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OPINION

Advancing breeding for climate-resilient yam production in Côte d'Ivoire

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Societal Impact Statement

Yam plays an important role in ensuring food security in Côte d'Ivoire, serving as a staple crop for 60% of the population and a significant source of income. It holds deep cultural significance for the Akan and Gour ethnic groups. Preserving yam production is essential for both food security and the preservation of cultural heritage. However, productivity is decreasing while demand is expected to double in the next 30 years. Soil degradation and climate change are major threats to yam production. This article contextualizes the main factors threatening yam production (i.e., soil degradation and climate change) and discusses the consequences and ways to mitigate them.

Summary

The anticipated twofold increase in Côte d'Ivoire's population within the next three decades poses a significant challenge for agricultural research to sustain food security. Despite being an under-researched and often neglected crop, yam remains the primary staple food and a crucial source of income in the country. With an annual estimated market value of over 2000 billion CFA francs, yam ranks among the top five most economically valuable crops in Côte d'Ivoire. For the past 15 years, yam production has experienced a decline in productivity, which has been compensated for by expanding the cropped area. Unfortunately, this approach exacerbates the risk of deforestation and soil degradation. Additionally, the impact of climate change on yam production, coupled with a lack of financial resources to address it, has rendered this unsustainable mode of production even more precarious. The purpose of this study is to provide an overview of the effects of climate change on yam production in Côte d'Ivoire. We investigated the reasons for the productivity decline and described the risks on food security. Furthermore, we explained how varietal innovation of *Dioscorea alata* could play a critical role in mitigating these effects and outlined related research avenues that need to be explored. To help policymakers and research programme directors justify the importance of this agenda, this article presents the main arguments in favour of a substantial investment in adapting yam production to the global changes affecting Côte d'Ivoire.

KEYWORDS
Côte d'Ivoire, crop, food security, global change, livelihoods, neglected and underutilized species, West Africa, yam (*Dioscorea* spp.)

1 | INTRODUCTION

In the context of rapid population growth, West Africa food security remains a major cross-sectoral issue (IFPRI, 2022). This concern is reinforced by the uncertainty of the international situation due to the war in Ukraine and its consequences, in particular, the soaring price of gas, fertilizer and cereals. Shortages of basic products will have dramatic consequences at several levels (episodes of famine, emergence of diseases, political instability and exodus of the most affected populations). Furthermore, climate change, as recently documented by IPCC expert reports, will lead to a reduction in crop yields under any scenario, even though agriculture is considered the backbone of the African economy (IPCC, 2022).

Yam is an important food crop for more than 13 countries in the intertropical zone (i.e., more than 40 kg per capita per year) with a total population of more than 300 million (Figure 1; FAOSTAT, 2022). Most of these countries are in Africa, the Caribbean and the Pacific. However, yam production is dominant in West Africa, where it is an important crop for food and nutrition security and income generation. From the field, where its distinctive mounds rise from the soil (Figure 2), to the plates of urban dwellers, Côte d'Ivoire has the highest per capita production of yam in the world (FAOSTAT, 2022). This crop is an integral part of both rural and urban life (Monney et al., 2009; Stessens et al., 1998). Its consumption dates back more than 5000 years (Coursey, 1976). However, the current regional trend shows a significant decrease in yam productivity. Far from the hoped-for resilience, yields have been declining for 15 years (Danquah et al., 2022) and climate change is disrupting actual practices and threatening future harvests (Bakayoko et al., 2017).

Based on public agricultural and food databases and targeted bibliographic reviews, this paper highlights the essential role of yam in Côte d'Ivoire, both in terms of food security and socio-economic status and the non-negligible risk associated with current trajectories and projections (i.e., demographic and climatic). From these observations, investment avenues are proposed to reduce the technological and knowledge gaps necessary to maintain food security in Côte d'Ivoire.

2 | YAM A MULTIPURPOSE CROP IN CÔTE D'IVOIRE

2.1 | The ancestral role of yam in Ivorian society

The period at which yam-based agriculture developed in different parts of the world is uncertain because tuber crops such as yams do not leave archaeological evidence of their use (Davies, 1960). However, the collection of wild yams associated with African artefacts dates back to 50,000 BP, while organized yam production based on the selection and protection of natural hybrids at the rainforest/savanna ecotone may have occurred as early as 10,000 to 7000 BP (Coursey, 1972; Davies, 1960).

Among the approximately 600 species in the genus *Dioscorea*, approximately 10 hold significance in the context of food production (Orkwor et al., 1998). In Africa, *D. rotundata* stands out as the primary species and the most substantial contributor to global yam production. Water yam (i.e., *D. alata*), which was most probably domesticated in Asia and Oceania (Sharif et al., 2020), was introduced to Africa around the 16th century. While indigenous *D. rotundata* is preferred in West Africa due to its higher tuber quality (Wireko-Manu et al., 2011), *D. alata* is more ubiquitous and productive (Diby et al., 2011; Takada et al., 2017). Interestingly, Côte d'Ivoire is the only country in West Africa where yam production is based almost equally on the two species *D. alata* and *D. rotundata*. The underlying reasons for the prevalence of *D. alata* in Côte d'Ivoire lack consensus (Thiele et al., 2021). Bakayoko et al. (2021) have postulated that the extensive adoption of *D. alata* cultivation in the country is attributable to its ease of propagation, rapid growth, which allows it to outcompete weeds, consistent yields across varying soil fertility and ecological conditions, and extended post-harvest tuber storage capabilities.

Currently, about 60% of the Ivorian population consumes yam as a staple food (INS, 2021). Yam cultivation is an integral part of the life and subsistence of the Akan (e.g., Baoulé, Brong, Agni) and Gour (e.g., Sénoufo, Lobi, Koulango) peoples encompassing over 55% of Côte d'Ivoire's population (Bado, 2017). These people live mainly from the cultivation and consumption of yams, the marketing of which generates substantial income. For instance, among the Gour people, who constitute 22% of the Ivorian population, yam stands as the principal cash crop. Prominent cultivars include Kponan, Sopèrè, Kpassadjo (early maturing), as well as Krenglè, Bêtê-bêtê and Florido (late maturing). The Akans' social-cultural lifestyle is also heavily dependent on yam cultivation. Most of their production is self-consumed (Chaléard, 1990; Mahyao, 2008). Strongly attached to yam, these peoples have transported this commodity from its traditional areas of cultivation to all the agroecological zones to which they have migrated (Ruf, 2010). This attachment to yam has led to the popular saying in Côte d'Ivoire: 'We are not birds to eat rice' (Ruf, 2010). Akans have thus developed adaptation methods (cultivation practices and varieties) to ensure that their favourite yam is always available.

Culturally, the yam festival holds significant importance as a tribute to the staple that sustains the Ivorian population. Celebrated every year throughout the country (between October and February),

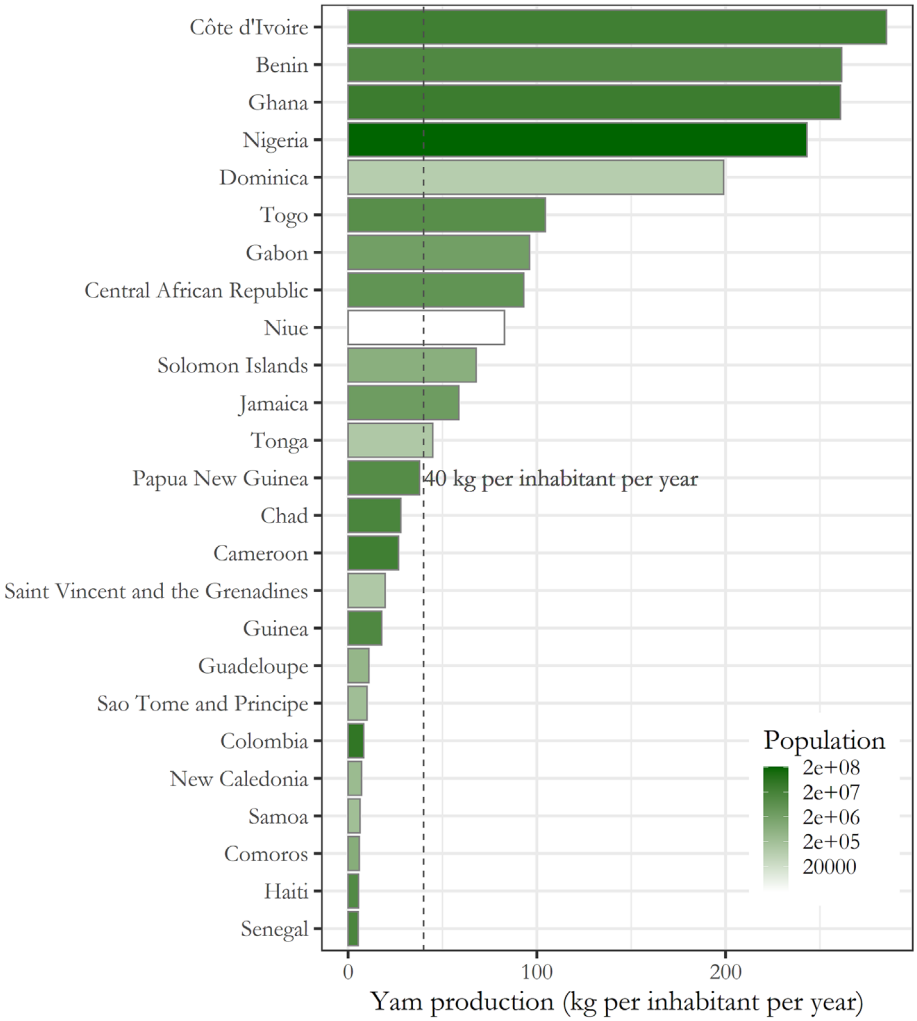

FIGURE 1 Yam production by country presenting more than 5 kg of yam per capita per year (*source*: FAOSTAT, 2022).

FIGURE 2 Traditional land preparation for yam (*Dioscorea* spp.) cultivation in Fo Boure, Benin Republic. © CIRAD, image credit: CIRAD/Denis Cornet.

it allows people from different ethnic groups to congregate in a fraternal way and represents a renewal of identity for the occasion (MTCI, 2020; Perrot, 1998).

2.2 | Major food and nutritional income

Côte d'Ivoire is the third largest producer of yam in the world. With 7,450,467 t produced on 1,349,681 ha in 2019 (FAOSTAT, 2022), yam is the leading food crop, far ahead of cassava (1,036,478 ha), plantain (501,667 ha) and maize (524,224 ha). Côte d'Ivoire is also the country with the highest per capita consumption of yam, exceeding 160 kg per capita per year (Bricas & Attaie, 1998; INS, 2021). While rice takes the lead in providing daily caloric intake at 749 kcal per person, yam follows closely with 524 kcal. It is worth noting that while yam is produced entirely locally, over half of the rice consumed is imported (FAOSTAT, 2022).

Yams are recognized for their substantial nutritional content compared to other tropical root and tuber crops. They contain essential nutrients like starch, proteins, lipids, vitamins and minerals. Water yams, in particular, have notable antioxidants that can reduce inflammation associated with various diseases. These yams are also abundant in potassium and provide key micronutrients like manganese, copper and vitamin C. Their low sodium but high potassium and dietary fibre content suggest potential benefits in preventing chronic diseases (Wireko-Manu et al., 2013). Among root and tuber crops, water yam stands out for its higher mineral and vitamin content, especially its rich protein content; known for their positive physiological effects (Lebot et al., 2023). While storage and preparation methods do influence yam tuber characteristics (Didier et al., 2014; Kouakou Dje et al., 2010), varietal differences are the primary source of variation, offering opportunities for improvement (Lebot et al., 2023; Otegbayo et al., 2018).

Yam tubers are consumed fresh and are usually cooked in water or fried. After boiling, they can be served as porridge, foutou (cooked tubers crushed in a mortar to form a paste) or foufou (cooked tubers crushed to form a puree). There has been limited development in yam processing at the industrial level in Côte d'Ivoire. The production of processed products such as amala (paste made from tuber flour) and wassa-wassa (yam semolina) has not been as successful in Côte d'Ivoire as it has been in Nigeria, Benin, Togo and Burkina Faso (Bricas et al., 1997).

2.3 | Key economic lever for rural populations

Yam is essential not only for socio-cultural traditions and food security but also increasingly as a source of income, whether for local consumption or for export (Doumbia et al., 2006; Mahyao, 2008). Over the past three decades, there has been a notable shift in dietary habits, with yams making inroads into the menus of traditionally non-consuming populations. This evolution is favoured by the meeting of the different populations in large urban centres (Bricas & Attaie, 1998). Today, yam is a cash crop for more than 40% of the population in the main producing regions. For example, the Gours sell more than 90% of their production (Chaléard, 1990; Mahyao, 2008). In Côte d'Ivoire, more than 75% of the yam trade is supplied by *D. rotundata*, while *D. alata*, which is the dominant species in the total national production (estimated at 60%), is mainly consumed by farmers themselves (Doumbia, 1998). Because of their longer shelf-life, *D. alata* varieties are present on the markets long after the harvest period, from January to July. They are also sold as a substitute for the Krenglè variety of *D. rotundata* after May (Doumbia et al., 2006; Girardin, 1996).

In addition to domestic sales, yams are also exported to other countries in the sub-region. During the harvest period, more than 400 t of yams pass through the wholesale market in Bouaké every day, mainly destined for Sahelian countries such as Mali, Burkina Faso and Niger (Figure 3). Furthermore, Côte d'Ivoire has also been exporting yams internationally since 2010, although the quantities remain marginal (i.e., 14,000 t in 2019; FAOSTAT, 2022). In 2022, the estimated market value of the total yam production in Côte d'Ivoire exceeded 2000 billion CFA francs, and it ranks among the top five most economically valuable crops, both in terms of local price and world market value (Figure 4).

3 | A WORRYING EVOLUTION

3.1 | An increasing demand

The population of Côte d'Ivoire was estimated at 29,389,150 in 2021 (ISN, 2021). Over the past 50 years, the rural population has declined from 72% to 48%. This trend towards urbanization is expected to continue in the coming years. The population of West Africa, and Côte d'Ivoire in particular, is expected to almost double in the next 30 years. Population growth and urbanization are likely to increase food demand and food prices, making a shift from cocoa to food crops as sources of income a probable scenario in the future (Wessel & Quist-Wessel, 2015). To meet demand, Côte d'Ivoire will need to increase its production of roots and tubers by 2.12 times by 2050 (IFPRI, 2017). While national figures for Côte d'Ivoire are not available, IFPRI (2022) predicted that the West and Central African countries will move from an export situation to an import situation of roots and tubers by 2050 (net trade of 2.5 and −13.9 Mt, respectively).

3.2 | A declining yield

Although yam production has more than doubled over the last 40 years, this has been mainly achieved by increasing the cultivated area, with significant impact on forests and savannahs (Kouakou et al., 2019; Danquah et al., 2022; Figure 5). Notably, the cocoa-producing regions of Côte d'Ivoire have experienced deforestation and land over-exploitation, leading to permanent soil degradation.

FIGURE 3 Loading a truck with yams tuber at the wholesale market of Bouaké, Côte d'Ivoire. © CIRAD, image credit: CIRAD/Denis Cornet.

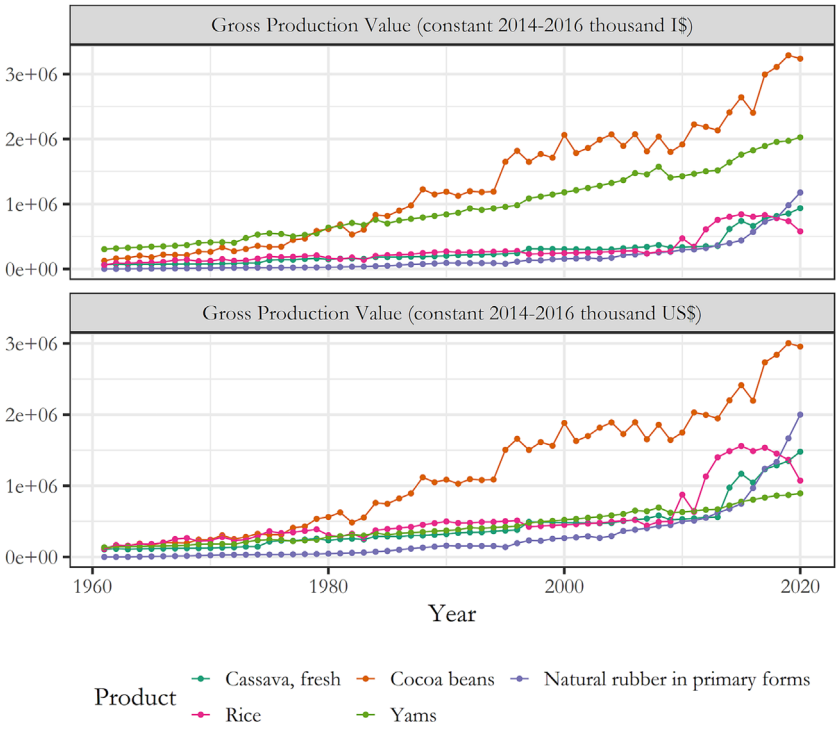

FIGURE 4 Evolution of the five most economically valuable produce in Côte d'Ivoire, both on the basis of the local selling price (lower plot) or the world market (upper plot).

This phenomenon has compelled farmers to constantly look for new and more fertile land to sustain their crop production (Leonard, 1997). During the second half of the 20th century, a strong pioneer front advanced from east to west in Côte d'Ivoire (Gastineau et al., 2017). Consequently, more than half of the total forest cover (57%) was destroyed in a quarter of a century (1990–2015), with an actual annual deforestation rate of 4.95% (Ouattara et al., 2021). It is likely that the increasing scarcity of fertile land and long fallow periods reserved for cash crops (such as cocoa) have favoured the adoption of *D. alata* to the detriment of *D. rotundata*, which is more sensitive to growing conditions.

However, despite deforestation, arable land could become scarce in the short term. Indeed, it is estimated that the amount of land available per person in Côte d'Ivoire has fallen from 0.31 to 0.13 ha per person in 50 years (World Bank, 2022). For yam, this has led to progressive soil degradation and reduced yields (Frossard et al., 2017). As a result, despite its importance, yam productivity in Côte d'Ivoire remains very low, declining from 11 t/ha in 1980 to 6 t/ha in 2020

FIGURE 5 Slash-and-burn of long fallow land before yam soil preparation in Glazoue, Benin Republic. © CIRAD, image credit: CIRAD/Denis Cornet.

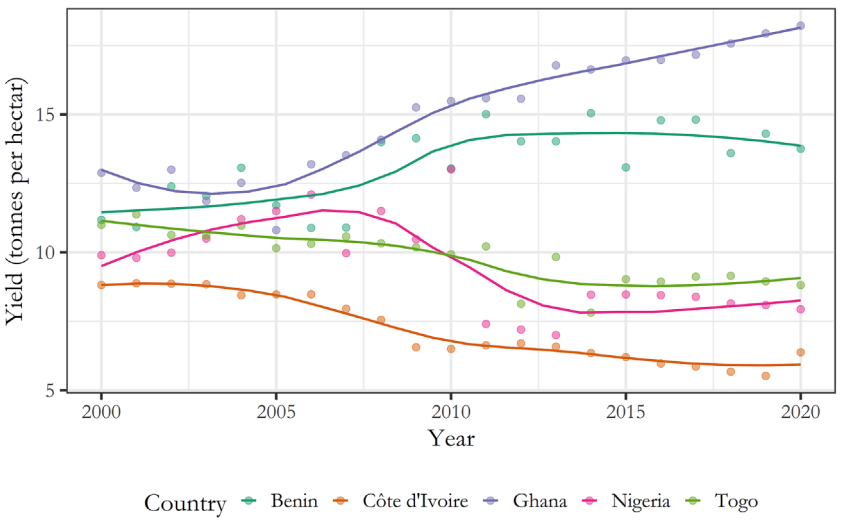

FIGURE 6 Evolution of yam yields over the last 20 years in the five main producing countries.

(FAOSTAT, 2022; Figure 6) and representing only 12.5% of the potential yield (Danquah et al., 2022). If no increase in productivity is achieved, doubling production within 50 years, as projected by ICPP (2022), means finding an additional 1,400,000 ha. For comparison, this represents about half of the remaining forests in the country; a frightening figure given the current rate of deforestation.

3.3 | Observed and projected climate change impact on yam yield

According to the IPCC's (2022) report, climate change is expected to worsen and speed up current patterns worldwide. This will have a particularly detrimental effect on food security in Africa, where over 85% of the impoverished population resides in rural areas and relies on rain-fed agriculture for over 90% of their food (IPCC, 2022). In Africa, for scenarios ranging from a 1 to 4°C increase in global temperatures, the continent's overall gross domestic product (GDP) is expected to decline within a range of 2.25% to 12.12%. By the middle of the century, the main crops will be affected by a yield decline down to 41% for a warming of 1.5°C (Mechiche-Alami & Abdi, 2020). Côte d'Ivoire will be among the 10 most affected countries in Africa, with an 18% decline in GDP per capita due to observed climate change. This actual trend in GDP per capita is expected to worsen to a 90% decrease for a 4°C global warming compared to a no-warming scenario (IPCC, 2022).

The effects of climate change in West Africa are already visible over the last 50 years, with an increase in average temperatures of around 0.2–0.5°C per decade (Ranasinghe et al., 2021) and a trend towards rainfall being more concentrated in the second half of the season (Biasutti, 2019). However, the medium- to long-term evolution of the climate remains highly uncertain. While experts agree on a

strong increase in temperatures in the future, the evolution of precipitation is still debated. Nevertheless, there is a consensus that rising temperatures will have a negative impact on yields due to shortened crop cycles and increased evapotranspiration (Sultan & Gaetani, 2016).

Root and tuber crops are often considered less vulnerable to climate change due to their high optimal temperature range, which favours plant growth (Carr et al., 2022; Jarvis et al., 2012). Unfortunately, systematic assessments of the climate response of root and tuber crops are lacking (Manners & van Etten, 2018; Raymundo et al., 2014) and do not allow for consensus. Thus, yam is mostly negatively affected by climate change in the projections of recent studies (van Zonneveld et al., 2023). In fact, depending on the projection period, climate scenario, modelled process and soil type, yam yield is likely to decrease slightly (between 2% and 5%; Paeth et al., 2008; Lobell et al., 2008; Carr et al., 2022) to severely (−18% to 48%; Srivastava et al., 2012, 2016). However, these yield projections are based on small sample sizes and are therefore more influenced by study-specific factors than other crops. For example, the strong yam yield decrease described by Srivastava et al. (2012, 2016) is associated with declining rainfall, which is highly uncertain in the future scenario in West Africa (Pendergrass et al., 2017). Furthermore, none of the models used specifically considered the phenology of yam and, in particular, its photoperiod sensitivity (Marcos et al., 2011). While shifting, the planting date is often proposed as a solution to compensate for delayed rainfall, the influence of photoperiod on the onset of tuberisation and thus the shortening of the vegetative period is not considered. However, delayed emergence has been shown to reduce yield (Cornet et al., 2014; Marcos et al., 2011). As suggested by Raymundo et al. (2014), there is an urgent need to develop crop models that are sufficiently mechanistic to account for the effects of climate change while taking into account crop specificities. For yam in Côte d'Ivoire, this implies being able to model specifically the influence of dormancy, seed tuber, photoperiodism, mineral nutrition (e.g., nitrogen-potassium ratio) and their effect on source-sink allocation dynamic.

4 | A NEGLECTED CROP WITH HIGH POTENTIAL

In Côte d'Ivoire, importing foods such as rice to improve food availability is not a viable strategy for poor rural households because of the strong connection between international food price increases and local food prices. The continued increase in the share of rice imports reinforces this weakness. Unlike cereals, various root and tuber crops are locally produced, and their prices are not strongly affected by global food price increases (Danquah et al., 2022). This provides an opportunity to improve food availability and accessibility for all, including smallholder farmers. However, indigenous yams (mostly *D. rotundata*) are traditionally grown without fertilizer as the first crop after a long fallow period, accelerating soil degradation and deforestation (Frossard et al., 2017). In this context, *D. alata* appears to offer an opportunity. Research has shown that soil fertility significantly affects yam yields differently, with *D. alata* showing higher yield potential than *D. rotundata*, mostly on more degraded soils (Diby et al., 2009). This difference means that *D. alata* can be integrated into a rotation without the need for systematic slash and burn. It also responds better to fertilizer (Hgaza et al., 2012) or improved soil management option (Frossard et al., 2017; Kassi et al., 2017). Thus, promoting the use of this species could help to maintain or even increase yam production while limiting new land clearance and environmental impacts.

However, high-yielding and disease-tolerant water yam varieties have not been widely adopted. Thiele et al. (2021) showed that the seed system was not the main barrier to their adoption, and illustrated this with the rapid adoption of the Florido and C18 varieties (Walker et al., 2015). On the other hand, the quality of yam-based dishes such as 'foutou' plays an important role in technology adoption in West Africa, as both producers and consumers place high value on food quality (Thiele et al., 2021). Although water yam is known to produce tubers of inferior quality, less suitable for the preparation of products valued by consumers, some of its varieties appear to achieve a quality similar to that of *D. rotundata*. For example, in Côte d'Ivoire, it has been suggested that the success and rapid adoption of C18, a water yam cultivar introduced from Cameroon, was due to its ability to produce an appreciated pounded yam (Kouakou et al., 2012). Walker et al. (2015) argued that the importance of consumer preferences has not been given sufficient attention in breeding programmes, which are poorly equipped to address such preferences. For root and tuber crops, this situation has recently changed thanks to the Bill and Melinda Gates Foundation (BMGF) RTBfoods project (https://rtbfoods.cirad.fr/), which enabled the development of high-throughput phenotyping methods for quality traits, opening up the possibility of improving tuber quality in water yam.

Yam is considered a neglected crop by the African Orphan Crops Consortium and Bioversity International (Hendre et al., 2019; Ulian et al., 2020). A recent study confirmed that yam is severely underresearched in West Africa compared to its actual and projected importance (Manners & van Etten, 2018). Moreover, research funding for yam remains low in Côte d'Ivoire and other West African countries, despite the projected impact of climate change on its production. For instance, although rice, sugarcane and yam together account for 27% of the total cultivated area in Africa, they account for only 6 out of 162 observations in the scientific literature on the impact of climate change on crop yields in Africa (Knox et al., 2012). Increased investment to accelerate crop productivity growth in low- and middle-income countries can have a large impact on key development indicators (Wiebe et al., 2021). According to Lobell et al. (2008), a sub-Saharan African institution wishing to mitigate the negative impacts of climate change should prioritize investment in West African yams. For example, faster productivity growth in rice, yam and sorghum is estimated to increase economy-wide income in West African countries by $6.26 billion, $4.83 billion and $4.75 billion, respectively, in 2030 (reflecting the scale of their production and consumption). However, of the $620 million earmarked for climate change research in Africa between 1990 and 2020, $480 million went to research institutions in Europe and the United States, and only $89.15 million to

those in Africa. This represents only 3.8% of global funding for climate-related research—a figure that does not reflect Africa's high vulnerability to climate change (Overland et al., 2022). Most of the funding for Africa-related climate research comes from outside Africa and goes to research institutions outside Africa (ICPP, 2022).

According to a recent IFPRI report on Agricultural Science and Technology Indicators, Côte d'Ivoire's agricultural research spending has significantly improved the number and skill level of Ivorian agricultural researchers in recent years, both in the government sector and in higher education (Domgho et al., 2018). Between 2012 and 2016, the national agricultural research capacity increased by around 80 Ph. D. scientists. However, the pattern of agricultural research expenditure over the last decade shows a stagnating trend. In 2016, the country invested only 0.50% of its GDP in agricultural research. Low funding for the promotion of neglected and under-researched crops such as yams is therefore a major challenge for most countries that rely on them for food security and income (Ulian et al., 2020).

5 | CONCLUSION AND PERSPECTIVES

Improving yam production will have a significant positive impact on the lives of farmers and communities in West Africa, particularly in Côte d'Ivoire. However, current national resources may not be up to the challenge. Massive structural (e.g., human resources, laboratory and field equipment) and project-based investments are therefore needed. This is all the more necessary as current production, which is already declining due to soil fertility, is severely threatened by the effects of climate change. While the entire value chain needs to be considered, from the current situation, two main avenues could help achieve this goal: breeding new yam varieties with desirable traits and implementing best practices in planting, irrigation, fertilization and pest management. Recent studies along a latitudinal gradient representative of future changes in temperature and rainfall showed that tested improved agricultural practices alone could not mitigate the influence of climate on yam yield (Alabi et al., 2019; Pouya et al., 2022).

Therefore, breeding new yam varieties with desirable traits such as high yield, disease resistance, longer shelf-life and tolerance to environmental stresses (e.g., drought, marginal soils or heat) is seen as a major lever to raise yields, improve farmers' incomes and ensure food security (Agre et al., 2022). Among yam species, *D. alata* has a higher yield capacity and environmental adaptability than other species and could therefore be privileged to improve food security and income generation under future climate change (Bredeson et al., 2022; Hamaoka et al., 2022). As more than half of the national production is already based on this species, Côte d'Ivoire could play a central role in its improvement. The *D. alata* germplasm collection held by the CNRA provides a solid basis for initiating work on variety improvement in the face of climate change (Bakayoko et al., 2021). In addition, the latitudinal gradient present in Côte d'Ivoire is representative of the target population of environments (Alabi et al., 2019), making it possible to anticipate climate change and its management by farmers. A study on traditional varieties grown in the driest areas could make it possible to identify adaptive traits in relation to high temperature increases or changes in the rainy season. As mentioned above, crop modelling should be used to refine the definition of adapted ideotypes and key traits.

Furthermore, *D. alata* was clonally introduced into Africa, which explains the narrow genetic base of African cultivars (Lebot et al., 1998). It is therefore important to broaden the genetic diversity by introducing new cultivars from the area of origin of this species, and genetic material exchange is crucial for significant progress in breeding programmes. However, yam exchange is challenging due to virus susceptibility and complex sanitation procedures (Diouf et al., 2022). Although virus elimination and quarantine remain options for biosecurity, lyophilization offers a practical way of storing yam pollen samples, facilitating safe exchange and enhancing genetic diversity for accelerated genetic gains in breeding programmes (Malédon et al., 2023). It would be helpful for yam breeders to also continue to investigate the potential for interspecific hybridization between *D. alata* and some of the other cultivated species. Similarly, the use of wild relatives could increase the resilience of varieties by introgressing genetic factors that contribute to greater environmental tolerance (Satori et al., 2021). For this, it is essential to continue research on the wild relatives of *D. alata*, which are still unknown to date (Sharif et al., 2020).

Climate change adaptation traits, especially water and heat stress, yield and quality traits, are polygenic and difficult to improve using conventional breeding methods. Consequently, new technologies and breeding strategies are needed to significantly increase the rate of genetic gain needed to meet these challenges. Thanks to the BMGF projects, much effort has been made in recent years to intensify the improvement of yam varieties in West Africa. Since 2014, the AfricaYam project has specifically focused on improving the efficiency of yam breeding programmes through the use of faster and more accurate phenotyping tools and breeding methods (https://africayamphase2.com/). To accelerate the impact of these projects on the release of improved varieties, it is now necessary to implement the methods and knowledge gained in the national programmes. Despite its participation in the BMGF's yam initiatives (AfricaYam and RTBfoods projects), Côte d'Ivoire could have benefited more from the technology advancements predominantly oriented towards CGIAR and English-speaking nations. For example, tuber quality phenotyping is mainly based on near-infrared spectroscopy developed by and within the international research system. According to Overland et al. (2022), former British colonies in Africa receive more research funding than other African countries. These situations emphasize the necessity to broaden the scope of climate change research in Africa and increase funding for African researchers. Doing so will enhance African participation in research and enable the development of climate change solutions that are more relevant to African contexts.

To meet this challenge, it is imperative that Ivorian agricultural research, led by the CNRA and the universities, incorporate scientific and technological advances into its yam breeding programme. This must include capacity building in phenotyping and genomic and phenomic selection. This means improving both the equipment (e.g., crop

canopy monitoring using unmanned aerial vehicles equipped with hyperspectral or thermal sensors, tuber quality phenotyping facilities) and the capacity to analyse the data generated (e.g., image analysis, near infrared spectroscopy signal processing, phenotypic prediction based on genotyping data). Ivorian national research will have to meet these objectives in the coming years in order to maintain or improve national production and food security.

AUTHOR CONTRIBUTIONS

Denis Cornet, Amani Michel Kouakou, Hana Chair, Komivi Dossa and Konan Evrard Brice Dibi conceived and edited the manuscript. Denis Cornet, Amani Michel Kouakou, Gemma Arnau, Adou Emmanuel Ehounou and Konan Evrard Brice Dibi analysed the data. All authors contributed to the writing of the manuscript.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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REFERENCES

Agre, A. P., Mondo, J., Edemodu, A., Matsumoto, R., Asiedu, R., Akoroda, M. O., Bhattacharjee, R., Gedil, M., Adebola, P., & Asfaw, A. (2022). Breeding for abiotic stress resistance in yam (*Dioscorea* Spp.) using biotechnology approaches: present practices and prospects. In C. In Kole (Ed.), *Genomic designing for abiotic stress resistant technical crops* (pp. 429–457). Springer International Publishing. https://doi.org/10.1007/978-3-031-05706-9_11

Alabi, T. R., Adebola, P. O., Asfaw, A., De Koeyer, D., Lopez-Montes, A., & Asiedu, R. (2019). Spatial multivariate cluster analysis for defining target population of environments in West Africa for yam breeding. *International Journal of Applied Geospatial Research*, *10*(3), 1–30. https://doi.org/10.4018/IJAGR.2019070104

Bado, A. (2017). Democracy in conflicting ethnic pluralism: Two Tales of success and failure in Ghana and Côte D'Ivoire. https://doi.org/10.2139/ssrn.2892738. Accessed November 2023.

Bakayoko, G. A., Kouamé, K. F., & Boraud, N. K. M. (2017). Culture de l'igname au Centre-Est de la Côte d'Ivoire: Contraintes, caractéristiques sociodémographiques et agronomiques. *Journal of Applied Biosciences*, *110*, 10701–10713. https://doi.org/10.4314/jab.v110i1.1

Bakayoko, L., Pokou, D. N., Kouassi, A. B., Agre, P. A., Kouakou, A. M., Dibi, K. E. B., Nzue, B., Mondo, J. M., Adebola, P., Akintayo, O. T., Asfaw, A., & N'Guetta, A. S. P. (2021). Diversity of Water yam (*Dioscorea alata* L.) accessions from Côte d'Ivoire based on SNP markers and agronomic traits. *Plants*, *10*(12), 2562. https://doi.org/10.3390/plants10122562

Biasutti, M. (2019). Rainfall trends in the African Sahel: Characteristics, processes, and causes. *Wiley Interdisciplinary Reviews: Climate Change*, *10*(4), e591. https://doi.org/10.1002/wcc.591

Bredeson, J. V., Lyons, J. B., Oniyinde, I. O., Okereke, N. R., Kolade, O., Nnabue, I., Nwadili, C. O., Hřibová, E., Parker, M., Nwogha, J., Shu, S., Carlson, J., Kariba, R., Muthemba, S., Knop, K., Barton, G. J., Sherwood, A. V., Lopez-Montes, A., Asiedu, R., … Rokhsar, D. S. (2022). Chromosome evolution and the genetic basis of agronomically important traits in greater yam. *Nature Communications*, *13*(1), 2001. https://doi.org/10.1038/s41467-022-29114-

Bricas, N., & Attaie, H. (1998). La consommation alimentaire des ignames. Synthèse des connaissances et enjeux pour la recherche. In J. Berthaud, N. Bricas, & J. L. Marchand (Eds.), *L'igname, plante séculaire et culture d'avenir: actes du séminaire international, 3–6 juin 1997*. ORSTOM, CIRAD, INRA, CORAF. ISBN 2–87614–313-5

Bricas, N., Vernier, P., Ategbo, E. A., Hounhouigan, J. D., Mitchikpe, E. C., Etoudo, N. K., & Orkwor, G. (1997). Le développement de la filière cossettes d'igname en Afrique de l'Ouest. *Les Cahiers de la Recherche développement*, *44*, 100–114. Accessed September 2023.

Carr, T. W., Mkuhlani, S., Segnon, A. C., Ali, C., Zougmoré, R., Dangour, A. D., Green, R., & Scheelbeek, P. (2022). Climate change impacts and adaptation strategies for crops in West Africa: A systematic review. *Environmental Research Letters*, *17*, 053001. https://doi.org/10.1088/1748-9326/ac61c8

Chaléard, J. L. (1990). Croissance urbaine et dynamisme rural: l'igname des Lobi (Côte d'Ivoire). In C. Blanc-Pamard, P. Bonnefond, P. Couty, V. Lassailly-Jacob, J.-Y. Marchal, & F. Piton (Eds.), *Dynamique des systèmes agraires: la dimension économique* (pp. 129–147). ORSTOM. (Colloques et Séminaires). Séminaire Dynamique des Systèmes Agraires, 4., Paris (FRA), 1987. ISBN 2–7099–0989-8

Cornet, D., Sierra, J., Tournebize, R., & Ney, B. (2014). Yams (*Dioscorea* spp.) plant size hierarchy and yield variability: Emergence time is critical. *European Journal of Agronomy*, *55*, 100–107. https://doi.org/10.1016/j.eja.2014.02.002

Coursey, D. G. (1972). *The origins and domestication of yams in Africa*. Wenner Gren Foundation for Anthropological. Research, Burg Wartenstein Symp. No. 66. The Origin of African Plant Domesticates.

Coursey, D. G. (1976). The origins and domestication of yams in Africa. In J. R. Harlan (Ed.), *Origins of African domestication* (pp. 383–408). Mouton Publisher.

Danquah, E. O., Danquah, F. O., Frimpong, F., Dankwal, K. O., Weebadde, C. K., Ennin, S. A., Asante, M. O. O., Brempong, M. B., Dwamena, H. A., Addo-Danso, A., Nyamekye, D. R., Akom, M., & Opoku, A. Y. (2022). Sustainable intensification and climate-smart yam production for improved food security in West Africa: A review. *Frontiers in Agronomy*, *4*, 858114. https://doi.org/10.3389/fagro.2022.858114

Davies, O. (1960). The neolithic revolution in tropical Africa. *Transactions of the Historical Society of Ghana*, *4*(2), 14–20. https://www.jstor.org/stable/41405727, accessed September 2023

Diby, L., Hgaza, V. K., Tié, T. B., Assac, A., Carsky, R., Girardin, O., & Frossard, E. (2009). Productivity of yams (*Dioscorea* spp.) as affected by soil fertility. *Journal of Animal and Plant Sciences*, *5*, 494–506. accessed on September 15th 2023.

Diby, L. N., Tie, B. T., Girardin, O., Sangakkara, R., & Frossard, E. (2011). Growth and nutrient use efficiencies of yams (*Dioscorea* spp.) grown in

two contrasting soils of West Africa. *International Journal of Agronomy*, 2011, 175958. https://doi.org/10.1155/2011/175958

Didier, A. C., Hubert, K. K., Djè, K. M., Koné, F. M., Yapi, A. Y. D., Kouadio, J. P. N., & Kouamé, L. P. (2014). Assessment of some antinutritional compounds and some organic acids of "bete-bete" yam (*Dioscorea alata*) tubers as influenced by boiling times. *Asian Journal of Applied Sciences*, *2*, 494–504. accessed September 2023

Diouf, M. B., Festus, R., Silva, G., Guyader, S., Umber, M., Seal, S., & Teycheney, P. Y. (2022). Viruses of yams (*Dioscorea* spp.): Current gaps in knowledge and future research directions to improve disease management. *Viruses*, *14*(9), 1884. https://doi.org/10.3390/v14091884

Domgho, L. V. M., Doumbia, S., & Stads, G. J. (2018). *Côte d'Ivoire: ASTI–CNRA fFiche d''information 2018*. Institut international de recherches sur les politiques alimentaires et Centre National de la Recherche Agronomique (Eds.). https://www.asti.cgiar.org/sites/default/files/pdf/C%C3%B4ted%E2%80%99Ivoire-Fr-Factsheet-2018.pdf. Accessed April 2023.

Doumbia, S. (1998). Les systèmes de culture à base de plantes à racines et tubercules: Cas de l'igname. *Revue Technique d'informations Agricoles de l'Association Des Sciences Agronomiques*, *6*, 285–290.

Doumbia, S., Touré, M., & Mahyao, A. (2006). Commercialisation de l'igname en Côte d'Ivoire: état actuel et perspectives d'évolution. *Cahiers Agriculture*, *15*, 273–277. https://revues.cirad.fr/index.php/cahiers-agricultures/article/view/30586. Accessed September 2023.

FAOSTAT. (2022). *Food and agriculture Organization of the United Nations. FAOSTAT statistical database*. FAO. Accessed December 2022.

Frossard, E., Aighewi, B. A., Aké, S., Barjolle, D., Baumann, P., Bernet, T., Dao, D., Diby, L. N., Floquet, A., Hgaza, V. K., Ilboudo, L. J., Kiba, D. I., Mongbo, R. L., Nacro, H. B., Nicolay, G. L., Oka, E., Ouattara, Y. F., Pouya, N., Senanayake, R. L., … Traoré, O. I. (2017). The challenge of improving soil fertility in yam cropping Systems of West Africa. *Frontiers in Plant Science*, *8*, 1953. https://doi.org/10.3389/fpls.2017.01953

Gastineau, B., Gibigaye, M., Kosmowski, F., Adjamagbo, A., & Houngbégnon, T. (2017). Chapter 11. Rural populations faced with environmental hazards: African experiences. In B. Sultan, R. Lalou, M. A. Sanni, A. Oumarou, & M. A. Soumaré (Eds.), *Rural societies in the face of climatic and environmental changes in West Africa*. IRD Éditions. https://doi.org/10.4000/books.irdeditions.12361

Girardin, O. (1996). *Technologie après-récolte de l'igname: étude de l'amélioration du stockage traditionnel en Côte d'Ivoire*. PhD Thesis. Ecole Polytechnique Federale Zurich. 145p.

Hamaoka, N., Moriyama, T., Taniguchi, T., Suriyasak, C., & Ishibashi, Y. (2022). Identification of phenotypic traits associated with tuber yield performance in non-staking cultivation of water yam (Dioscorea alata L.). *Agronomy*, *12*(10), 2323. https://doi.org/10.3390/agronomy12102323

Hendre, P. S., Muthemba, S., Kariba, R., Muchugi, A., Fu, Y., Chang, Y., Song, B., Liu, H., Liu, M., Liao, X., Sahu, S. K., Wang, S., Li, L., Lu, H., Peng, S., Cheng, S., Xu, X., Yang, H., Wang, J., … Jamnadass, R. (2019). African orphan crops consortium (AOCC): Status of developing genomic resources for African orphan crops. *Planta*, *250*(3), 989–1003. https://doi.org/10.1007/s00425-019-03156-9

Hgaza, V. K., Diby, L. N., Oberson, A., Tschannen, A., Tié, B. T., Sangakkara, U. R., Aké, S., & Frossard, E. (2012). Nitrogen use by yam as affected by mineral fertilizer application. *Agronomy Journal*, *104*, 1558–1568. https://doi.org/10.2134/agronj2011.0387

IFPRI. (2017). *2017 global food policy report: Climate change and food systems* (p. 148). International Food Policy Research Institute. https://doi.org/10.2499/9780896294257

IFPRI. (2022). *2022 Global Food Policy Report: Climate Change and Food Systems* (p. 189). International Food Policy Research Institute: Washington, DC. https://doi.org/10.2499/9780896294257

INS. (2021). Recensement Général de la Population et de l'Habitat (RGPH) 2021: Résultats globaux, Rapport final (p. 37). Ministère de l'Economie, du Plan et du Développement. https://plan.gouv.ci/assets/fichier/RGPH2021-RESULTATS-GLOBAUX-VF.pdf, Accessed September 2023.

IPCC. (2022). In H. O. Pörtner, D. C. Roberts, M. Tignor, E. S. Poloczanska, K. Mintenbeck, A. Alegría, M. Craig, S. Langsdorf, S. Löschke, V. Möller, A. Okem, & B. Rama (Eds.), *Climate change 2022: Impacts, adaptation, and vulnerability. Contribution of working group II to the sixth assessment report of the intergovernmental panel on climate change* (p. 3056). Cambridge University Press. https://doi.org/10.1017/9781009325844

Jarvis, A., Ramirez-Villegas, J., Campo, B. V. H., & Navarro-Racines, C. (2012). Is cassava the answer to African climate change adaptation? *Tropical Plant Biology*, *5*(1), 9–29. https://doi.org/10.1007/s12042-012-9096-7

Kassi, S.-P. A. Y., Koné, A. W., Tondoh, J. E., & Koffi, B. Y. (2017). *Chromoleana odorata* fallow-cropping cycles maintain soil carbon stocks and yam yields 40 years after conversion of native- to farmland, implications for forest conservation. *Agriculture, Ecosystems & Environment*, *247*, 298–307. https://doi.org/10.1016/j.agee.2017.06.044

Knox, J., Hess, T., Daccache, A., & Wheeler, T. (2012). Climate change impacts on crop productivity in Africa and South Asia. *Environmental Research Letters*, *7*, 034032. https://doi.org/10.1088/1748-9326/7/3/034032

Kouakou Dje, M., Dabonne, S., Tagro Guehi, S., & Kouame, L. P. (2010). Monitoring of some biochemical parameters of two yam species (*Dioscorea* Spp) tubers parts during post-harvest storage. *Advance. Journal of Food Science and Technology*, *2*, 178–183. https://api.semanticscholar.org/CorpusID:56412655. Accessed September 2023.

Kouakou, A. M., Yao, G. F., Dibi, K. E. B., Mahyao, A., Lopez-Montes, A., Essis, B. S., N'zue, B., Kouamé, B., Adebola, P. O., Asfaw, A., & Asiedu, R. (2019). Yam cropping system in cote d'Ivoire: Current practices and constraints. *European Scientific Journal*, *15*(30), 278–300. https://doi.org/10.19044/esj.2019.v15n30p278

Kouakou, A. M., Zohouri, G. P., Dibi, K. E., & N'zue, B., & Foua, B. (2012). Émergence d'une nouvelle variété d'igname de l'espèce *Dioscorea alata* L., la C18, en Côte d'Ivoire. *Journal of Applied Biosciences*, *57*, 4151–4158. https://www.m.elewa.org/JABS/2012/57/2.pdf, Accessed September 2023.

Lebot, V., Lawac, F., & Legendre, L. (2023). The greater yam (*Dioscorea alata* L.): A review of its phytochemical content and potential for processed products and biofortification. *Journal of Food Composition and Analysis*, *115*, 104987. https://doi.org/10.1016/j.jfca.2022.104987

Lebot, V., Trilles, B., Noyer, J. L., & Modesto, J. (1998). Genetic relationships between *Dioscorea alata* L. cultivars. *Genetic Resources and Crop Evolution*, *45*, 499–509. https://doi.org/10.1023/A:1008603303314

Leonard, E. (1997). Crise écologique, crise économique, crise d'un modèle d'exploitation agricole. Ajustements et recomposition sociale sur les anciens fronts pionniers ivoiriens. In B. Contamin & H. Memel-Fote (Eds.), *Le modèle ivoirien en questions, Karthala, ORSTOM* (pp. 393–413). Karthala & ORSTOM.

Lobell, D. B., Burke, M. B., Tebaldi, C., Mastrandrea, M. D., Falcon, W. P., & Naylor, R. L. (2008). Prioritizing climate change adaptation needs for food security in 2030. *Science*, *319*, 607–610. https://doi.org/10.1126/science.11523

Mahyao, A. G. (2008). *Etude de l'efficacité du système d'approvisionnement et de distribution des ignames précoces kponan à travers le circuit Bouna-Bondoukou-Abidjan en Côte d'Ivoire*. PhD Thesis. Université de Cocody.

Malédon, E., Nudol, E., Perrot, C., Gravillon, M. C., Rivallan, R., Cornet, D., Chair, H., & Dossa, K. (2023). First report of a successful development of yam hybrids (*Dioscorea alata* L.) from lyophilized and long-term stored pollens. *Phyton-international. Journal of Experimental Botany*, *92*(10), 2861–2874. https://doi.org/10.32604/phyton.2023.042397

Manners, R., & van Etten, J. (2018). Are agricultural researchers working on the right crops to enable food and nutrition security under future climates? *Global Environmental Change*, *53*, 182–194. https://doi.org/10.1016/j.gloenvcha.2018.09.010

Marcos, J., Cornet, D., Bussière, F., & Sierra, J. (2011). Water yam (*Dioscorea alata* L.) growth and yield as affected by the planting date: Experiment and modeling. *European Journal of Agronomy*, *34*, 247–256. https://doi.org/10.1016/j.eja.2011.02.002

Mechiche-Alami, A., & Abdi, A. M. (2020). Agricultural productivity in relation to climate and cropland management in West Africa. *Scientific Reports*, *10*, 3393. https://doi.org/10.1038/s41598-020-59943-y

Monney, R. F., Coulibaly, S., Sylla, K., Diallo, S. S., & N'Kamleu, B. (2009). Determinants de l'adoption des technologies de transformation de l'igname: cas de la transformation en cossettes et en farine au nord de la Côte D'Ivoire. In *Securing livelihoods through yams: Proceedings of a technical workshop on progress in yam research for development in west and Central Africa*. IITA. 329 p.

MTCI. (2020). *Fête de l'igname: Le royaume Djuablin prône la paix et la prospérité pour la Côte d'Ivoire*. Ministère du tourismes Côte d'Ivoire. https://www.tourisme.gouv.ci/accueil/actualitedetail/fete-de-l-igname-le-royaume-djuablin-prone-la-paix-et-la-prosperite-pour-la-cote-d-ivoire921. Accessed September 2023.

Orkwor, G. C., Asiedu, R., & Ekanayake, I. J. (1998). *Food yams: Advances in research*. IITA, Ibadan and NRCRI.

Otegbayo, B. O., Oguniyan, D. J., Olunlade, B. A., Oroniran, O. O., & Atobatele, O. E. (2018). Characterizing genotypic variation in biochemical composition, anti-nutritional and mineral bioavailability of some Nigerian yam (*Dioscorea* spp.) land races. *Journal of Food Science and Technology*, *55*(1), 205–216. https://doi.org/10.1007/s13197-017-2913-0

Ouattara, T. A., Kouamé, K. F., Zo-Bi, I. C., Vaudry, R., & Grinand, C. (2021). Changements d'occupation et d'usage des terres entre 2016 et 2019 dans le Sud-Est de la Côte d'Ivoire: Impact des cultures de rente sur la forêt. *Bois et Forêts Des Tropiques*, *347*, 89–104. https://doi.org/10.19182/bft2021.347.a31868

Overland, I., Sagbakken, H. F., Isataeva, A., Kolodzinskaia, G., Simpson, N. P., Trisos, C., & Vakulchuk, R. (2022). Funding flows for climate change research on Africa: Where do they come from and where do they go? *Climate and Development*, *14*(8), 705–724. https://doi.org/10.1080/17565529.2021.1976609

Paeth, H., Capo-Chichi, A., & Endlicher, W. (2008). Climate change and food security in tropical West Africa - a dynamic-statistical modelling approach. *Erdkunde*, *62*(2), 101–115. https://doi.org/10.3112/erdkunde.2008.02.01

Pendergrass, A. G., Knutti, R., Lehner, F., Deser, C., & Sanderson, B. M. (2017). Precipitation variability increases in a warmer climate. *Scientific Reports*, *7*(1), 17966. https://doi.org/10.1038/s41598-017-17966-y

Perrot, C. H. (1998). L'igname dans les cérémonies politico-religieuses de l'aire culturelle akan. In J. Berthaud, N. Bricas, & J.-L. Marchand (Eds.), *L'igname, plante séculaire et culture d'avenir. Actes du séminaire international*. CIRAD.

Pouya, N., Hgaza, V. K., Kiba, D. I., Bomisso, L., Aighewi, B., Aké, S., Frossard, E., & Water, E. (2022). Yam (*Dioscorea alata* L.) growth and tuber yield as affected by rotation and fertilization regimes across an environmental gradient in West Africa. *Agronomy*, *12*, 792. https://doi.org/10.3390/agronomy12040792

Ranasinghe, R., Ruane, A. C., Vautard, R., Arnell, N., Coppola, E., Cruz, F. A., Dessai, S., Islam, A. S., Rahimi, M., Ruiz Carrascal, D., Sillmann, J., Sylla, M. B., Tebaldi, C., Wang, W., & Zaaboul, R. (2021). Climate Change Information for Regional Impact and for Risk Assessment. In Climate Change 2021: The Physical Science Basis. In V. Masson-Delmotte, P. Zhai, A. Pirani, S. L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M. I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J. B. R. Matthews, T. K. Maycock, T. Waterfield, O. Yelekçi, R. Yu, & B. Zhou (Eds.), *Contribution of working group I to the sixth assessment report of the intergovernmental panel on climate change* (pp. 1767–1926). Cambridge University Press. https://doi.org/10.1017/9781009157896.014

Raymundo, R., Asseng, S., Cammarano, D., & Quiroz, R. (2014). Potato, sweet potato, and yam models for climate change: A review. *Field Crops Research*, *166*, 173–185. https://doi.org/10.1016/j.fcr.2014.06.017

Ruf, F. (2010). Les Baoulé ne sont pas des oiseaux pour manger du riz. Alimentation, migrations et écologie du sud-ouest ivoirien. *Anthropology of Food*, *7*, 16. https://doi.org/10.4000/aof.6686

Satori, D., Tovar, C., Faruk, A., Hammond Hunt, E., Muller, G., Cockel, C., Kühn, N., Leitch, I. J., Lulekal, E., Pereira, L., Ryan, P., Willis, K., & Pironon, S. (2021). Prioritising crop wild relatives to enhance agricultural resilience in sub-Saharan Africa under climate change. *Plants, People, Planet*, *4*, 269–282. https://doi.org/10.1002/ppp3.10247

Sharif, B. M., Burgarella, C., Cormier, F., Mournet, P., Causse, S., Van, K. N., Kaoh, J., Rajaonah, M. T., Lakshan, S. R., Bhattacharjee, J. W. R., Badara, G., Pachakkil, B., Arnau, G., & Chaïr, H. (2020). Genome-wide genotyping elucidates the geographical diversification and dispersal of the polyploid and clonally propagated yam (*Dioscorea alata*). *Annals of Botany*, *126*(6), 1029–1038. https://doi.org/10.1093/aob/mcaa122

Srivastava, A. K., Gaiser, T., & Ewert, F. (2016). Climate change impact and potential adaptation strategies under alternate climate scenarios for yam production in the sub-humid savannah zone of West Africa. *Mitigation and Adaptation Strategies for Global Change*, *21*, 955–968. https://doi.org/10.1007/s11027-015-9639-y

Srivastava, A. K., Gaiser, T., Paeth, H., & Ewert, F. (2012). The impact of climate change on yam (*Dioscorea alata*) yield in the savanna zone of West Africa. *Agriculture, Ecosystems & Environment*, *153*, 57–64. https://doi.org/10.1016/j.agee.2012.03.004

Stessens, J., Nindjin, C., Daouda, D., & Girardin, O. (1998). *Amélioration du stockage de l'igname au Nord et au centre de la Côte d'Ivoire*. Centre Suisse de Recherches Scientifiques, Centre National de Recherches Agronomiques, Katholieke Universiteit Leuven. 49p.

Sultan, B., & Gaetani, M. (2016). Agriculture in West Africa in the twenty-first century: Climate change and impacts scenarios, and potential for adaptation. *Frontiers in Plant Science*, *7*, 1262. https://doi.org/10.3389/fpls.2016.01262

Takada, K., Kikuno, H., Babil, P., Irie, K., & Shiwachi, H. (2017). Water yam (*Dioscorea alata* L.) is able to grow in low fertile soil conditions. *Tropical Agriculture and Development*, *61*, 8–14. https://doi.org/10.11248/jsta.61.8

Thiele, G., Dufour, D., Vernier, P., Mwanga, R. O. M., Parker, M. L., Schulte Geldermann, E., Teeken, B., Wossen, T., Gotor, E., Kikulwe, E., Tufan, H., Sinelle, S., Kouakou, A. M., Friedmann, M., Polar, V., & Hershey, C. (2021). A review of varietal change in roots, tubers and bananas: Consumer preferences and other drivers of adoption and implications for breeding. *International Journal of Food Science and Technology*, *56*, 1076–1092. https://doi.org/10.1111/ijfs.14684

Ulian, T., Diazgranados, M., Pironon, S., Padulosi, S., Liu, U., Davies, L., Howes, M. R., Borrell, J. S., Ondo, I., Pérez-Escobar, O. A., Sharrock, S., Ryan, P., Hunter, D., Lee, M. A., Barstow, C., Łuczaj, Ł., Pieroni, A., Cámara-Leret, R., Noorani, A., … Mattana, E. (2020). Unlocking plant resources to support food security and promote sustainable agriculture. *Plants People Planet*, *2*, 421–445. https://doi.org/10.1002/ppp3.10145

Walker, T. S., Alwang, J., & Alene, A. (2015). Varietal Adoption Outcomes and Impact. In T. S. Walker & J. Alwang (Eds.), *Crop improvement, adoption and impact of improved varieties in food crops in sub-Saharan Africa* (pp. 388–405). CABI. https://doi.org/10.1079/9781780644011.0388

Wessel, M., & Quist-Wessel, P. F. (2015). Cocoa production in West Africa, a review and analysis of recent developments. *NJAS-*

Wageningen Journal of Life Sciences, *74*, 1–7. https://doi.org/10.1016/j.njas.2015.09.001

Wiebe, K., Sulser, T. B., Dunston, S., Rosegrant, M. W., Fuglie, K., Willenbockel, D., & Nelson, G. C. (2021). Modeling impacts of faster productivity growth to inform the CGIAR initiative on crops to end hunger. *PLoS ONE*, *16*(4), e0249994. https://doi.org/10.1371/journal.pone.0249994

Wireko-Manu, F. D., Ellis, W. O., Oduro, I., Asiedu, R., & Dixon, B. M. (2011). Physicochemical and pasting characteristics of water yam (*D. Alata*) in comparison with pona (*D. Rotundata*) from Ghana. *European Journal of Food Research & Review*, *1*(3), 149–158. http://www.journalrepository.org/media/journals/EJFRR_1/2011/Dec/1322825635-WirekoManuetal_2011EJFRR659.pdf. Accessed September 2023.

Wireko-Manu, F. D., Oduro, I., Ellis, W. O., Asiedu, R., & Maziya-Dixon, B. (2013). Potential health benefits of water yam (*Dioscorea alata*). *Food & Function*, *4*, 1496–1501. https://doi.org/10.1039/C3FO60064E

World Bank. (2022). *Arable land (hectares per person) - cote d'Ivoire*. World Development Indicators, The World Bank Group. URL: data.worldbank.org/indicator/EN.ATM.CO2E.PC. Accessed January 2023.

van Zonneveld, M., Kindt, R., McMullin, S., & Dawson, I. K. (2023). Forgotten food crops in sub-Saharan Africa for healthy diets in a changing climate. *PNAS*, *120*(14), e2205794120. https://doi.org/10.1073/pnas.220579412

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