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Review

Current Practices and Prospects of Climate-Smart Agriculture in Democratic Republic of Congo: A Review

Katcho Karume [1,2], Jean M. Mondo [1,*], Géant B. Chuma [1], Angele Ibanda [3], Espoir M. Bagula [1], Alex Lina Aleke [4], Serge Ndjadi [1], Bintu Ndusha [1], Pascaline Azine Ciza [1], Nadege Cirezi Cizungu [1], Daniel Muhindo [5], Anthony Egeru [6], Florence Mayega Nakayiwa [6], Jackson-Gilbert M. Majaliwa [6], Gustave N. Mushagalusa [1] and Rodrigue B. Basengere Ayagirwe [1]

[1] Faculty of Agriculture and Environmental Sciences, Université Evangélique en Afrique, Bukavu 3323, Democratic Republic of the Congo
[2] Centre de Recherche en Géothermie, Bukavu 327, Democratic Republic of the Congo
[3] Faculty of Sciences, Université de Kisangani, Kisangani 2012, Democratic Republic of the Congo
[4] Faculty of Sciences and Applied Sciences, Université Officielle de Bukavu, Bukavu 570, Democratic Republic of the Congo
[5] Faculty of Agriculture, Université Catholique de Bukavu, Bukavu 285, Democratic Republic of the Congo
[6] Regional Universities Forum for Capacity Building in Agriculture (RUFORUM), Kampala 16811, Uganda
* Correspondence: mondo.mubalama@yahoo.fr or mondo.mubalama@uea.ac.cd

Abstract: Climate-smart agriculture (CSA) is one of the innovative approaches for sustainably increasing the agricultural productivity, improving livelihoods and incomes of farmers, while at the same time improving resilience and contributing to climate change mitigation. In spite of the fact that there is neither explicit policy nor practices branded as CSA in Democratic Republic of Congo (DRC), farmers are utilizing an array of farming practices whose attributes meet the CSA criteria. However, the intensity, distribution, efficiency, and dynamics of use as well as the sources of these technologies are not sufficiently documented. Therefore, this review paper provides a comprehensive evidence of CSA-associated farming practices in DRC, public and private efforts to promote CSA practices, and the associated benefits accruing from the practices as deployed by farmers in the DRC. We find evidence of progress among farming communities in the use of practices that can be classified as CSA. Communities using these practices are building on the traditional knowledge systems and adaptation of introduced technologies to suit the local conditions. Reported returns on use of these practices are promising, pointing to their potential continued use into the future. While progressive returns on investment are reported, they are relatively lower than those reported from other areas in sub-Saharan Africa deploying similar approaches. We recommend for strategic support for capacity building at various levels, including public institutions for policy development and guidance, extension and community level to support uptake of technologies and higher education institutions for mainstreaming CSA into curricula and training a generation of CSA sensitive human resources.

Keywords: climate-smart agriculture; climate change; university curricula; food security; smallholder farming; DRC

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1. Introduction

Climate change is a serious threat to food production worldwide [1,2]. Rural Africa is by far the most vulnerable due to its farmers' heavy dependence on rain-fed agriculture, low adaptive capacity, and insufficient investment in mitigation and resilience-building systems [3,4]. The Congo Basin countries, including the Democratic Republic of Congo (DRC), present an acute vulnerability situation considering that more than 70% of the population are agricultural dependent and rural inhabitants [5,6]. Climate change poses a significant threat to the DRC's poverty reduction effort and food security [7,8]. This calls for an urgent need to transform agriculture to secure food security and sustainable management of natural resources.

Local level adaptation efforts have been gaining pace across the world, especially those efforts seeking to strengthen society's capacity to deal with the effects of climate change [9]. Within the DRC, smallholder farmers have implemented a number of adaptation strategies and practices to counter adverse effects of the changing climate [10–13]. These efforts are, however, noted to have had limited effects [3]. Like other countries in the sub-Saharan Africa region, DRC is seeking for effective alternatives for countering adverse effects of climate change that are undermining the livelihoods of communities. Climate-smart agriculture (CSA) has been presented as one of the alternative and innovative approaches that sustainably increases the productivity of crops, livestock, fisheries, and forestry production systems and improves rural people livelihoods and income. It is shown that CSA does this whilst at the same time building resilience and contributing to climate change mitigation efforts [7,14,15]. In spite of this fact, the DRC remains without a known policy framework for the promotion of CSA as well as a lack of a detailed account of which practices, how, where, and to what extent CSA is being practiced within the country [16].

Documenting the state of knowledge on practices in use, how they are used, where and how effective they have been, and/or how they are perceived as well as how they have been disseminated across the country is critical for decision-making cycles. According to Thornton et al. [17], it is always critical to identify entry points for interventions in a system especially as it regards to how inputs, activities, and outputs can lead to outcomes and impacts. As such, through undertaking this review, we sought to establish the state of knowledge regarding CSA and CSA practices in DRC and explore how CSA as an approach is providing an alternative promise that supports communities to improve their resilience and contribute to climate change mitigation in DRC. The review further elaborates on how this could best be achieved by implementing the CSA approach under the new realities of climate change.

2. Materials and Methods

This review was written gathering information from published and unpublished reports on CSA in DRC. Published articles and reports (written whether in French or English) were retrieved from search engines and open access databases such as Google Scholar, Research4life (OARE, ARDI, and AGORA), and institutional websites. Unpublished reports were sourced from governmental and non-governmental agencies, universities, and research institutions. Three main inclusion criteria for a report were defined after Rosenstock et al. [18]: (1) It refers at least one CSA management practices or technologies, (2) the study location is in a DRC province, and (3) published by a reputable institution or scientific journal. The check-list of CSA practices provided by Rosenstock et al. [18] was adopted in this review. It contains 73 practices (under five general themes: agronomy, agroforestry, livestock and aquaculture, post-harvest management, and energy systems) used in developing countries and based on the literature by FAO CSA sourcebook and IPCC. Since CSA term is not explicitly used in most DRC literature, the search strings were based on potential CSA practices as by Rosenstock et al. [18] check-list. This string for each of these CSA practices was run in above-listed search engines. The titles and abstracts of these references were exported to EndNote v7.0 (Thompson Scientific, London, United Kingdom) for screening, and duplicate records were removed. The full texts for abstracts meeting the inclusion criteria were downloaded and screened by the same eligibility criteria [18].

The crop sensitivity/suitability analysis to climate change was performed for the three major crops in DRC, including cassava, maize, and common beans, using the Food and Agriculture Organization of the United Nations (FAO) Land Evaluation Guidelines developed by Sys et al. [19]. It consists of matching land characteristics against crop requirements and assigning a suitability rate for each land characteristic. The FAO approach defines Land Suitability as the aptitude of a given type of land to support a defined use. The basic idea underlying the proposed method of land suitability classification is that the land should be rated only on its value for a specific purpose. According to the classification proposed by FAO [20], four and five different classes, ranging from "Unsuitable" to "Highly suitable", whose codes are constituted by a capital letter (indicating the order) and a number (indicating the class), identify the land suitability for a specific purpose. In the present paper, we used climate requirements for evaluating the effect of climate change. WorldClim data were used for historical and future climate under CMIP6 project and ssp585 scenarios. Three models were selected according to Bagula et al. [21].

3. Agricultural Production Systems and Climate in DRC

3.1. Agricultural Production Systems and Productivity

Agricultural production in DRC is primarily based on small-scale subsistence farming [22]. This sector employs ~70% of the country population, mainly as smallholder farmers exploiting ~10 million ha out of the country's 80 million ha of arable land. The average farm size per household is 1.5 ha (but much smaller in eastern DRC where the population density is higher compared to the national average [23]). The farming system is not very productive, and food crop production systems are mainly rainfed [21,24]. According to a report by the International Monetary Fund [25], the country agricultural productivity declined by 60% between 1960 and 2006 as a consequence of a persistent political instability that pushed producers to flee from their regions, abandoning agriculture. Moreover, there is a faulty agricultural extension service (even absent in remote areas), because of the government disengagement in agriculture, that had significantly impeded the dissemination of adequate crop husbandry practices and technologies, resulting in low yields, poverty, and food insecurity [26,27].

The agriculture in DRC is still predominantly traditional in forest areas where slash-and-burn agriculture is a common farming practice. This consists of slashing the vegetation and burning its residues to create new fertile farmland [28,29]. Moreover, contour farming is also performed in high-altitude volcanic mountain areas (Kivus). Such extensive farming system is not sustainable as it contributes to the emission of greenhouse gases (GHGs) and accelerates deforestation when searching for new fertile lands. The country is diversified in terms of agroecological conditions that vary from tropical rainforests to mountainous terraces, highlands, savannahs, dense grasslands, and mountains [30]. It is divided into three agroecological zones based on relative homogeneity considering the altitude, climatic, and agro-soil parameters, the population density, and the vegetation cover. These zones include the following:

(1) A vast alluvial Congo central basin in the center, with an altitude of 300–500 m, which covers one-third of the country. Its vegetation consists of equatorial forests and wetlands. It is relatively sparsely populated. The climate is equatorial, hot, humid in the center; the rainy season lasts on average eight months a year, with an annual rainfall of 1500–2000 mm, alternating with one dry season [24]. These agroecological conditions are conducive to the cultivation of a wide variety of crops such as rice, maize, banana, yam, and pineapple [31].

(2) The savannah plateaus border the central basin from the north to south (700–1200 m altitude) and are more densely populated. The region is bimodal and characterized by two rainy seasons (between March and May and between September and December) in the north and has subtropical savanna climate in the south, and southeast with a single rainy season between February and September. Temperatures are slightly lower but constant, varying between 22 and 23 °C [24,32]. These agroecological conditions are conducive to cultivating a wide variety of crops such as rice, cassava, peanut, soybean, cowpea, sorghum, millet, sweet potato, yam, potatoes, cotton, simsim, etc., [31].

(3) The high-altitude volcanic mountain ranges in the east and northeast (1500–5000 m above sea level) (in the Kivu region) have a very high population density. The region separates the Congo River basin from that of the Nile. The landscape is the tropical rainforests along the Congo River and its tributaries, characterized by two rainy seasons (between March and May and between September and December), followed by two short dry seasons (between June and August and between January and February). The average temperature varies between 24 and 25 °C; variability is limited throughout the year [24,32]. The agroecological conditions are conducive to cultivating a wide variety of staple crops such as cassava, beans, rice, bananas, soybean, cowpea, sweet potato, and potatoes as well as industrial crops such as coffee, tea, cocoa, sugar cane, etc., [31].

In DRC, over 15 million tons of cassava are produced yearly. Cassava alone accounts for >70% of all food production in the country [33,34]. In 2015, the western area (Kinshasa, Kwilu, and Kongo Central) produced 31% of cassava, followed by Kasaï (14%) and the Kivus (9%). Maize and rice accounted on average for 69 and 30% of the total cereal production, respectively. The former Province Orientale (now split into Ituri, Bas-Uele, Haut-Uele, and Tshopo) is the major rice producer in DRC, accounting for ~35% of the country production. The two former Kasaï provinces provided 16.6%, while the provinces of Kinshasa, Kongo Central, and Kwilu accounted each for 13.4% of the national rice production. Legume crops are less produced in DRC (<1% of total food production), of which common beans are predominant. The two provinces of Kivu are the largest bean producers (~70% of the country production) due to favorable weather conditions. Like legumes, oilseed crops represent ~1% of domestic production, with peanut accounting for the majority. The western region represented 36.6% of groundnut production, followed by Kasaï (20.3%). Plantain and banana represent on average 10% of annual agricultural production in DRC. The former Province Orientale provides 45% of the national banana production, followed by the two provinces of Kivu (27.2%) [31].

The livestock population is dominated by poultry, followed by the goat. About 20% of the poultry production in the DRC comes from the Kasaï region, 19% from the former Province Orientale, 17% are from the western areas, and 9% from the two Kivus. The Kasaï region produces half of the goat population in DRC, followed by the two provinces of Kivu (14%) and the western area (11.6%) [31]. After successive civil wars which decimated livestock in eastern DRC, 70.4% of the cattle population is now concentrated in three former provinces: Bandundu (29.1%), Province Orientale (28.2%), and Katanga (13.1%) [35,36].

3.2. Agriculture and Climate Change in DRC

3.2.1. Agricultural Greenhouse Gas Emissions

Land-use and land cover (LULC) change and the massive deforestation are the main sources of the DRC's GHG emissions (80.1%). Moreover, sectors such as agriculture and energy account for 9 and 5.5% GHG emissions, respectively [37,38]. For instance, ~1.31 million ha of natural forest were deforested in DRC in 2020, emitting ~854 million tons of CO_2. There are governmental and non-governmental initiatives to reduce GHG emissions in DRC, but wide poverty among populations hinders such efforts. Nevertheless, the country committed to reducing its GHG emissions by 17% from 2021 to 2030, if external financing of ~$21.6 billion is provided to allow the country to reduce its heavy dependence on natural resources, including forests [39]. The agriculture contribution to GHG emission is related to the expansion of cropping to forest areas in search of more fertile lands since Congolese agriculture is still extensive, with less external farm inputs [40]. In eastern DRC, there is also a rapid conversion of wetlands into farmlands, altering its ability to sequestrate the carbon [41,42].

3.2.2. Predicted Effects of Climate Change on Congolese Agriculture

In DRC, it has been predicted that temperatures will rise by the end of the century, between +1.7 °C and +4.5 °C [6]. The same projections warned that heat waves will be more frequent and longer-lasting. The end-century will also experience an increase of 13–58% and 33–86% in hot days and nights, respectively. Furthermore, there would be 6–10% decrease in the number of cold days and nights [6]. The central DRC will experience frequent extreme rainfall events while aridity and drought are expected to increase in the southern regions. Extreme rainfall events would lead to frequent landslides and waterlogging of agricultural fields, accelerating soil erosion and depletion especially in highland areas, and consequently, leading to severe food insecurity. The impact of natural disasters will be more harmful to poor populations with limited control strategies who tend to occupy hazard-prone locations [43]. Extreme rainfall and floods will also affect people and agricultural goods mobility by damaging road networks, decreasing access to markets and isolating rural communities [6].

Heavy precipitation and high temperatures that would characterize the country by the mid- and end- century (Figure 1), would considerably effect crop productivity. Anticipatively, climate-smart measures (including agroforestry, agronomy, crop-livestock or crop-aquaculture integration, etc.,) should be devised to improve the resilience of current farming systems to climate change's adverse effects [21,44,45]. In areas that would experience prolonged drought due to high temperatures and erratic rainfall, soil and water conservation practices should be promoted to reduce their negative impacts on crop growth and productivity. By the same means, pressure on natural resources would be slowed since farmers would not be tempted to expand their cropland into forests [46]. For instance, Bagula et al. [21] predicted, using global climate models (GCMs), that there would be an increase in average annual temperatures for both RCP 4.5 and 8.5, with the highest increase (3.05 °C) under hot/dry conditions for RCP8.5 and the lowest (1.04 °C) under cool/dry conditions for RCP 4.5 in eastern DRC. All the models they selected, for five climate regimes for 2022–2099, showed no change in the rainfall trends for RCP 4.5. The models projected maize yield declines of 5–25%, with less yield losses under tied ridges as CSA adaptation practice. They concluded that a use of efficient soil water conservation practices could be a promising strategy in reducing potential losses from climate change in drylands of eastern DRC. Heavy rainfall and floods may force shifts in the timing of the planting and harvesting seasons [6,21,44,47]. Several efforts are ongoing to adjust the crop calendar with the aim of strengthening smallholder farmers' resilience to climate change.

Though major Congolese crops such as sweet potatoes, cassava, and maize are tolerant to an array of climate conditions and biotic factors (pests and diseases), other crops such as the common beans show high vulnerability to diseases, drought, and heat stress. Unfortunately, farmers growing these crops have relatively low adaptation strategies to cope with climate change adverse effects. For instance, common bean farmers have established very low capacity to cope with climate-sensitive diseases, such as the bean root rot, which is a highly damaging disease with substantial impact on the crop productivity [48]. Moreover, high temperatures, resulting from climate change, would certainly affect the quality and productivity of other food and income security crops such as coffee, soybean, banana, and plantain as well as altering the dynamics of pests and pathogens. As opposed to other crops' trends, the Kivu regions could experience a rise in rice yields. In addition to rise in productivity, rice is extensively substituting other crops grown in Kivu wetlands that can no longer adapt to regular flooding, occurring even during dry seasons.

In addition to threatening crop yields, livestock could also be affected by extended dry spells and erratic rainfall, resulting in considerable livestock losses and/or spoilage of livestock products [46]. Spatial distributions in the number of hot days (>35 °C) for the mid- (2050s) and end-century (2090s), as projected under a high emission scenario are presented in Figure 1.

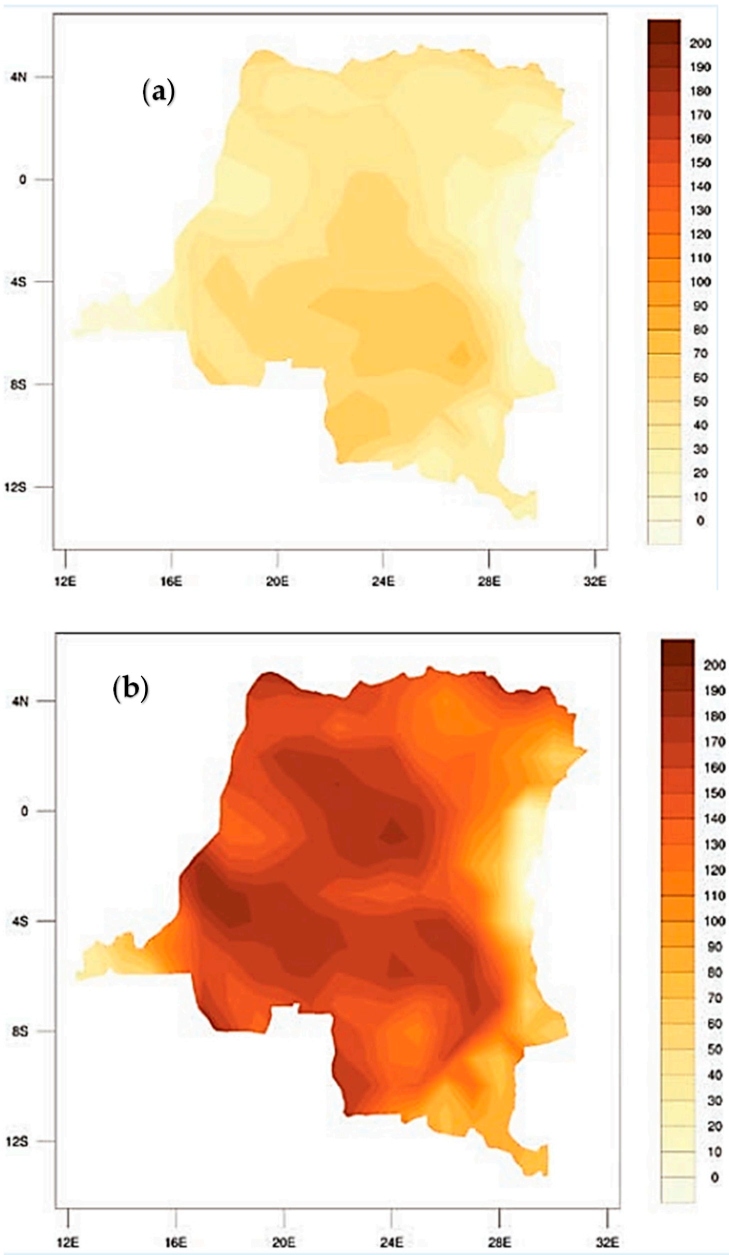

Figure 1. Spatial distribution of changes in the number of heat days (>35 °C) by mid-century (2040–2059) (**a**) and by end-century (2080–2099) (**b**), as compared to the 1986–2005 baseline, under a high emission (RCP 8 552) scenario.

Predicted Climate Suitability Analysis for Cassava under Climate Change Conditions in DRC. Cassava seems to be a highly resilient crop to climate change. The climatic suitability analysis of cassava shows that DRC has highly suitable lands and production potential. This suitability is almost present in the whole country except for some eastern-highland areas. With climate change, little changes will be observed at the mid-century. Climate models show that DRC could lose some potential cassava production lands. Most highly suitable lands will be converted to suitable lands by the 2061–2080 period and for the ssp585 (RCP85 in CMIP5) scenarios (Figure 2). The prediction supports that cassava is the least sensitive staple crop to the climate conditions compared to other major food crops in Africa (e.g., maize, sorghum, millet, beans, potatoes, and bananas) [49].

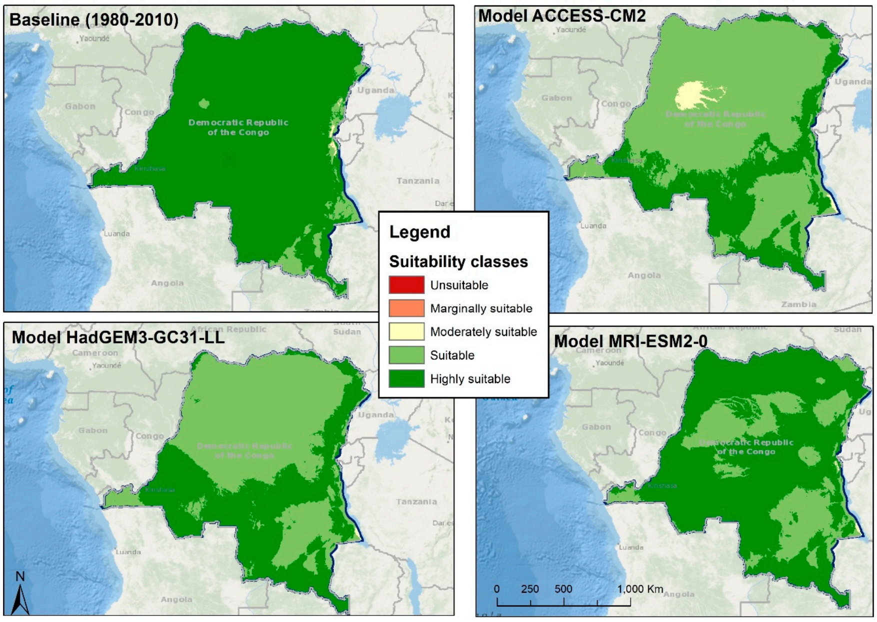

Figure 2. Cassava climate suitability under climate change conditions (ssp585) for 2061–2080 in DRC.

Predicted Climate Suitability for Maize under Climate Change Conditions in DRC. Suitability analysis based on climate data shows that the southern regions, i.e., former provinces of Katanga, Kasaï, Bandundu, Bas-Congo, and some parts of the east and north-east are suitable for maize production. A large part of the country remains moderately suitable for maize. However, the result of climate change projection in extreme conditions (ssp585 or RCP 85) shows that DRC will lose its maize production potential and its suitable areas will be converted into moderately suitable ones in most cases (Figure 3). As a result, there will be a significant increase in marginally suitable lands with climate change. Maize sensitivity to temperature and precipitation are high and proven by several authors, and therefore, it is a highly susceptible crop to climate change [21]. This situation will accelerate farmers' vulnerability to climate change due to the direct negative impacts of climate change on the suitability and productivity of crops they rely on for both subsistence and income.

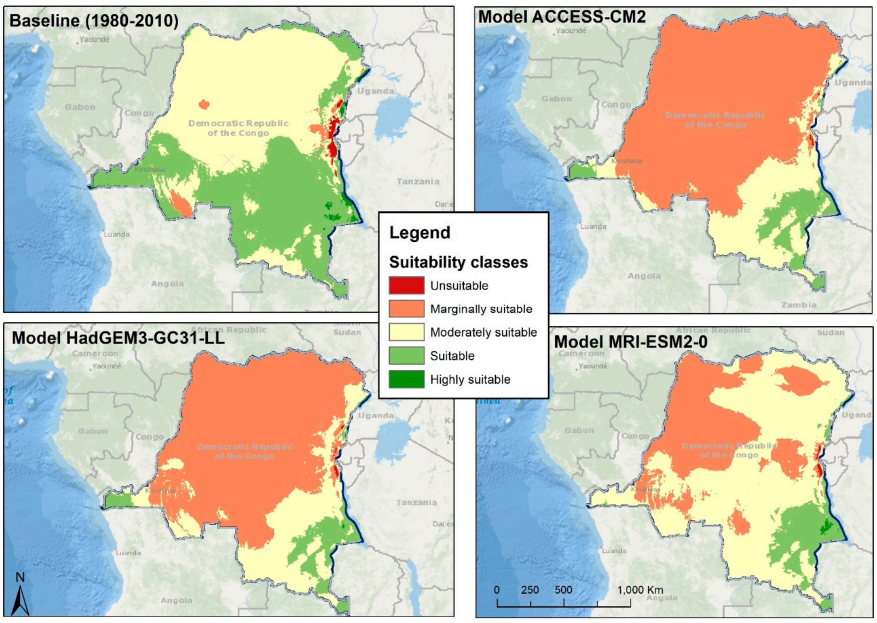

Figure 3. Maize climate suitability under climate change conditions (ssp585) for 2061–2080 in DRC.

Predicted Climate Suitability for Common Bean under Climate Change Conditions in DRC. Except for the highlands of eastern DRC and part of Katanga, climate-based suitability for common beans is very marginal in DRC. Moreover, only the eastern highlands will remain suitable with climate change, and the Katanga side will become marginal. This drastic situation will increase if the region follows ssp585 scenarios (Figure 4). Therefore, it will increase farmers' vulnerability if they continue cultivating common beans as one of the major crops, as it is the case in eastern DRC. Regarding spatial distribution, all regions are currently similar in land suitability.

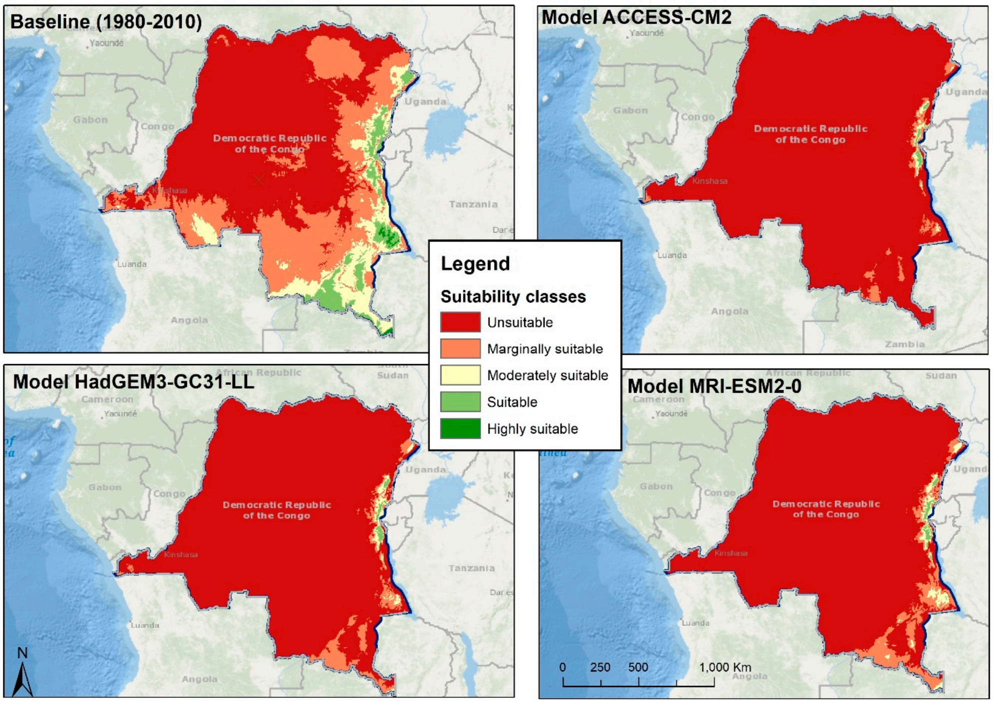

Figure 4. Common beans climate suitability under climate change conditions (ssp585) for 2061–2080 in DRC.

As above-described, climate change poses a serious threat to the present and future of the agricultural sector in DRC and could hinder its capacity to alleviate hunger and poverty in the country, where more than 70% of the populations are rural and agriculture-dependent. There is, therefore, an urgent call for promoting CSA practices among farmers to strengthen their resilience to climate change as these practices have proven their potential to reduce climate change adverse effects and to increase farming communities' adaptive capacity to long-term climatic trends in the country [21,45].

4. Climate-Smart Agriculture in DRC

This section summarizes practices implemented by farmers whose attributes meet the CSA criteria. It also describes initiatives by farmer-support structures, research and higher education institutions in promoting CSA practices in DRC. Governmental and no-governmental supports as well as incentive policies are discussed and gaps raised.

4.1. Inventoried CSA Technologies and Practices

Previous studies revealed that farmers in DRC have no adaptation and resilience techniques branded as CSA [4,16]. However, farmers in the DRC engage in several practices that aim to increase productivity, adapt to changing climate scenarios, and mitigate adverse effects of high carbon emissions [4,16]. Some of these CSA practices are described in Table 1 and Supplementary Table S1. Inventoried CSA practices are clustered under five general themes: agronomy, agroforestry, livestock and aquaculture, post-harvest management, and energy systems) as suggested in Section 2.

Table 1. Most popular CSA practices in DRC.

Category	Practices	References
Agronomy	Conservation agriculture	[28,50–52]
	Soil restoration	[51]
	Soil and water conservation techniques	[16,21,44,45,51,53]
	Natural fertilizer	[54–57]
	Natural pesticide	[58]
	Waste recycling	[59]
	Use of stress-resilient crops	[4,40]
	Crop rotation	[4,60]
	Fallow practice	[4,61]
	Mulching	[51]
	Increased diversity of crops	[62–65]
	Increased diversity of cultivars	[62]
	Adjusting planting dates	[16,52,62]
	Irrigation	[61,65]
	Integrated soil fertility management	[61,66]
Agroforestry	Boundary planting	[52]
	Manure and compost	[52]
	Legume trees	[16,67–69]
	Multi-strata agroforestry	[70]
Livestock and aquaculture	Changing breeds for yield and quality	[71]
	Disease resistant breeds	[71]
	Hybridization	[72]
	Crop-livestock integration	[53]
	Crop-aquaculture integration	
Food energy systems	Biogas production	[73]
	Improved cookstoves	[74]
	Solar energy	[73]

4.1.1. Agroforestry

CSA practices in the forestry sector aim at using agriculture as a response to reducing deforestation while at the same time lowering agriculture's carbon footprint and promoting a resilient and more productive farming system [4,75]. Scientists prominently promote agroforestry in DRC because of the large hectarage of forests; the country records one of the highest potential zones for REDD+. For instance, Kavira [75] reported that 87% of surveyed farmers of Kubagu area in North East of DRC adopted agroforestry practices following technical supervision of the Lutheran World Federation (LWF). However, Unega [67] reported that only 42.2% of surveyed farmers surrounding the UMA forest in the east of Kisangani planted trees following technical and financial support from the *Association pour le Developpement Integré de Kisangani et de la Cuvette Centrale Congolaise* (ADIKIS/CCC).

The University of Kisangani has been undertaking efforts to implement studies in few areas surrounding forest regions in the north and central-east, with a great potential of enhancing sustainable production, improving smallholders' livelihood, and promoting resilience and/or mitigation of carbon emissions. However, these results need to be disseminated and scaled up among smallholder farmers in their specific villages since climate-smart interventions are highly location-specific. For example, a study was conducted to assess the response of legume trees as an integrated soil fertility management alternative at the experimental site of the University of Kisangani in Simisimi, eastern DRC. Results revealed that *Albizzia chineensis* was the best legume for agroforestry with 17.6 kg of fresh matter and 5.8 kg of dry matter and would play a critical role in the integrated soil fertility management in that area, while at the same time lowering agriculture's carbon footprint [68]. This finding was confirmed by Zalo [69] who reported that *Albizia Chineensis* and *Albizia laureniii* cultivated in alley cropping with banana recorded relatively higher fresh matter contents (0.3 and 0.2 kg, respectively) at Simisimi. These findings suggest the use of agroforestry as a response to reducing deforestation, preserving biodiversity, and sustaining soil fertility.

Furthermore, small-scale agroforestry actions, seeking at regenerating Miombo forests mixed with agriculture, were implemented in the vicinity of Lubumbashi, though these initiatives remain marginal due to the lack of financial and public policy support [70]. The low adoption rate recorded among smallholder farmers implies inefficient extension services in disseminating and increasing awareness of farmers on agroforestry benefits and how it is instrumental in coping with climate change. Moreover, technical and financial supports from government or non-governmental organizations are crucial to perpetuate such CSA technique. However, to achieve these goals, commitment by all stakeholders, including the government, private sectors, NGOs, universities, and farmers, is essential from conception to implementation.

The Geographic Information System (GIS) coupled with the remote sensing are being used in eastern DRC to identify suitable zones for agroforestry and assess the impact of the forest cover in reducing the soil erosion [51,76,77].

4.1.2. Agronomy

In eastern DRC, the Université Evangélique en Afrique (UEA) with its partners has initiated a series of project dealing with CSA practices. These include soil restoration at the hill scale, adapted agroforestry tree selection, soil and water conservation techniques, land use and land cover assessment in wetlands, biofertilizer and biopesticide development, waste recycling, use of resilient crops, etc., [21,40,42,44,45,51]. Some of those practices, partners involved, and resource-persons are presented in Supplementary Table S2. Other institutions involved in CSA practices in DRC are presented in Supplementary Table S3, while Figures 5–7 present some of the common CSA practices in eastern DRC.

Figure 5. *Cont*.

Figure 5. Steps in making briquettes by smallholder farmers supported by a local non-governmental organization, DIOBASS, in eastern DRC.

Figure 6. *Cont.*

Figure 6. Biogas production process using cow dung at the Faculty of Agriculture, UEA, eastern DRC.

Figure 7. *Cont*.

Figure 7. Predominant soil and water conservation practices in South-Kivu highlands, eastern DRC: (**a**) Terraces, (**b**) Zaï pits, (**c**) ridges, (**d**) mulching, (**e**–**h**) hedges with green manure and forages as implemented by smallholder farmers of Kabare, eastern DRC with a support from UEA scientists under Food Security Project (FSP) in partnership with Mercy Corps, World Vision, HarvestPlus, and Action pour la Paix et la Concorde (APC).

CSA practices in crop production identified in DRC include also the use of crop rotation, fallow practice, bio-fertilizers, bio-pesticides, mulching, different crop varieties, crop diversification, adjusting planting dates, and strengthening nonfarm activities as a climate change resilience strategy [4,62,65,78]. For example, mixed cropping systems based on maize and peanuts; cassava, peanuts and maize; banana, maize and peanuts; pumpkin, coffee, or cocoa are performed in Kisangani, north-eastern DRC. According to Mugisa [63], the cultivation of maize associated with peanut at spacing of 1.30 m $\times$ 0.25 m for maize and 0.30 m $\times$ 0.15 m for peanuts recorded up to 69% increase in yield in maize compared to the monoculture of maize in the region of Kisangani. This implied that maize benefit from the association, especially high-density spacing treatments. More other positive effects of crop associations have been demonstrated in a series of studies conducted by Ndjadi et al. [62] in South-Kivu while using the permagarden farming approaches.

Promotion of multiple stress-resistant cultivars of crops such as cassava, common bean, rice, maize, cowpea, and groundnut is another climate-resilient strategy used by farmers and farmer-support structures in DRC to secure better yields and support household food security in the face of climate change. Since irrigation is rarely performed by farmers (except in vegetable production) due to lack of appropriate equipment, high cost, and sometimes due to marginal topography; soil and water conservation practices, including Zai, tied ridges, mulching, crop associations, etc., have been tested in semi-arid areas of the country (mainly in the Ruzizi Plain), in addition to drought-resistant cultivars, to adapt to water-scarce conditions, currently exacerbated by climate change [21,45]. An initiative by DRC's PANA-ASA project (*Adaptation du Secteur Agricole au changement climatique*) has been strengthening farmers' resilience to climate change by promoting better seeds in eastern Kasaï, Bandundu, Bas Congo, and Katanga since 2010 [70]. Crop diversification through promotion of neglected and underutilized crops is being encouraged in eastern DRC since these represent a valuable strategy for increasing the resilience of farmers to climate change [64]. However, such effort is being challenged by the absence of improved varieties for such crops and the lack of a functional seed delivery system.

4.1.3. Livestock and Aquaculture

Efforts to promote CSA practices in the livestock production sector target to mainly enhance the meat and milk production, and to ensure better animal nutrition using environmentally friendly approaches. Some of these approaches include introducing high-value species or crossbreeding with locally adapted breeds. For instance, farms of nearly 100,000 hens cover a good part of the Kinshasa market, at the same time numerous farms having between 1000 to 5000 hens are established for breeding for improved laying hens [71]. The local cattle breeds that are exploited in the regions of North-Kivu (Beni, Lubero, Walikale, Rutshuru, and Masisi) and South-Kivu are adapted to their environment but show poor dairy performance. Breeders have been crossing them with exotic bulls with better milk potential [72]. Currently, crop-livestock, crop-aquaculture, or crop-livestock-aquaculture practices are being encouraged in eastern DRC. Several efforts to improve livestock nutrition through better pastures are undergoing in eastern DRC.

4.1.4. Food Energy Systems

Though less expanded, there are initiatives that can be clustered under "Food energy systems" theme. These include the biogas production and improved cookstoves that are promoted by UEA under "Projet Environnement" in eastern DRC. The solar energy is also gaining pace and increasingly used in farms in remote areas where electricity is difficult to access [73,74].

No record exists for CSA practices under the post-harvest management theme. Efforts are, therefore, necessary to identify techniques already in use by farmers for conservation, to assess their effectiveness and to suggest improvements.

4.2. Institutions and Finance for CSA

The National Institute of Agricultural Studies and Research (INERA) partners with the Ministry of Agriculture, high education institutions, United Nations' agencies such as the Food and Agriculture Organization (FAO), local and international non-governmental organizations (NGOs), and community-based organizations of smallholder farmers to implement and promote agricultural innovations. However, there are a few, albeit limited, examples of projects that seek to promote CSA practices implemented or tested in DRC. These projects are limited in scale owing to little systematic investment or coordination across ministries and intervening stakeholders [7,16].

For example, the government developed a profile of projects supporting the recovery of the agricultural and rural sectors in the context of its initiative on "*Environmental Awareness for the Agricultural and Rural Population*". The initiative "*an effort to raise awareness of cultural practices found harmful to biodiversity*" was carried out in the former provinces of Bas-Congo and Bandundu in the south-western DRC. Among projects implemented in DRC, few aimed at addressing the gender inequalities in agriculture through CSA. Another project is the UN Women's CSA initiative that had four specific objectives: (i) Ensuring sustainable and secured access to land; (ii) improving women's access to technology and information by facilitating digital platforms for women and real-time agricultural data; (iii) improving women's access to funding, credit and investments; and (iv) increasing women farmers' access to markets by supporting them to form cooperatives and strengthening their capacity to participate in the green value chain meaningfully. The GEF-LDCF (Groupe de Recherche et Echange Technologique) funded a project, *Building Adaptive Capacity and Resilience of Women and Children in the Democratic Republic of the Congo*, supporting women and children through a community-centered approach to adopting and adapting livelihood strategies in innovative ways, based on current and future climate change scenarios. The FAO has also been implementing and sponsoring CSA practices in DRC [7].

As mentioned in previous sections, the project PANA-ASA initiated activities aimed at deploying quality seeds of water stress resistant varieties of staple crops such as maize, common beans, and soybean to enhance the household's livelihood through better yields, and food security, especially in the regions around Lubumbashi City. Its activities were also extended to areas where INERA, in partnership with the International Institute of Tropical Agriculture (IITA), played the role of a research partner [16]. These areas included four sites within four former provinces of DRC (Eastern Kasaï, Bandundu, Bas-Congo, and Katanga).

Agroforestry project around Kisangani in North-East of DRC is ongoing. In the city of Kisangani, the European Union project, namely FORETS project (FOrmation, Research, Environment in TShopo) is designed as a substantial contribution to integrated landscape development. It includes the Yangambi Biosphere Reserve in DRC. The project focuses on the conservation and enhancement of biodiversity and ecosystem services to contribute to the sustainable development of local populations (https://www.cifor.org/knowledge/project/PMO-1343, accessed on 27 December 2021). The activities defined on the Yangambi–Kisangani axis in Tshopo Province concern the support to local communities through awareness-raising, extension, and supervision. They also strengthen national human resources, mainly through formal training (Master of Science and doctoral programs in Sustainable Biodiversity and Natural Resources Management) at the University of Kisangani. The Centre for International Forestry Research (CIFOR) and the Norwegian Agency for Development Cooperation (NORAD) support all research implemented. A project in Lubumbashi (Southern DRC) focusing on agroforestry is being implemented by GRET (Groupe de Recherche et Echange Technologique). The aim is to regenerate the Miombo forest while achieving food security and wealth for the farmers' households [7]. The Regional Universities Forum for Capacity Building in Agriculture (RUFORUM), an organization of more than 140 African universities, has recently helped launching a Ph.D. program in Agroecology and Climate Sciences at a consortium of four Congolese universities UEA-UCB-UOB-UCG, to boost research and training on sustainable farming production in DRC. Other organizations involved in CSA practices in DRC are presented in Supplementary Table S3.

However, reports (e.g., [70]) showed that most of these CSA initiatives suffer from the lack of sufficient financial supports and governmental incentives for scaling-up. Fundraising, sufficient public budgets, and conducive policies are necessary to ensure a wide promotion of CSA practices across different agroecologies of DRC.

5. Conclusions and Recommendations

DRC has examples of both traditional and research-based agricultural practices that can be deemed climate-smart, but they are not mainstreamed. Such practices include those clustered under agronomy, agroforestry, livestock and aquaculture, and energy systems categories. No practice related to the post-harvest management theme was inventoried from consulted literature (Supplementary Table S4). Generally, barriers to wide use/dissemination of CSA practices seem to be linked to low governmental investment, lack of technical supervision, and weakness of extension services and farmer-support structures. A faulty agricultural extension services is due to several causes: shortage of qualified staff, lack of facilities and mobility means, low budget, dominance by old staff, and more importantly a limited awareness of the extension officers on CSA practices and technologies. Consequently, there is inability of such services to scale-up innovative technologies at the village level. Therefore, there is a need for coordinated efforts among stakeholders (from governmental and non-governmental sectors) to ensure CSA practices are disseminated to end-users across the country and that enabling policies are elaborated by concerned agencies. By that way, CSA would help improve the population livelihoods by increasing agricultural productivity, rural incomes, and growth, and subsequently alleviating hunger and poverty under the context of climate change. The government of DRC should set policy frameworks that effectively incentivize CSA and emphasize on building the capacity of its extension workers, producers, and other stakeholders in the use of CSA technologies. Higher education institutions' curricula should also be revised accordingly to meet current needs under climate change. The current courses with themes aligning with CSA and the capacity building gaps for future interventions are provided at Supplementary Tables S5 and S6. These could be useful as entry points to promote CSA practices in DRC. Among these research and training gaps are the inclusion of Information and Communications Technology (ICT) in CSA practices dissemination; climate information service and real-time agricultural data; capacity building on the elaboration of effective CSA and CIS-specific policies; assessment of carbon sequestration and greenhouse gas emission (carbon footprint) potential by different agro-ecologies, farming systems and land-uses; digital-based platforms for plant and animal disease monitoring and control; etc.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/land11101850/s1. Table S1: CSA practices undertaken by farmers in DRC as adaptation and mitigation strategies. Table S2: CSA practices in eastern DRC by UEA staff members. Table S3: Organizations involved in CSA in eastern DRC. Table S4: Most relevant documentation on CSA in DRC. Table S5: Courses referring to CSA practices at undergraduate level at the Faculty of Agriculture of UEA. Table S6: Training gaps on CSA and CIS in DRC.

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