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End Hunger, Achieve Food Security, and Improve Nutrition by Promoting Sustainable Agricultural Practices in Chad.

*"I have the audacity to believe that people everywhere can have three meals a day for their bodies, education and culture for the minds and dignity, equality and freedom for their spirits." ~ **Martin Luther King, Jr.***

*"The first essential component of social justice is adequate food for all mankind. Food is the moral right of all who are born into this world." ~ **Norman Borlaug, biologist and humanitarian.***

From pizza to chicken nuggets, American children often develop strong preferences for certain comfort foods, eagerly requesting them at mealtimes, while the average child in Chad instead experiences hunger, with a significant portion suffering from malnutrition. The Republic of Chad, faces some of the highest levels of food insecurity and starvation globally, with 42 percent of its population living in poverty. Chad is home to extreme food insecurity, with about 400,000 children under 5 years of age suffering from malnutrition, and over 13 million people having inadequate access to food. As a result, almost 37 percent of children aged under 5 suffer from malnutrition and stunted growth (World Bank in Chad, 2024). In the 2024 Global Hunger Index, Chad ranks 125th out of 127 countries, with an alarming score of 36.4 (GHI, 2024).

History of Resilience: Background on the Country and Family

Chad is a landlocked country located in north-central Africa, and is the fifth largest country in the African continent. At 1.28m km² (WorldData.info, 2025), it is a vast nation that is larger than Nigeria, twice the size of Texas, three times the size of California, and home to over 20 million people as of 2025 (Worldometers, 2025). Chad is a diverse nation with French and Arabic as the national languages, along with almost 120 tribal languages (WorldAtlas, 2025). The population comprises about 200 ethnic groups. Religions include Islam, Christianity, and African tribal religions. Chad has struggled with several external and self-inflicted misfortunes ranging from Emirati slave raids starting in the 1500s, French colonization in early-1900 (UNHCR, 2023), internal conflicts after independence, increasing desertification due to climate change, loss of fertile lands and water bodies, and indifference of its oil-rich leadership. Chad's families have shown remarkable resilience in the face of these challenges.

The average family in Chad contains six people, which is 50% more than the size of an average global household. Most of these people work in agriculture, making up 80% of the workforce living in rural communities, in poor conditions (Oxfam, 2025) and practicing subsistence farming. Chad has many infrastructure deficits, such as not having a good road network, and most people have poor access to electricity. Chad's distinct geographic regions affect people's approach to agriculture, sustenance, and children's roles within their families. There are three main geographical regions in Chad: the northern desert zone, which lies in the Sahara desert; the semi-arid Sahelian belt in the center, containing the capital city and the eponymous Lake Chad; and the Sudanese tropical and fertile savanna zone in the south.

1. In the drier **Northern** Chad, most families follow a nomadic lifestyle, moving throughout the year with their herds of camels, cattle, and goats to find grazing land. The primary source of income is livestock, which is used for milk, meat, and sometimes trade (Country Studies, 1988). Families subsist on rations of various grains such as millet, sorghum, and rice, as well as some vegetables and meats. Children in these communities take on important tasks early in life, helping with herding, fetching water, and collecting firewood. Schools are difficult to establish and staff due to the region's remote and sparse population and vast size.
2. **Southern** Chad, with its higher rainfall, is able to support a wider variety of crops compared to the drier areas. In addition to sorghum and millet, crops like rice, maize, peanuts, and cotton (Landlinks, 2010) are more prevalent. Children in these communities contribute to their families through agricultural work and domestic tasks like caring for younger siblings. Although basic education is officially available in this region, there is a shortage of schools and teachers - particularly in rural areas, creating education barriers.

Despite these geographic and lifestyle differences, the average family in Chad shares a common thread of resilience in the face of poverty and hardship in a desertifying landscape. It is the "Boule," a porridge-like dish that comes closest to being a true national dish (Together Women Rise, 2025), made with millet in the north and maize in the south, this is a simple yet nourishing meal where fermented porridge is cooked and served with various sauces, made of meat, dried fish, tomatoes, spices, and vegetables, especially okra.

Why Sustainable Agriculture for Chad?

The population density in Chad increases southward from less than 1% in the northern desert to over 75% in the fertile southern savannah (USAID, 2005), showing Chad's reliance on its farmland. Even though a substantial 40% of Chad is dedicated to agriculture, most of it is not suitable for sustainable crop yield. Less than 1% of Chad's farmland is irrigated, and only 3.9% is arable.

1. Climate change is one of the main causes of lost farmland in Chad. Prolonged dry spells and intense precipitation events are turning Chad's fertile land into desert. A negative Atlantic Multi-decadal Oscillation (AMO - the planet's dominant multi-decadal climate system) is

associated with reduced rainfall, droughts, and lower crop yields in the Sahel region of Africa (NASA, 2016), increasing food insecurity. Also, due to increasing greenhouse gas (GHG) concentrations, air temperature over Chad is projected to rise by 2.1 to 4.3 °C by 2080 relative to the year 1876 (Agrica, 2021), causing droughts and destroying farmland. Heavy precipitation events are also expected to become more intense in Chad. Since July 2024, catastrophic flooding in Chad has severely impacted crop yield.

2. Another reason for the loss of farmland in Chad is the lack of coordinated water management strategies between the countries sharing the Lake Chad basin. This has led to over-extraction and inefficient water usage, most noticeably on Lake Chad, which has shrunk by about 90% since the 1960s (UNEP, 2015), due to diversion of significant amounts of water, for agricultural purposes, from the Chari and Logone rivers that feed Lake Chad.
3. High demand for firewood for domestic use due to a large population relying on traditional cooking methods puts pressure on forests. Chad has lost around 17% of its tree cover since 2000 (Global Forest Watch, 2023).

All of these external and self-inflicted misfortunes in the Sahel have caused a flight of refugees across the Mediterranean and internal displacement closer to home in Southern Chad. **Northern** herding families have moved south due to the desertification of their communal pastures. This internal displacement has contributed to the strain on existing farmland. Large herds grazing in the same ever-shrinking grazing fields deplete vegetation, preventing regrowth and further contributing to desertification. Similarly, **Southern** farming families have had to flee farther south to escape droughts and loss of fertile land, leading to the clearing of forests for temporary crop cultivation.

These trends are pointing towards a future where Chad's resources will not be able to sustain its large population. Families without a future will send away their best and brightest youth in a search for survival, **instead of employing them locally** to improve Chad's future. Hopelessness will lead to more short-sighted resource management and even more desertification. And worst of all, many humans will **starve to death in our lifetime** - something that we thought only belonged in the history pages of the Dark Ages.

Due to these significant environmental challenges and a strong reliance on traditional agriculture, Chad is an ideal candidate for innovative farming techniques and has an urgent need and clear opportunity for improvement. The right innovations can help mitigate severe climate impacts, boost low agricultural productivity, and enhance food security.

Exploring Solutions

Chad's condition was not always so. Northern Chad, now in the Sahara, was once filled with water, and people lived and farmed around its shores. Cliff paintings depict elephants, cattle, and others, but only camels survive there today (US State Dept, 2009). Chad once controlled its region of the Trans-Saharan trade route, serving as a crossroads for the nomadic traders of the desert and savanna regions, and the settled communities of the tropical forests. This version of a normal Chad is possible, and next, I will explore some solutions to achieve this.

One such effort underway, launched in 2007 by the African Union with help from global organizations, is the **Great Green Wall (GGW)**. GGW is a rural development initiative in the Sahel-Saharan region with the goal of restoring degraded land and combating desertification through the mass planting of trees. It works by using the multiple ways in which trees hold back deserts. Trees act as windbreaks, preventing topsoil from being carried away. Tree roots bind the soil together, preventing erosion, and helping it retain moisture. Trees provide shade, reduce evaporation, and can change microclimates leading to localized increases in rainfall. The GGW initiative's ambition is to restore 100 million hectares of currently degraded land by 2030 (UNCCD, 2025). This initiative, while having the potential to transform Chad, is on a longer timeline than more immediate solutions.

Crop/Fallow rotation farming is another effective practice in the Sahel region, used widely by farmers to restore soil fertility in the arid climate. This process allows the land to rest and recover between crop cycles, which is crucial in a region prone to desertification and low rainfall. Crop rotation in the Sahel region traditionally begins with sorghum or millet in the first year. Mixed crops of sorghum and/or millet, with peanuts, legumes, or tubers, are then cultivated for approximately three years. Farmers then return the land to fallow for periods of up to fifteen years, turning to different fields for the next cycle. The preparation of a field begins with cutting down heavy bushes and unwanted low trees or branches. Fields are then burned just before the onset of the first rains, usually around March. Harvesting begins in September and October with the early varieties of sorghum (Country Studies, 1988). This technique, in spite of its wide use and long history, has a 15-year cycle and doesn't have the immediate results to address Chad's urgent needs.

The Zai technique is another traditional farming method that involves digging pits in the soil to collect water and nutrients for growing crops in dry conditions. The word Zai has been variously attributed to the Burkinabe word *zai* (Ati, 2024) which means 'take maximum advantage of' or the Mooré word "*zaïégré*" (WEF, 2023) which means 'get up early and hurry to prepare your land'. The technique involves some basic steps, where farmers dig small pits, fill the pits with organic material like animal dung or crop residues, and plant seeds like millet or sorghum in the pits during the rains. The technique requires minimal external inputs and is financially accessible to farmers. In addition to cost-saving benefits and healthy crop yields, Zai also helps bring trees back to fields, as the pits have a tendency to trap seeds from many tree species, which are carried to them by wind, rainfall run-off, and livestock droppings. Once the rain arrives, bushes spring up alongside cereals within the fertile, humid environment of the Zai holes.

Recommendation

Zai technique is the most promising for Chad's immediate food security needs due to:

1. **The Great Green Wall initiative has a longer implementation timeline and primarily focuses on large-scale tree planting.** This may not be as efficient in extremely dry environments and can face challenges with water availability and local community engagement.
2. **Fallow Farming offers long-term promise for Chad, but simply leaves land idle for long periods of time.** This makes it less efficient in boosting crop yields, particularly in dry conditions.
3. **Zai farming uses natural fertilizers to enhance soil fertility and addresses water conservation and soil improvement at the plant level by creating small pits that capture rainwater, leading to significantly higher crop yields in arid regions.** It actively concentrates water and nutrients directly around plant roots by digging pits, allowing for better moisture retention and improved soil fertility, especially in arid environments. The results of this process are remarkable: millet and sorghum, grown on previously non-productive soils, achieved yields of up to 1,500 kg per hectare of grain, compared to less than 500 kg per hectare in normal conditions (Ati, 2024).
4. **Bacterial concentration and organic material of soil improves the rate of plant growth.** Over the early part of this year, I worked on a research project with AI experts from Stanford on predictive analysis to predict crop yield based on bacterial composition, and proved the effects of the bacterial concentration and organic material of soil on the rate of plant growth.

Figure-1. Soil analysis results for sample farms (farm_2 show high concentration of good bacteria)

	Xanthomonadales	Glutamicibacter	Geobacillus	Rickettsia	Armatimonadales	Phaselicystis
farm_0	0.0	0.0	0.0	0.0	0.0	2.0
farm_1	156.0	0.0	0.0	0.0	0.0	77.0
farm_2	133.0	0.0	0.0	7.0	95.0	60.0
farm_3	199.0	0.0	0.0	0.0	0.0	95.0
farm_4	0.0	0.0	0.0	0.0	0.0	0.0

Figure-2. Crop-Yield distribution in local farms.

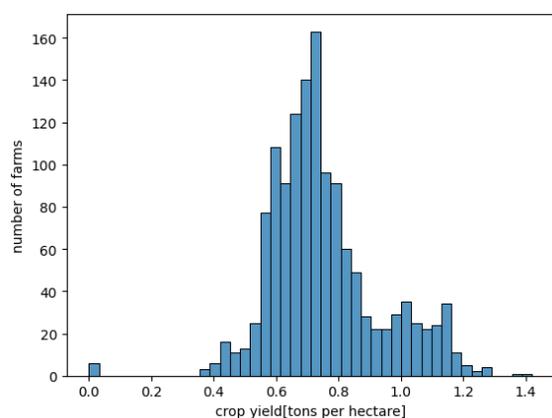


Figure-3. Crop-Yield AI Model:

(Decision-Tree Regressor) Training and Test Results

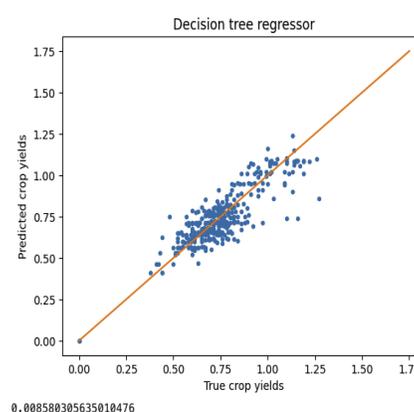


Figure-1 shows a sampling of soil analysis results from farms, figure-2 shows that some farms have higher crop yields, and figure-3 shows that a decision-tree-model trained on bacterial composition was able to correctly predict crop yields based on soil composition data. This strengthens the argument for Zai farming since the science behind the Zai farming technique involves increasing the concentration of certain bacteria, which are conducive to the Sahel's crops by concentrating water and manure at one spot close to the root of plants (MDPI, 2024).

5. **Zai technique has been practiced effectively by people in the countries of Western Sahel, like Burkina Faso, Mali, and Niger, for centuries as a response to the challenges of the Sahelian lifestyle — subsistence farming in a region with erratic rainfall and prolonged droughts.** The technique was revived by local farmers after the devastating droughts of the 1970s and 1980s. One local farmer, Yacouba Sawadogo, is credited with the innovation of digging wider and deeper pits, and with promoting such planting pits by organizing "market days" involving farms from more than 100 Burkina Faso villages (Reij, 2009). Yacouba Sawadogo has become known locally as "the man who stopped the desert" (Right Livelihood, 2023). Another local farmer, Oussen Zorome, began a "Zai school" with the resources he could gather, and by 2001, he had built a network of more than 20 schools and 1000 members, each group charged with restoring its own degraded land. In addition, in various villages, water levels in wells were found to have increased by 5 to 17 meters, providing year-round access to water in areas that previously faced severe water shortages. This improvement in water availability has been crucial in sustaining both agriculture and daily life.

Implementation and Scaling

The Zai technique usually suffers from its labor-intensive nature, and the shift to mechanized Zai can help make it a more viable solution. Mechanization can drastically reduce manual work to 12% while crop yields can increase up to 40% compared to the manual Zai method (Ati, 2024). The systematic pattern of seeding or planting in the Zai technique makes it easier to mechanize crop maintenance and weed control (FarmingAfrica, 2014), but the cost of acquiring and maintaining mechanized Zai equipment is often out of reach for small holder farmers who lack access to credit and capital.

Local Government support for Mechanized Zai technique is limited in Chad and mainly facilitated through collaborations with international partners - The World Food Program has helped implement various water-resource projects (WFP, 2024), providing equipment for digging Zai pits and building dams. Their work is part of a broader Integrated Resilience Programme designed to build infrastructure and sustainable food systems. The United Nations Development Programme (UNDP) has provided agricultural credit and microfinance for small farmers. It has also provided direct support like agricultural kits for Zai, and has supported initiatives to restore ecosystems in areas surrounding Lake Chad (UNDP, 2017). Collaboration with these international partners has helped small holder farmers implement mechanized Zai farming. Even if mechanized equipment is provided by these organizations, farmers may lack access to spare parts in the event of a breakdown. Furthermore, operating and maintaining machinery requires new skills, and adequate training for farmers is often unavailable.

As a result, long term reliance on these International partners is not a sustainable solution, and we should instead give agency to local farmers, respect their expertise and empower them by partnering with grassroots organizations. The success of Zai in Burkina Faso has proved that farmers can effectively coordinate, share knowledge, and support each other once they have the right solution and a success story to back them. Creation of smart-farming communities like Sawadogo's "market days" groups, with access to agronomists and non-profit foundations to help with occasional organization and financial support will help small holder farmers create and maintain their farms. Small holder farmers can pool funds to purchase and share essential supplies that would be too costly for one person to acquire alone. These include improved seeds, farming tools, and organic fertilizers like manure. Farmers can also work in groups to complete the arduous task of digging hundreds or thousands of zai pits more efficiently. These groups serve as social networks, where farmers teach each other best practices and adaptations of the Zai technique.

Finally, agri-AI businesses can donate their AI expertise for analyzing visual data from drones, cameras, and satellite imagery to monitor crop and soil health, detect pests and diseases, and assess the ripeness of produce. Projects such as Stanford's Sustainability Accelerator use AI and satellite data to create high-resolution soil moisture maps in dryland regions. This can help zai farmers understand water retention in their fields and evaluate the effectiveness of their pits. AI-powered agricultural advisory service, AgriLLM developed by CGIAR (CGIAR, 2025), provides evidence-based, context-specific advice to smallholder farmers. It can help zai farmers with everything from planting schedules to soil and water management. For larger-scale zai operations, autonomous drones like the aptly-named ZAi-Q100 (HKG,

2025) can help with precision crop monitoring and irrigation management. A grassroots ecosystem of small business in Chad for ZAi-drone rentals and pilots, modeled on grassroots solar-panel (WEF, 2024) ecosystems in the global south, can benefit from cheap connectivity options like Starlink. It can provide smallholdings farmers with low-cost crop-monitoring, livestock tracking, automated maintenance and harvesting services (Clarus Networks, 2025) for the lands they own.

For Chad to become a Zai success story, we need political, government, and institutional support along with socio-economic empowerment. Funding, improving agricultural policy and supporting the development of suitable technology are necessary. Policies should support locally led, grassroots organizations rather than imposing expensive, top-down solutions. This was reinforced for me recently when I attended a talk by Dr. Adam Seth Levine at the Global Health Leadership Conference at Johns Hopkins University (JHU-GHLC 2025). His Research4Impact organization shows there is an unmet desire in policy makers for collaboration with researchers (Cambridge University Press, 2019), and sustainable results are possible when our research is tailored towards helping local leaders and practitioners. Rather than individual ownership, a community-based approach can make machinery more accessible and affordable. Government policies can expand access to microfinance and agricultural credit, and so empower even more farmers to invest in mechanization and technology.

Conclusion

My research combines the cultural significance and scientific validation of Zai's mechanisms with the practical lessons of partnering with grassroots organizations for implementing Zai automation successfully.

My recommendation focuses on sustainable agriculture, but it opens the possibilities for so much more. Chad's farmers with the help of small local businesses could build a Zai-automation infrastructure around connected Zai-drone services and education, so that agri-AI farming is eventually democratized. It shows a way to modernize Chad's economy, allowing people to move beyond subsistence farming. It can result in communities that develop high-tech careers in areas like agricultural AI, creating opportunities that will shape the country's future.

Ultimately, every child in Chad deserves to know that their next meal is guaranteed. Through automated Zai farming - supported by international partnerships and local innovation - we can turn this vision into reality.

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