variation in Cameroon in order to boost small-scale farmers' livelihood.

Effects of Climate change. Climate change has a significant impact on agricultural systems as it affects both plant and animal health. Increased temperatures, especially in the number of extreme hot days, as well as changes in precipitation, are the main climatic variables affecting agriculture in Cameroon and on the African continent as a whole.

Temperature impacts. Temperature influences the rate of reactions and is considered as the biological clock of plants. However, temperatures above the optimum for a plant is unfavourable for growth and development. Over the last century, temperatures in Cameroon (Fig. 2) and across the continent of Africa have increased by 0.5°C or more, with minimum temperatures rising faster than maximum temperatures (Niang *et al*., 2014) hence decreasing the temperature amplitude.

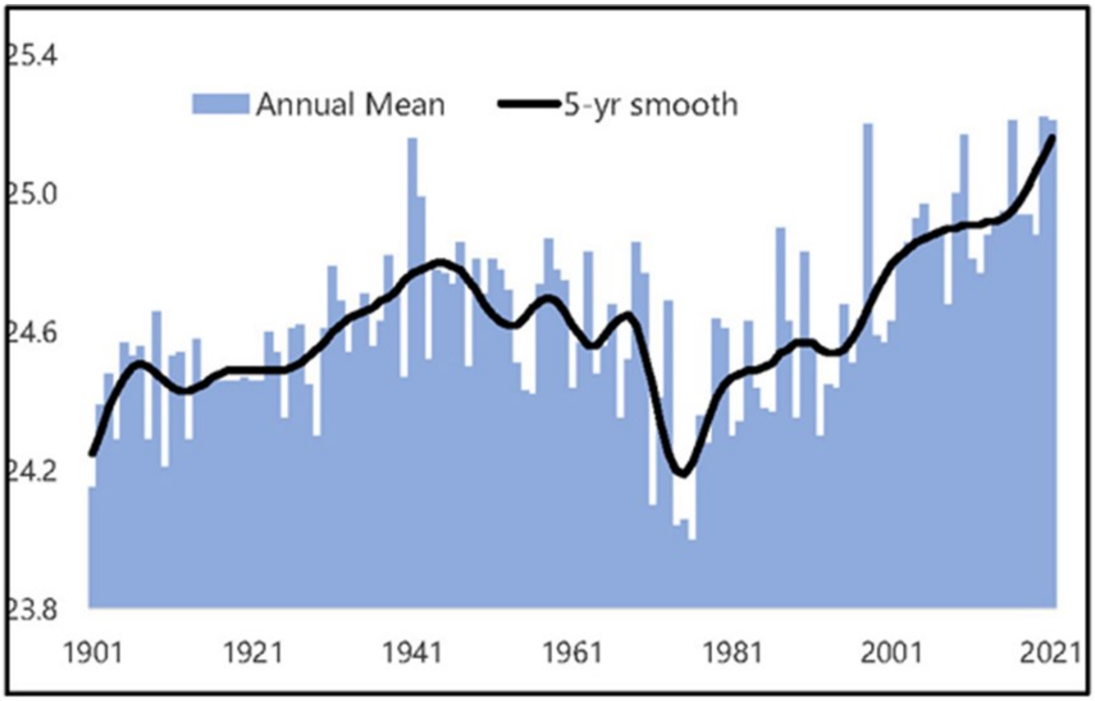

Figure 2. Observed annual mean temperature in Cameroon (1901 – 2021) Source: IMF, 2024

Most regions within Africa have recorded an increase in the number of extreme temperatures (Seneviratne *et al*., 2012), indicating more heat waves (Niang e*t al*., 2014). Subtropical southern and northern Africa have seen temperature rises on the order of twice the global rate of temperature increase. Models project further temperature increases (James and Washington, 2013; Niang *et al*., 2014; Engelbrecht *et al*., 2015).

Rainfall

Precipitation projections for Africa are less certain than the corresponding temperature futures due to a lack of observational data and discrepancies between different observed precipitation datasets (Niang *et al*., 2014). In general, precipitation projections suggest a trend toward wetter tropical regions and drier subtropical regions (James and Washington, 2013). Nonki *et al*. (2019) postulated that under global warming, northern Cameroon will experience extremely dry conditions due to a projected rapid decrease in water availability and increased evaporation.

Diverse Impacts on Agriculture. Agriculture is dependent on biophysical characteristics which include rainfall and temperature. In the tropics, rainfall is the most limiting climatic factor for agriculture. Each crop species has specific temperature thresholds viz: absolute minimum temperature (below which the crop is injured), base temperature (temperature above which growth begins), optimum temperature (temperature at which optimum growth is ensured) and absolute maximum temperature (temperature above which the crop is injured). For example, maize is a warm season crop and grows optimally with mean daily temperatures above 15°C (but not exceeding 45°C) and is easily killed by frost (FAO Water, 2016). Tuber growth in potatoes is severely limited below 10°C and above 30°C (FAO Water, 2016). Climate also influences livestock farming as it determines the growth of forage, the availability of water for the animals, and conditions such as heat stress (Thornton *et al*., 2009).

A changing climate will impact temperature and precipitation which are two very important variables for crop growth. It is likely that the mean annual temperature in the African continent will increase by more than 2°C by the end of this century (Niang *et al*., 2014). High temperatures and changes in rainfall patterns are likely to reduce cereal crop productivity across sub-Saharan Africa, ranging from a two percent decrease for sorghum to a 35% decrease for wheat (Nelson *et al.*, 2009).

Climate change effects are crop-specific. Cassava yields are expected to increase into the 2030s, assuming that there is a CO_2 fertilization effect expected to be more favourable to C_3 crops compared to C_4 crops (Schlenker and Lobell, 2010; Lobell *et al.*, 2008). Yields of beans are estimated to decrease by the mid-21st century (Thornton *et al*., 2011; Jarvis *et al*., 2012), while for groundnuts is controversial as some studies show a positive effect from climate change, especially in rain-fed systems (Tingem and Rivington, 2009; Dube *et al*., 2013) and others, a negative effect (Lobell *et al*., 2008; Schlenker and Lobell, 2010). Bambara groundnuts (*Vigna subterranea*) are projected to benefit from moderate climate change (Tingem and Rivington, 2009; Niang *et al*., 2014).

Pests and Diseases. Pressures from pests, weeds, and diseases are also expected to increase due to climate change with detrimental effects on crops and livestock (Niang *et al*., 2014). Warming trends could lead to latitudinal shift from low latitudes to high latitudes to introduce crop pests into previously cold-limited areas; for example, the coffee berry borer (*Hypothenemus hampei*) could become a serious threat in coffee-growing regions to previously colder higher latitude producing aeas (Jaramillo *et al*., 2011). Threats to banana production could come from the altitudinal range expansion of the burrowing nematode *Radopholus similis*, and warming trends could expand the range of black leaf streak disease (*Mycosphaerella fijensis*) that also threatens bananas (Niang *et al*., 2014).

Striga weed (*Striga hermonthica*) is a major cause of cereal yield reduction in sub-Saharan Africa and changes in temperature, rainfall and seasonality could result in more suitable habitats for this weed (Cotter and Sauerborn, 2012; Niang *et al*., 2014). However, climate change could result in an overall decrease in the suitable range of major cassava pests- whitefly, cassava brown streak virus, cassava mosaic geminivirus and cassava mealybug (Jarvis *et al*., 2012),

Climate change is emerging as a major challenge to agriculture development in Cameroon in particular and Sud-Saharan Africa in general. The increasingly erratic nature of weather systems has placed an extra burden on food security and rural livelihoods. Flooding and drought in some localities demonstrate the extent of the threat posed by the changing climate. Temperatures are likely to increase by between 1.5-4ºc in this century. Projections on yield reduction show a drop of up to 50% and crop revenue is forecast to fall by as much as 90% by 2100. Levels of viable arable land for production are predicted to decline by 2080, with 9-20% of arable land becoming much less suitable for agriculture. In response to variations in temperature and precipitation, Africa is predicted to see an increase in crop pests and diseases in addition to altered soil fertility.

Climate change will also intensify temperature extremes, resulting in potentially deadly heatwaves–take. A rapid increase in continental temperatures, combined with a growing population, has led experts to predict that by the end of this century, 20 to 50 times more people in African cities will be exposed to extreme heat.

There are many reasons climate change poses such an immense challenge for African agriculture. Many crops fundamental to African diets, such as wheat, maize, sorghum and millet, will struggle to survive rising temperatures. Under warming of 2℃, crop yields across sub-Saharan Africa will decrease by 10 per cent. Warming beyond the 2℃ mark will cause crops yields to fall by up to 20 per cent. If warming is allowed to hit the 3℃ mark, all present-day cropping areas for maize, millet and sorghum in Africa will become unsuitable. This would be devastating for Africa's food security as sorghum and millet are both vitally important cereals in most African diets, and maize accounts for almost half of the calories and protein

Livestock are also vulnerable to Africa's rising temperatures. Increase in the number of days of extreme heat stress will make it increasingly difficult to raise livestock outdoors and could result in extended areas of the continent becoming unsuitable for livestock production. Another looming threat to Africa's agricultural systems is the dwindling availability of water. Up to 95 per cent of the continent's farmers do not have irrigation systems, meaning they are entirely reliant on rainfall. With rainfall projected to decrease in many parts of Africa and the incidence of drought already rising rapidly, farmers living in the continent's dry regions will struggle to find enough water to keep their crops and livestock alive. It is not always a lack of water that poses the biggest threat to food production. In Africa's coastal regions, floods and storms have already proven to be devastating for agriculture.

An often-overlooked impact of climate change is the proliferation of agricultural pests. Warming temperatures and shorter winters will make it easier for pests to spread into new regions and will also allow them to reproduce more quickly and more often. Warming temperatures and changing rainfall patterns were a major impetus behind east Africa's locust plagues of 2019. As the locusts spread across the region, they decimated crops and pastureland, leaving 13 million people at risk of severe food insecurity.

Adaptation strategies. Generally, the future of agriculture and food security in Africa does not look bright. Experts warn that under current climate projections, Africa will only be fulfilling 13 per cent of its food needs by 2050, resulting to African countries losing up to 16 per cent of gross domestic product (GDP). Fortunately, there are still steps we can take to address the climate crisis and prevent this unwelcoming vision of the future from becoming reality.

Generally, efforts to address climate change should start with mitigation. Adaptation begins with improving Africa's agricultural sector. This will require significant investments in irrigation systems, improved infrastructure and wider access to financial instruments such as crop and livestock insurance. Research and development are indispensable to produce stress-tolerant crops and livestock breeds along with more sustainable methods of resource management. Without extensive adaptation the effects of climate change on agriculture is expected to exacerbate food crisis in Cameroon in particular and SSA in general. Different types of adaptation outlined by Food and Agriculture Organization of the United Nations (FAO) are: autonomous or incremental adaptation, planned or systematic adaptation, and transformational adaptation.

Autonomous adaptation uses both active and passive approaches involving both background knowledge and provision of alternatives to alleviate climate change. Examples include: the use of stress-tolerant crops or species (Ciscar *et al.,* 2010), changes in planting dates, reallocation of land, time, labour and other resources among different crops, livestock and activity systems (FAO *et al.,* 2018).

Planned or systematic adaptation is an active method that involves increased spending on research and development of new varieties, diversification strategies such as intercropping or rotational cropping systems, and risk management options such as index-based insurance (Ciscar *et al*., 2010; FAO *et al*., 2018) which is an innovative concept for evaluating agricultural risks and payouts using a set index or index combination instead of traditional on-site loss assessment.

An active method approach to alleviate climate change effects is well illustrated in the salinity intrusion attributable to sea-level rise, a major climate change risk for millions of residents in Bangladesh's low lying coastal deltaic zones as revealed by Gingerich *et al*. (2017) and Dasgupta *et al*. (2018). To save Pregnant women who are particularly vulnerable to the effects of saline water consumption, the provision of clean water has been proposed as an ideal incremental adaptation strategy while prioritizing women's education in order to equip the vulnerable female population with requisite skills to make them employable in less vulnerable places away from the hazardous coastal regions (Tanjeela and Rutherford, 2018), is a transformative approach.

Strategies to provide climate-change resilience in Cameroon

Passive methods. There exist two passive methods that can be exploited to alleviate climate change impacts in Cameroon. They are: choice of site and choice of species/varieties.

Choice of site. Microclimatic studies have revealed that different climatic conditions are created by various landscapes provide. Weather conditions vary within a microclimate, differing from the general prevailing conditions of an area as a whole. It is important to understand microclimates as they represent the physical conditions actually experienced by organisms.

Factors affecting Microclimates. A range of biotic and abiotic factors can affect microclimates. Microclimates can also be affected by geologic or man-made features that can influence precipitation, heat pockets, or additional shading. Microclimates can be found in most places but are most pronounced in topographically dynamic zones such as mountainous areas, islands, and coastal *areas (*Ellis and Eaton, 2021*)*

Topography or the shape of the land. On a large scale, weather systems are predictable due to the Earth's rotation and the interaction between ocean and land. However, these patterns can be disrupted by local topography, such as aspect and relief. Aspect is the direction that a slope faces. Aspect can determine the amount of sunlight an area receives. In turn, this affects temperature and shading. In the Northern Hemisphere (where Cameroon is located), south-facing slopes are exposed to more direct sunlight, casting longer shadows on the opposite side of the slope. This affects the performance of species of plants. However, it's not just mountains that lead to microclimates. Temperature inversion exists in small dips and depressions in valleys and low-lying areas which results to the formation of collection points for cold air, leading to frost pockets.

Relief is the way that the landscape changes in height. Areas at a higher altitude experience a different microclimate. Temperatures are colder determining the species that can survive in these conditions. Temperature tends to decline with altitude with a drop of between 5 to 10°C per every 1000m above sea level. Higher ground is often windier. Different plants and animal species and breed respectively, are thus adapted to these colder, harsher conditions. The leeward side of hills and mountains is usually much drier than the windward side affecting crop and animal production. This is because as air descends the slope, it dries adiabatically and warms. This is known as the Föhn effect.

Coastal climates are more strongly influenced by the sea than by the land. Typically, coastlines are more humid than regions inland. Crop and livestock performance will thus vary depending on the proximity to water bodies. A microclimate can offer an opportunity as a small growing region for crops that cannot thrive in the broader area. Microclimatic features are vital to choose appropriate crops and livestock given that temperature, solar radiation, and humidity affect plant growth by influencing physiological processes such as photosynthesis, respiration, seed germination, mortality, and enzyme activity. Therefore, it follows that ecosystem processes such as decomposition, nutrient cycling, succession, and productivity are partially dependent on microclimatic variables. The selection of appropriate sites can thus be used as a strategy to alleviate the effects of climate change and variation.

Cameroon has varying landscape ranging from mountainous regions to plains and plateaus. The elevation of the land heavily impacts the type of vegetation and wildlife found in the area. Selection of site entails allocating cool-season crops (that tolerate a light frost with some withstanding freeze event with little to no damage) such as solanum potato (*Solanum tuberosum*, Spinach *(Spinacia oleracea),* Beets (*Beta vulgaris*), cabbage (*Brassica oleracea*) and lettuce *(Lactuca sativa) to high altitudes in the country.* Warm season crops that grow best in warmer temperatures occupy the rest of the country.

The orientations of slopes can also be exploited in Cameroon to provide crops with enabling environments for biomass accumulation. In this regard, north-facing slopes in moisture limited zones of the country (mostly in the northern part of the country) would be appropriate for crop production as there will be less loss of soil moisture through evapotranspiration. However, where soil moisture is not a limiting factor (common in the southern part of the country), the south-facing slopes would provide higher temperature conditions for better growth and development of crops.

Choice of species. In addition to the fact that climate determines the distribution of crops and animals on the globe, it equally determines the level of production through the influence of climatic factors (solar radiation and temperature) that can be modified at a large scale. Climatic change that provide unfavourable conditions to existing crops can be alleviated by choosing other crops that can withstand the prevailing climatic conditions to substitute the former non-adapted crops due to climate change. Climate change could lead to: salinity that would require introducing halophytes; drought that would require the introduction of xerophytes; waterlogged conditions that would require the introduction of hydrophytes.

Active methods. The impacts of climatic change can also take into account the adaptation of farming systems or populations. Chuku and Okoye (2009) postulated four main categories for adaptation in agriculture to face climate change: income and asset management strategies; government programmes and support; farm production practices; and technological developments. These categories are characterised by scale (local, national) and type of agents involved. Numerous options for adaptation at the local scale are practiced in the Sahelian region which include production practices such as water management, the use of certain varieties, fertilisation and also income management techniques such as diversification of returns and migration.

Transformational adaptation strategies are those options that require substantial changes in the production systems in terms of institutional arrangements, priorities for investments, and changes in norms and behaviors (FAO *et al*., 2018). Transformational adaptation might be driven by changes in climatic or environmental conditions that result in existing systems and activities becoming unsustainable that compel people to adapt by fundamentally changing their behaviour or the nature of the existing systems. It is considered as “A dramatic state of change, after which current activities may no longer be feasible” (IEG 2012: 13).

In this light, one of the active CSA methods that can boost agricultural production in small-scale farming systems in Cameroon, is agroforestry. This approach can effectively substitute slash and burn systems, commonly found in some parts of Cameroon. In traditional slash-and-burn systems, fields are cultivated for 1 to 3 years in average and are further abandoned for more than 15 years because of soil depletion, weed invasion and low crop yields. As a consequence, new forest areas are regularly cleared to create new farms, causing deforestation.

Trees and or shrubs provide changes to radiation flux, air temperature, wind speed and saturation deficit when introduced on farms (Rao *et al*., 2007). Modification of aboveground microclimate with tree introduction on farms, has direct consequences on soil microclimate (e.g. Ong *et al*., 2000; Brandle *et al*., 2004; van Noordwijk *et al*., 2014; Karki and Goodman, 2015). In silvopastures, Karki and Goodman (2015) registered 2.1°C lower mean soil temperatures than in open pastures. Steffan-Dewenter *et al*. (2007) showed that shade tree removal increased soil surface temperature by about 4°C and reduced relative humidity at 2m by 12%. Likewise, van Noordwijk *et al*. (2014) showed higher daily amplitudes in soil temperatures (−5 cm) in open-field agriculture (about 9°C) than in coffee-based systems in Java (Indonesia). Moreno *et al*. (2007) reported lower daily and seasonal soil temperature amplitudes beneath holm oak (*Quercus ilex* L.) in Mediterranean woodland pastures. Microclimate changes can have major effects on crop performance.

In agroforestry systems, costs are reduced, especially in fertilizers, thanks to the nutrient-rich organic matter obtained from the biomass of the trees and/or shrubs used in the system to improve the soil. Agroforestry systems are very efficient: for food and feed security and for the environment, in terms of resource use. The system offers diversified sources of income, including wood for various uses and at various time scales, which can also buffer some economic shocks. The system also protects the soil from erosion, which is a major concern for fragile soils common in Cameroon and most SSA.

Another active SSA practice to alleviate climate change especially in the arid parts of Cameroon and during the dry spells experienced in the first growing season in other parts of the country, is rainwater harvesting to build the capacity to recover quickly from the damage and ensure supplies for dry periods. There are several methods which include rooftop capture for small-scale use and surface dams to slow run-off to reduce soil erosion and increase groundwater recharge or aquifer recharge.

Conclusion

Much of Cameroonian agriculture's vulnerability to climate change lies in the fact that the agricultural systems remain largely rain-fed and underdeveloped, as the majority of farmers are small-scale farmers with few financial resources, limited access to infrastructure, and disparate access to information. Both passive and active methods can offer considerable positive impacts to improve small-scale farming systems in Cameroon and beyond. The application of sound knowledge in Agricultural Climatology and Agricultural meteorology are invaluable tools for passive interventions to alleviate the effects of climate change in Cameroonian agricultural sector. Active transformational changes through Agroforestry offer myriad adaptation strategies to alleviate negative climate change and climatic variations situations. The systems can play a significant role in the process of adapting agriculture to climate change by attenuating extreme microclimate fluctuations such as reducing wind speed and alleviating extreme temperatures, protecting through the provision of permanent cover, contributing to soil fertility improvement by providing organic matter and soil nutrients, improving soil physical condition, enhanced soil biodiversity and soil microbial dynamics, thereby improving efficiency in the use of soil, water and nutrients by a deeper rooting system provided by the trees or shrub components in the system, and increasing opportunities for diversification of the agricultural systems.

Acknowledgement

The author thanks the European Union for sponsoring the CSAS Partnership to Strengthen Graduate Training and Research Capacity for developing climate smart agrifood systems in Central and Eastern Africa. This paper is a contribution to the 19th RUFORUM Annual General Meeting and Conference held 28th October-02 November 2023 in Yaoundé, Cameroon

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