EVOLVING POTENTIALS FOR PRECISION CLIMATE-SMART AGRICULTURE IN SUB-SAHARAN AFRICAN COUNTRIES #9421

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ABSTRACT

Progressively, there is increasing awareness on the significance of agriculture in both adaptation and mitigation to climate change. While adaptation has been typically highlighted in the most vulnerable countries, especially in Africa where the failure to adapt have been noted to exacerbate the dangers of food insecurity, there is limited effort at emphasizing mitigation as the ultimate resolution of the debacle. Climate-smart agriculture (CSA) is critical to achieving development irrespective of the attendant impacts of global warming, simultaneously ensuring food security through productivity and income growths, forcing resilient ecosystems thus boosting livelihoods and at the same time plummeting greenhouse gas emissions. Thus, CSA approach not only sustainably increases productivity but enhances adaptation and mitigations where possible, yet these benefits remain largely unexploited in the Sub-Saharan Africa (SSA), hence resulting in seemingly misplaced prospects, unrecognized impact, and gross inability to access climate finance. Whereas precision agriculture (PA) has enormous prospective for development in SSA, yet several social-economic and technological limitations abound for SSA countries. This is evident from the knowledge that more than half of these countries have not shown capacity to develop their potentials for precision climate-smart agriculture (PCSA). Therefore, there is need for more investigation on the low usage of precision agriculture as management strategy accounting for temporal and spatial variability to improve sustainability of agricultural production in Africa. Furthermore, the role of information and technology-based farm management systems to tackle variability in agriculture for optimum profitability and sustainability, needs further exploration. This study aims to acquire, interpret, and utilize as much spatial information as possible to enhance farming in SSA countries with the goal of reducing the climatic impacts associated with agricultural activities. This study estimates the mitigation potentials of PCSA agricultural practices using data from FAO, World Bank, IFAD, and other studies for evaluation. The study further shows emerging market countries, particularly in Sub-Saharan Africa, can possibly gain advantage from unconventional agribusiness technologies that mitigate the impacts of climate change from a country-by-country analysis. We also emphasis PCSA as the solution to feeding the SSA population that is growing faster than available land supply, while also ensuring the sustainable use of water and energy with the scientific plausibility of overcoming water scarcity due to drought by employing regional climate model forecasts towards 2100 for the adoption of climate smart technologies such as micro-irrigation, drip irrigation, and solar pumps etc. The role of agricultural extension through digital advisory services, as well as crop and soil monitoring, is also emphasized as a strategy to increase agricultural productivity and farmer income, make rural communities more resilient, and mitigate climate change. Finally, our findings identify land use and agricultural management practices with the largest mitigation potential, analyzed uncertainties in mitigation under different climate scenarios and provide recommendations to improve monitoring of mitigation benefits for PCSA project design and implementation in SSA.

INTRODUCTION

Agriculture is the most important economic sector in many sub-Saharan Africa (SSA) countries, contributing more than one-third of the gross national product (GNP) and employing more than two-thirds of the labour force (AfDB, 2020). Yet, the region has not invested enough into agricultural research and development, which is the reason for the reduction in agricultural productivity and growth as compared to other regions of the world (Fuglie *et. al.*, 2020). However, empirical evidence suggests that climate change will continue to have far-reaching consequences for agriculture which will disproportionately affect poor and marginalized groups in SSA who depend on agriculture for their livelihoods and have a low capacity to adapt (Zougmoré *et. al.*, 2018). Similarly, climate change may pose challenges in the region's quest to use agriculture as the mainstream opportunity to achieve food security as well as the poverty reduction targets entrenched in the sustainable development goals (Onafeso, Akanni, and Badejo, 2015). Regrettably, agriculture in SSA has remained primarily rainfall-dependent, with staple food production entirely from rain-fed farming systems (Bjornlund, Bjornlund, and Van Rooyen, 2020).

Climate-smart agriculture (CSA) including agricultural practices, restoration practices of degraded lands, forest and cropland regeneration practices, practices in the livestock sub-sector, water resources and use of weather and climate information services have been adopted across SSA (Ariom *et. al.*, 2022). Although, as the impacts of climate change vary from country to country, the CSA strategies adopted also varies significantly often influenced as well by numerous factors like financial preferences, role of policy legislation, access to climate information and farmers' knowledge levels. Besides, low inherent soil fertility combined with increased population pressure has led to soil degradation and nutrient depletion in most of the SSA countries (Drechsel, Kunze, and de Vries, 2001).

For sustainable agricultural growth to be achieved therefore, a more efficient use of resources must be employed, with the adoption of precision agriculture (PA) technologies considering temporal and spatial variability to improve sustainability of agricultural production (ISPA 2018). Progressing reasonably faster in the western countries with increasing affordability of onboard computing capacities, global navigation satellite system (GNSS), sensors, geo-information systems (GIS), geo-mapping, robotics, and emerging data analysis tools. The imminent challenge in the SSA countries is to evaluate crop health using performance *in situ* sensors, spectra radiometers, machine vision, multispectral and hyperspectral remote sensing, thermal imaging, and satellite imagery as it is being used by researchers and innovative farmers in other regions of the world (Khanal *et. al.*, 2020; Lowenberg-DeBoer *et. al*. 2021).

However, PA has enormous prospective for development in SSA, yet social-economic and technological limitations abound. More than half of SSA countries have not shown capacity to develop potentials for precision climate-smart agriculture (PCSA). This study aimed to acquire, interpret, and utilize as much spatial information as possible to enhance farming in SSA countries with the goal of reducing the climatic impacts associated with agricultural activities.

MATERIALS AND METHODS

We estimated the mitigation potentials of PCSA agricultural practices using data from FAO, World Bank, IFAD, and other studies for evaluation. The study further showed emerging market countries, particularly in SSA, can possibly gain advantage from unconventional agribusiness technologies that mitigate the impacts of climate change from a country-by-country analysis.

RESULTS AND DISCUSSION

SSA countries have adopted CSA to confront agricultural productivity challenges, build resilience to climate change, and reduce greenhouse gas (GHG) emissions, with extensive indication that the continent is disposed to precision agriculture (Barasa, Botai, Botai, and Mabhaudhi, 2021). Although, CSA research in Africa only began two decades ago, there has been several approaches involving low-tech precision farming to estimate millet yields successfully (Gandah, Stein, Brouwer, and Bouma, 2000). As impacts of climate change continues to manifest particularly as droughts and floods affecting agriculture, progress towards achieving potential solutions and increase productivity continues to promote CSA techniques and policy framework. Similarly, significant country level incorporation of agricultural practices and technologies with applicable indigenous knowledge and innovations encompassing the three pillars of CSA have also been widely reported among the few SSA countries that have taken the lead in advancing the research domain. Notwithstanding these progressions however, only few SSA countries (viz. Kenya, South Africa, Zimbabwe, and Mali) appeared to be forefront in global CSA implementation (Chandra, McNamara, and Dargusch, 2018).

In general, however, there is considerable evidence of some progress in CSA activities in East Africa, particularly in Kenya, Ethiopia, Uganda, Burundi, and Tanzania; in West Africa, particularly in Nigeria, Mali, and Ghana; and also in Southern Africa majorly in South Africa and Zimbabwe (https://ccafs.cgiar.org/resources/publications/csa-country-profiles). According to the World Bank data on Food production index, the SSA countries can do much better with PCSA as shown in Table 1 where only Southern Africa countries by region outperformed both the global average and that of the United States of America except for the decline in the recent decade. Quite noteworthy, however, the case is not the same for all other regions in SSA where values higher than both the global average and the United States of America indices have been observed. This implies that with improvements in PCSA, the SSA as a region have the potentials to outperform all other regions of the world in terms of Food production index.

Table 1. Food production index (2014-2016 = 100).

	1960	1970	1980	1990	2000	2010	2020
Northern Africa	18.40	24.58	36.17	48.96	66.12	91.42	**107.97**
Western Africa	26.90	31.23	33.98	43.98	61.47	91.97	**110.92**
Eastern Africa	40.61	52.10	59.97	73.36	78.04	**98.03**	**112.49**
Middle Africa	29.87	33.82	37.16	42.83	60.94	86.32	**109.23**
Southern Africa	**54.05**	**69.51**	**75.28**	**80.82**	**93.83**	**104.43**	99.00
USA	41.26	49.13	60.91	68.83	83.03	92.26	104.45
Global Average	52.05	61.35	71.26	75.65	80.91	92.76	107.79

Sustained progress in PCSA including optimization of existing resources such as land, soil and water to intensify productivity and improve agricultural processes as well as reducing the agrarian sector induced GHG emissions and ensuring sustainability through environmental quality protections are observable measure gradually shaping food production in SSA. Similarly, improved understanding in satellite positioning and navigation has made it possible to gather information required to apply decision-based precision agriculture in recent times. This ability to acquire on-farm information coupled with increased awareness of variability of soil and crop conditions by the farmers have been the main drivers of the recent advancement of precision agriculture (Stafford 2000). Further developments in PCSA expected in most SSA countries however includes adapting fertilizer application to variable soil conditions on large mechanized farmlands with the potentials to use automatic fertilizer application devices, autonomous farm machinery, and computer software for management of various production systems (Gebbers and Adamchuk (2010).

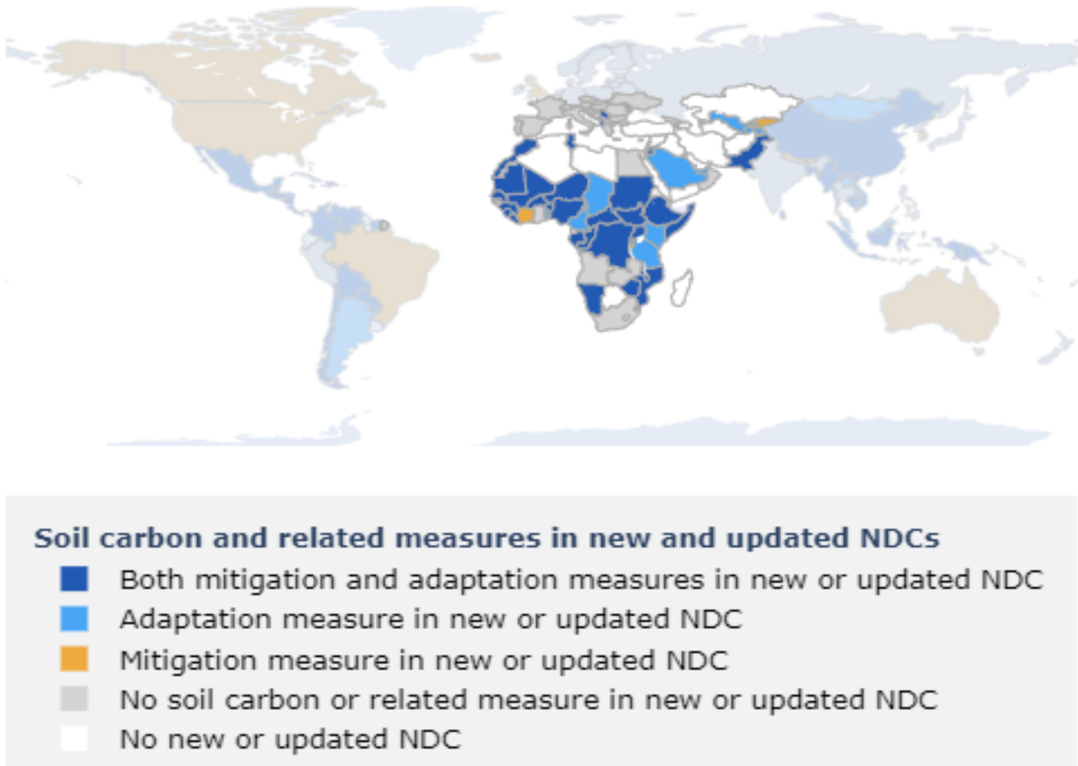

Fig. 1 Nationally Determined Contributions (NDCs) to COP 21 (Rose, *et. al*., 2021).

According to the Nationally Determined Contributions (NDCs) for climate action under the international agreement at the Conference of the Parties to the United Nations Framework Convention on Climate Change (UNFCCC) in Paris in 2015 (COP 21), most of the SSA countries as of September 3, 2022, have updated commitments to both mitigation and adaptation measures. This shows another significant progress towards PCSA with evidence that SSA can do much better with improved international collaborations such as those funded by IFAD involving South Africa, Kenya, Tanzania, and Zimbabwe, with the USA, Germany, the Netherlands, and Australia. While these collaborations are well appreciated, it is imperative to include under-developed countries in the CSA subject matter. This will serve as a steppingstone to implementing the CSA concept, realizing its benefits, and, consequently, achieving the much-needed agricultural transformation in sub-Saharan Africa.

There is, therefore, the need for further investigation on the squat practice of precision climate smart agriculture as management strategy accounting for temporal and spatial variability to improve sustainability of agricultural production in SSA. Furthermore, the role of information and technology-based farm management systems to tackle variability in agriculture for optimum profitability and sustainability, needs further exploration.

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