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 Mali, Climate Change

Addressing Food Insecurity in Mali: Traditional Practices and Modern Agricultural Solutions

Mali is a culture that faces a quiet and mostly unnoticed struggle against food insecurity. Food insecurity is a major issue in the country that affects most of their population and needs innovative and long-term solutions to combat. To solve hunger and increase food security in Mali, we need a mix of old and new methods and technologies. In addition, the people and communities should take the first step by adopting them. To achieve this, Mali's government needs to work together, plan accordingly, and communicate with their people.

To give context, Mali is a landlocked nation in West Africa which has a multi-party democracy (USAID, n.d.; Freedom House, 2022). Over half of its people live in rural areas, with a preference to agricultural occupations, especially around the Niger River due to abundant water resources (Trading Economics, 2024). But conflicts and climate shifts in the region cause poverty in almost half the population (USAID, n.d.; World Bank, n.d.). About 1.6 million kids need urgent help, and nearly a third of children under-five are stunted (UNICEF, n.d.b; World Food Programme, 2019), and climate change plays a big role in all this crisis (IMF, n.d.). This paper aims to solve Mali's urgent food-related problems caused by climate change.

Although merely 4% of Mali's land is cultivated, agriculture is still at the heart of its economy with cotton and cereals being the mainstay of both domestic livelihood and national exports, employing almost 80% of Malians and contributing 37% to GDP (IMF, 2023; Statista, n.d.). The average farm is 4.87 hectares which is considered extremely small, according to the USDA (FAO, n.d). Production also relies greatly on the seasons with the dry season between March and June, the wet season between June and September, and the cool season between October and February. Temperatures generally fluctuate between 24°C and 35°C (FAO, n.d.; World Bank Climate Change Knowledge Portal, n.d.).

Malian households are around six people living in huts or mud houses (Demographic and Health Survey Key Findings Mali, n.d.; AFS-USA, n.d.). They mostly rely on farming and home gardens for food, which is cooked on wood-fueled stoves, a limited resource (Crop Trust, n.d.; Sanankoua, B., & Sidibe, S., n.d.). Their diet includes raised chickens, lamb, beef, fish, and veggies like carrots, yams, sweet potatoes, peanuts; rice is also a major part of every meal (Together Women Rise, n.d.). Most jobs revolve around agriculture, with an average monthly income of roughly 71 USD, much lower than in the United States (World Data, n.d.). Healthcare and education are limited due to financial constraints, leaving over 50% of children aged 5-17 illiterate (UNICEF, n.d.a). Despite 80% of the population getting better drinking water, rural areas lag at 70% (UNICEF, n.d.c). Conflict-displaced folks suffer more, facing difficulties in accessing clean water and sanitation. Natural disasters and poverty contribute to hunger, while conflicts since 2012 worsened food insecurity and forced people to migrate within Mali and to nearby countries (USAID, 2022).

The most fundamental issue that Mali has is food insecurity. It impacts roughly 30% of the population, which is 6.3 million individuals, along with 1.2 million children (Action Against Hunger, n.d.; World Food Programme, 2019). Economic poverty is the greatest driver because it directly influences households' abilities to pay for caloric and protein-dense foods, yet climate change and conflict also

exacerbate the emergency (Action Against Hunger, n.d.; IMF, n.d.; USAID, 2022). Income poverty has a direct relation to malnutrition – a problem prevalent in the region – as it directly decides the affordability of caloric and nutritious foods (Action against Hunger, n.d.).

However, there are factors other than poverty that affect food insecurity, the primary one of which is climate change (World Food Programme, 2019). As already said, most of Mali is either a desert or a semi-desert, meaning that it doesn't get enough annual precipitation. This is further aggravated by the effects of climate change, the overall change in patterns of climate and natural disasters in a region over many decades (Shaftel, H., n.d.). These long-term changes occur mostly due to human driven actions such as burning of fossil fuels which increase the greenhouse gases in the atmosphere, raising Earth's temperature. However, natural processes such as ocean patterns – El Niño, La Niña and the Pacific Decadal Oscillation – or external forces – volcanic activity, changes in the Sun's energy output, variations in Earth's orbit – can also increase climate change.

The struggle in Mali is not just limited to rising temperatures however, as other natural disasters such as floods and pests continue to decrease food security and self-reliance (Encyclopaedia Britannica, 2018). These challenges are predicted to intensify due to climate change, and are becoming increasingly detrimental to development, health, and access to food. This is particularly affecting vulnerable regions like the Sikasso, Mopti, and Segou, which are the agriculturally productive regions of the country. These are also regions of Mali that bear the brunt of the climate change problem, which not only negatively affects securing food supply but also coping with the degradation of widespread poverty. To find how exactly climate change causes food insecurity in the region, detailed analysis must be conducted.

Climate change is an ongoing and grave problem in Mali, which gained spotlight starting from the late 20th century when natural disasters such as droughts became prevalent in the region (Held, I., n.d.). In the 1970s and '80s, a series of harsh droughts hit the Sahel, a dry region of Mali characterized by scarce rainfall (Holthuijzen, W., & Maximillian, J., 2011). These droughts caused crops to fail, leaving many food insecure and struggling (Holthuijzen, W., & Maximillian, J., 2011). These extreme droughts made it clear that Mali - and Africa in general - would face more frequent and severe weather problems because of climate change and increasing temperatures. Many solutions to the problem have been proposed, but most haven't been effective, and climate-related issues keep getting worse as time goes on.

Since the 1900s, Mali has experienced frequent droughts, partly driven by climate change, which has made its land increasingly desert-like. Five severe droughts put 1.2 million Malians at risk of famine and caused the deaths of tens of thousands of people and millions of livestock, due to water shortages, poor harvests, and disrupted planting seasons (Benjaminsen & Ba, 2009).

To elaborate, rainfall in Mali has decreased by about 30% since 1980, leading to major subsistence crops like wheat, millet, and sorghum decreasing in production by even 50% in some years (Benjaminsen, T. A., & Ba, B., 2009). This significant decline is partly due to past practices imposed by the French, which discouraged traditional farming methods that saved crops in the past. The droughts and reduced rainfall especially affected nomadic pastoralists in the north of Mali, forcing them to leave the area and move south. Climate-induced resource scarcity has intensified local conflicts, as extremist groups use fertile ground to exploit marginalized communities. Conflict in some southern areas of the country erupted as people fought over scarce resources (Benjaminsen, T. A., & Ba, B., 2009). This conflict has been worsened by rampant corruption in the government where officials favor certain groups over others, isolating many from much needed resources (NUPI, n.d.).

To provide background information, radical jihadist groups such as Katiba Macina - a group that seeks to expel western influence and consolidate an Islamic State in Mali - have gained increasing prominence in Mali by exploiting land rights and herder marginalization (Crisis Group, 2020). They promise economic incentives and food to rural communities in exchange for loyalty, recruiting heavily in the youth of the world's largest pastoral tribe, the Fulani. These groups, in absence of government presence, have played a major role in rural communities by mediating resource disputes, providing protection and support to people, and defining rules for resource usage, thereby acting as the de-facto government of the region (Walch, C., 2018). However, this harms the people in Mali as one of the primary objectives of the jihadist groups, as explained earlier, is to expel western influence, which includes vital assistance by the UN and other major institutions (Crisis Group, 2020). Thus, not only decreased precipitation, but also regional conflicts, are exacerbated by climate change. Solving problems related to the impacts of climate change can mitigate or even stop its consequences.

There are several reasonably achievable and effective ways to solve and address these impacts of climate change. To start, Cassava is a highly nutritious crop that has been a staple food in East and Central Africa since the late 1500s when it was introduced by the Portuguese. Its flour can be used for baking; its leaves are rich in calcium, protein, and essential vitamins and its starchy roots can serve various purposes from starch production to bioethanol/fuel production (IITA, n.d.; ReliefWeb, 2017). If Malian smallholders move from typical Sub-Saharan African cassava yields (≈ 8.0 tonnes fresh roots/ha) to a conservative improved-practice yield of 16.0 tonnes/ha, that incremental 8.0 tonnes per hectare would represent ~ 25.2 million extra kilocalories per hectare per year - enough to supply the annual energy needs of ~ 33 person-years ($2,100 \text{ kcal/day} \times 365 \text{ days} \approx 766,500 \text{ kcal/person-year}$) (Adebayo, W. G., 2023; IITA, n.d.; Morgan, N. K., et al. 2016). Furthermore, cassava can adapt to extreme situations, such as droughts and poor soil, making cassava the biggest major African food crop to adapt to climate change by 2030. However, despite its potential, Malian farmers constrict cassava to small-scale gardens due to its low yield among other problems (Adebayo, W. G., 2023). To alleviate these concerns and to elevate cassava to a primary crop, addressing this yield issue is important. The primary reason for low yield in cassava crops is the absence of disease-resistant and high-yielding varieties of cassava (English.news.cn., n.d.). Governments' lack of recognition of cassava as a significant crop to invest in exacerbates this by excluding incentives for organizations and companies to research cassava.

Yet, some success stories, the primary one being Nigeria's NextGen Cassava Breeding project which, in collaboration with the International Institute of Tropical Agriculture (IITA), offered a promising path to Nigerian farmers (Rabbi I., 2021). They used cutting-edge crop science to research cassava and utilized disease-resistant germplasm from Latin America, where cassava originated. Through the program, Nigeria tailored five new cassava varieties designed specifically for West Africa.

Nigeria's success proves cassava can be converted from a marginal crop to a key driver of food security when supported by research and policy (Rabbi, 2021; IITA, n.d.). The model offers clear lessons for Mali, where cassava remains a garden crop in spite of its potential (Adebayo, 2023; English.news.cn, n.d.).

Previous research in Southern Mali indicates that farmers are ready to commercialize cassava as a crop and as part of unorthodox purposes such as ethanol/alcohol production, which require minimal education due to existing familiarity (Birch-Thomsen, T., et al, 2014). Dispensing these new varieties through the Ministry of Agriculture of Mali, which is well-established in rural areas and focused on

reducing food insecurity, aligns seamlessly with this objective (Developmental Aid, n.d.). This ministry will also focus on giving expertise and guidance to the many farmers who chose to cultivate cassava for bioethanol production as this is unfamiliar in the region.

Hence, enhancing the standard and promoting cassava research, in addition to agricultural cultivation is a measure to boost agricultural sustainability and reduce food insecurity in Mali. However, centuries-old knowledge and agricultural methods and techniques such as multi-cropping and crop rotation shouldn't be forgotten. Multi-cropping is the cultivation of complementary crops in the same land over a year to improve soil quality and fertility by managing nutrients in the soil. It also stands as a proven strategy to augment soil carbon and nitrogen levels, thereby bolstering crop yield, especially in the long run, which is essential to make Mali truly self dependent and food secure (ScienceDirect Topics, N.d.; Chen T., et al, 2021). Therefore, multi-cropping has benefits beyond soil quality by securing long-term income for farmers.

Additionally, the diversity prevalent in multi-cropping mitigates risks of entire crop failure in the event of disease for one particular crop, securing at least some harvest from other crops that didn't get the disease. This will allow for decreased chances of a single crop disease wiping out the entire yield and throwing the farmer into debt and failure. Despite the many advantages multi-cropping offers, Malian farmers have not fully embraced it, indicating a missed opportunity but also an area to improve on in this aspect (Laborte, A. G. et al, 2017). In addition to multi-cropping, another sustainable agricultural method called crop rotation can enhance the use of soil nutrients throughout the seasons (Wonderopolis, n.d.). Crop rotation involves changing crops each season to complement the crops' ideal climate and manage the nutrients in the soil even more by allowing crops with different needs to be planted in the same piece of farmland (Wonderopolis, n.d.). Unlike monoculture, which depletes soil quality and nutrient concentration, crop rotation preserves nutrients, ensures quality, and decreases chance of erosion (USDA, n.d.).

What's concerning is that, just like with multi-cropping, the prevalence of crop rotation in Mali remains low, with monoculture of crops primarily limited to major crops like wheat, cotton, and maize (Vitale, J., et al, 2007). To combat this, initiatives led by organizations such as the World Food Program and the Catholic Relief Service strive to familiarize smallholder farmers with the advantages of crop rotation, as previously mentioned, integrating underutilized indigenous crops which could further revolutionize agricultural sustainability (Devex, 2017).

In addition to these scientific methods, Malian farmers already employ native strategies to adapt to climate extremes (Laborte et al., 2017; Wonderopolis, n.d.). Zai pits to capture precious rainwater, contour farming to hold back erosion, and intercropping cowpea with millet to cut pest incidence are all well-established local practices (Dakora, 1997). Starting from these established practices, the introduction of cassava, indigenous crops, and rotation systems becomes more feasible-instead of requiring farmers to set aside what they know, solutions can enhance what is already working and add proven innovations (ScienceDirect Topics, n.d.; USDA, n.d.).

Bambara, an indigenous African legume, shows excellent resilience against many conditions, exhibiting many climate-smart traits like nitrogen fixation and tolerance to poor soils and drought (Mayes, S., et al, 2019; Paliwal, R., et al, 2020; Tan, X. L., et al, 2020). Furthermore, its nutritional composition, which comprises 65% carbohydrates, 24% protein, 6% fat, and 5% fiber in addition to rich mineral content, renders it a holistic food source (Montagnac, J. A., et al, 2009). While Bambara was used

everywhere before colonization, it is very underused today, mostly due to the colonial mindset created by the emphasis for profits by cash crops like cotton (Mayes, S., et al, 2019). Field measurements and reviews put current average Bambara groundnut yields under smallholder conditions at roughly 0.8–0.9 t/ha (dry seed), while improved agronomy and varietal selection raise yields toward ~3.0 t/ha in trials - because Bambara seed contains ≈24% protein, raising yields from 0.85 to 3.00 t/ha would add roughly ~507 kg of edible protein per hectare ($3,000 \text{ kg} \times 0.236 - 850 \text{ kg} \times 0.236 \approx 507 \text{ kg}$), which - using a conservative adult protein requirement of 0.83 g/kg body weight/day ($\approx 18.2 \text{ kg protein/person-year}$ for a 60 kg adult) - equates to roughly 28 person-years of protein per hectare (Tan, X. L., et al., 2020; Mayes, S., et al., 2019; WHO, 2007). To capture that protein and market value, phase in seed-multiplication and small processing hubs (dehulling + local flour packaging) in year 2–4 and subsidize the first 12 months of off-season storage/aggregation (through co-op loans or seed grants); these actions convert the per-ha protein gains above into year-round household nutrition and cash income streams.

These actions will continue to benefit the Malian farmers for many decades past its implementation as Bambara's adaptability to diverse environmental conditions such as droughts, poor and acidic soil favors its cultivation across Mali's many terrains, ranging from deserts, semi-deserts, to a tropical climate in the South, offers farmers an advantageous array of varieties to suit their land (Paliwal, R., et al, 2020). Furthermore, its market demand, currently valued at \$100-150 million USD and growing annually by 6%, underscores its economic viability and untapped potential when compared to other crops such as peas or beans which currently have market values in the billions (Transparaencymarketsearch, n.d.).

However, adoption of improved crop practices in West Africa often faces significant barriers such as limited access to technology, credit, training, and secure land tenure (Baffour-Ata et al., 2024). Field studies and adoption reviews show the three largest, measurable constraints to smallholder uptake of improved varieties are (1) finance (lack of working capital/credit), (2) information/extension gaps, and (3) weak seed/planting material systems - which together these account for the majority of adoption shortfalls in West African staple crops in randomized and meta-analytic studies (Karlan, D., et al., 2017; Waddington, H., et al., 2014). To combat this issue, deploy a mixed package - (i) farmer-field-school (FFS) extension + demonstration plots (target: 20–25% of farmers in a target commune in year 1), (ii) small conditional micro-grants or input vouchers (US\$50–\$150 per participating farm to buy cuttings/fertiliser/transport), and (iii) community seed nurseries - because meta-analyses show FFS-type training raises adoption and intermediate production outcomes (and micro-finance/VSLAs increase productive investment and resilience), this package can plausibly lift early adopters' yields by ~15–30% in the first 2–3 seasons when combined with improved planting material (Devex/field pilots, 2017).

Bambara has been proven as a way to enhance maize and other crops' yields when used in multi cropping and rotation schemes, showing that it can combat food insecurity and increase soil quality and nutrient quantity effectively (Dakora, F. D. 1997). While multi cropping and crop rotation, especially with Bambara, hold promise, we need more agriculturally sustainable and tested and proven techniques in Mali such as indigenous ways. Therefore, Mali's people should combine and intertwine age-old indigenous customs in addition to agricultural expertise, which should create a varied agricultural structure that should guarantee decades, if not centuries long harvests while safeguarding the land for many generations to come.

But Mali is not the only country trying to bring back traditional crops in the name of climate resilience. Other African countries have demonstrated how re-engaging with heritage foods can enhance

both food systems and cultural identity (Mayes et al., 2019; Montagnac et al., 2009; Paliwal et al., 2020). Teff in Ethiopia has gone from being eclipsed by wheat to a global export. In Ghana, they have brought back fonio for its drought tolerance as well as cultural significance, and Nigeria has turned yam festivals into marketing campaigns that increase farmer incomes. These demonstrate how mixing tradition with modern markets can work—a pathway Mali can pursue with Bambara. Bambara has potential to be a nitrogen-fixing crop in rotation systems like multi-cropping and crop rotation mentioned above with major crops like wheat and cotton which provides an underutilized solution/crop as a way to replenish soil nutrients like nitrogen which is known to be the biggest limiting nutrient (the nutrient that plants lack and causes less growth) for plants. By incorporating Bambara into rotation and multi-cropping systems, Mali can improve soil nutrients, boost yields, and enhance food security while tapping into a growing \$100–150 million market (Transparencymarketresearch, n.d.).

However, to successfully scale cassava and Bambara adoption in Mali, there needs to be a structured, phased approach.

Phase 1: Research and Distribution. IITA and other research institutions would supply high-yield, disease-resistant varieties of cassava and Bambara to the Ministry of Agriculture, which oversees rural extension offices for seed distribution (IITA, n.d.; NextGen Cassava, n.d.). Local cooperatives CNOP and AOPP would select participating farmers, targeting areas most impacted by food insecurity, including Sikasso, Mopti, and Segou. Funding from USAID, the African Development Bank, and the Bill & Melinda Gates Foundation would cover seed procurement, logistics, and initial farmer training (ReliefWeb, 2017; USAID, 2022).

Budget and scale target: for a pilot covering ~5,000 smallholders (3 high-risk regions: Sikasso, Mopti, Segou), plan for an approximate 3–5 year pilot budget in the range US\$3–6 million (breeding/distribution, extension, storage and 1st-round processing capex) to reach measurable yield and nutrition outcomes at scale; donors and MDBs commonly underwrite these pilot budgets before private co-investment (NextGen Cassava, n.d.; CGIAR, 2012).

Phase 2: Adoption and Farmer Training. Training would be provided by cooperative-led "farmer schools" through demonstration plots, hands-on workshops, and mobile extension teams. These would instruct cassava and Bambara farming, integration with crop rotation and multi-cropping systems, and sustainable indigenous methods like zai pits and contour farming (Laborte et al., 2017; Dakora, 1997). Adoption incentives, like micro-grants or subsidized inputs, would persuade smallholder farmers to try out new crops without jeopardizing traditional staples.

Phase 3: Processing, Market Integration, and Scaling. To ensure economic sustainability, cassava flour, ethanol, and Bambara product processing facilities are to be established at regional centers. Partnerships with local traders and cooperatives would enable the establishment of supply chains aimed at nearby urban markets and export channels. Monitoring and evaluation teams, structured by the Ministry of Agriculture and assisted by NGOs like the World Food Programme, would measure crop yields, the adoption rate of farmers, and market penetration levels, adjusting strategies as required to improve efficiency and sustainability (World Food Programme, 2019; Devex, 2017).

Phase 4: Long-Term Sustainability. After widespread adoption, farmers would be incentivized to continue multi-cropping and crop rotation methods, blending indigenous knowledge with enhanced varieties. Community-based committees might manage resource allocation, pest control, and water

conservation, making food security gains long-lasting. In the long run, this integrated strategy-funding, institutional coordination, farmer training, market development, and monitoring combined-has the potential to establish a resilient, climate-smart agricultural system in Mali, decreasing food insecurity for generations to come.

Institutional donors (e.g., Bill & Melinda Gates Foundation) fund cassava breeding and scale because improved varieties produce measurable food-security outcomes for millions and fit SDG impact metrics; impact investors and agribusiness funds (e.g., Sahel Capital and other Ag-PE managers) invest because value-chain build-out (processing, flour/ethanol, packaging, urban markets) creates scalable revenue streams, measurable farmer income gains, and verifiable social impact (so capital providers can claim both financial returns and impact KPIs) (GIIN, 2013; Sahel Capital, n.d.). The combination of demonstrable yield gains, processed-product market demand, and measurable farmer reach (number of farmers served) is exactly the set of metrics that blended-finance vehicles and impact funds target.

In conclusion, achieving food security in Mali requires a holistic approach that combines modern agricultural innovations with traditional knowledge. Progress in cassava research is important, but sustainable solutions also include integrating climate-resilient crops like cassava and Bambara into farming systems, promoting multi-cropping and crop rotation, reviving indigenous and forgotten farming practices, and supporting farmers through training and market access. Together, these strategies can create a resilient, productive, and climate-smart agricultural environment, securing livelihoods, improving nutrition, and protecting Mali's land for future generations.

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