Geo-agriculture for Climate Resilience: Towards Pioneering Anticipatory Adaptation in Namibia

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SUMMARY

The impact of climate change on agricultural production in Namibia (and Africa at large) is worsening as a result of increasing loss of fertile soil and water scarcity thereby leading to food insecurity. Therefore, geo-agriculture emerges as a promising solution to food insecurity as an mitigative and adaptive measure that utilizes geological resources like rocks and minerals to enhance crop yields. Geo-agriculture offers benefits that align with key Sustainable Development Goals (SDGs), like zero hunger and climate action. This paper portrays the geo-agricultural dimension of climate change mitigation and adaptation. This is done by cultivating seeds to maturity in geological formations (with or without soil). As a result, farmers may utilize local geological resources, thus reducing their dependency on costly external inputs such as chemical fertilizers, which are harmful to the environment. Additionally, the implementation of geo-agriculture creates knowledge exchange and innovation within communities as farmers experiment with various geological amendments tailored to their specific soil and climate conditions. Therefore, this paper presents geo-agriculture as an anticipatory adaptive measure to help address the immediate challenges posed by climate change but also as a foundation for long-term sustainable development in Namibia and across Africa. Finally, the implementation of geo-agriculture promises a pathway toward increasing climate resilience and fostering sustainable development in Namibia and other similar situations worldwide.

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1. INTRODUCTION

Ripple et al. (2022) emphasized climate change as a widely acknowledged worldwide concern, albeit one that is perceived differently depending on a country's socioeconomic development. Several academics have stated that climate change is a complex issue with ecological, environmental, socio-political, and socioeconomic implications. Climate change, as defined by the Intergovernmental Panel on Climate Change (IPCC) (2019), is a long-term shift in temperature and weather patterns that impacts both mankind and the environment. Furthermore, the World Meteorological Organization (WMO) (2022) stated that Africa's climate has witnessed a greater warming trend than the global average from pre-industrial times (1850-1900). This paper explores the need to pioneer anticipatory adaptation with geo-agriculture in Namibia. The basic assumption behind the study presented in this paper is that the agricultural sector faces high climate change challenges. “The agricultural sector faces looming challenges including dwindling fertilizer reserves, environmental impacts of conventional soil inputs, and increasingly difficult growing conditions wrought by climate change” (Pratt et al., 2020: p. 1). Since dealing with climate change requires change in approach practical human behavior and factors that create it, any adaptative or mitigative actions against climate change in that sector could come from within (Chigbu, 2023a-b). Geo-agriculture presents an opportunity to utilize amendments to agricultural land as a means of engaging in climate action. The paper argues for pioneering anticipatory adaptation with geo-agriculture countries where agriculture is most negatively impacted. Namibia is one of such countries. The paper outlines the challenges posed by climate change to important sectors such as agriculture in Namibia and Africa, while introducing the potential of Geo-agriculture as a solution to enhance soil fertility and crop yields. It explores the benefits, challenges, and opportunities associated with Geo-agriculture adoption, highlighting its alignment with key Sustainable Development Goals (SDGs) and proposing strategies for its promotion and integration at household level in achieving sustainable development.

2. IN BRIEF: CLIMATE CHANGE IN AFRICA AT LARGE

Africa is vulnerable to climate change because majority of the population relay on agriculture, meanwhile, agriculture relies heavily on rainfall. Over the years, climate change has caused shifts in precipitation patterns, lowering annual rainfall (Mataya et al., 2020). Due to a heavy reliance on agriculture, and a lack of available adaptation options, Africa is anticipated to experience higher climate-related consequences. While many parts of southern Africa are expected to become drier and hotter, some locations of the continent (i.e., eastern Africa) are forecasted to experience different effects such as a reduction in crop production (Collier, Conway & Venables, 2008). In addition, according to The United Nations Framework

Convention on Climate Change (UNFCCC) (2020), 2019 was one of the three warmest years ever recorded for the continent. Also, in recent decadal forecasts', which cover the five years from 2020 to 2024, Africa will continue to warm up, with rainfall declining over North and Southern Africa while increasing in the Sahel. According to IPCC forecasts, warming circumstances run the risk of affecting food security and crop production (UNFCCC, 2020). This results in reduced crop output caused by heat and drought stress which in the long term may cause soil degradation, among other drivers such as deforestation, urbanization and intense agricultural activities. Soil degradation is the loss of soil quality or health caused by a variety of human or natural factors. It comprises a wide range of negative changes in soil attributes, including fertility loss, erosion, salinization, acidification, pollution, and organic matter loss. Soil degradation can have a negative impact on agricultural productivity, biodiversity, water quality, and ecological stability (UNFCCC, 2020). Sebsequently, a loss in mean yield of 13% in West and Central Africa, 11% in North Africa, and 8% in East and Southern Africa is anticipated under the worst-case scenario for climate change (UNFCCC, 2020). Due to their greater resilience to heat-stress conditions, millet and sorghum are the most promising crops, with yield losses of just 5% and 8%, respectively, by 2050. In contrast, rice and wheat are anticipated to be the most negatively impacted, with losses of yield of 12% and 21%, respectively (UNFCCC, 2020).

3. CLIMATE CHANGE SCENARIOS IN NAMIBIA

The land uses in northern Namibia regions are typically agricultural and livestock farming while these regions receive higher rainfall compared to the southern areas (Siyambango et al., 2019). Historically, the rainfall seasons were approximately experienced during November-December; however, due to climate variations recent years have witnessed a shift to January through April. This variation in rainfall seasons adversely affects period of cultivation, impacting household food security and diminishing overall yields, thereby impacting livelihoods (Personal communication, 10 February 2022). Variations in rainfall frequency have led to instances of scarcity, causing drought and subsequently reducing crop yields and livestock (Tjitemisa, 2019). The cultivation of maize meal, a staple food in northern Namibia, has notably declined due to the effects of climate change (Personal communication, 12 February 2022). Moreover, Folwell et al. (2006), stated that the increase in water demands is in line with projections that indicated reduced rainfall, increased evaporation, and a potential of 73% decline in dry season flows by 2080. For example, the discrepancies in rainfall distribution exacerbate water scarcity concerns, notably in the Omatako sub-basin. Understanding and addressing these intertwined factors are crucial for sustainable water management and ecosystem preservation. Namibia has a disproportion of precipitation, with the north-east receiving more than the west and south-west. About 2% of the precipitation that falls in Namibia is thought to end up as surface runoff, and just 1% of it is available to replenish groundwater (World Bank Group, p. 21, 2021). Furthermore, it is expected that the precipitation received over Angola and western Zambia will increase the flow of perennial rivers along Namibia's Caprivi strip. However, the inflow to the perennial rivers is expected to subside by 2050, with projections of between 10-20% rainfall over Angola and Zambia. Catchments of the Zambezi, Kavango, Cuvelai, and Kunene rivers are estimated to decrease by 25 percent of runoff and drainage in the river systems (World Bank

Group, 2021). Therefore, adaptation to climate change is crucial, considering the vulnerabilities and social-ecological dynamics of a region (Shinn, 2018). The existing approaches to adaptation often lack a comprehensive understanding of these intricacies, highlighting the need for a more transformative and anticipatory approach. This approach should prioritize the understanding of socially produced vulnerabilities and the contextual interplay between society and the environment (Shinn, 2018).

4. CLIMATE CHANGE AND LAND TENURE

Land tenure, as defined by Chigbu et al. (2022), incorporates the involved relationships between people and land, involving the exercise of rights, restrictions, and responsibilities over land resources. These tenure systems are shaped by a combination of historical and cultural factors, comprising customary and/or legal rights that individuals or groups hold over land and its related resources. They not only reflect but also determine the social dynamics within a society. According to Place and Hazell (1993), land tenure systems in Sub-Saharan Africa affect agricultural productivity, and argue that land tenure systems do not provide enough security for investments or for lenders to support such investments. In contrast, several studies have investigated and recommended land tenure to be a long-term climate change adaptive mechanism at the household level and for soil conservation practices for improved crop yields. (Mitchell & McEvoy, 2019; UN-Habitat, 2010; Chigbu et al., 2017 & 2022). Additionally, tenure security influences decision-making and behaviors at the household level, promoting soil conservation efforts which contributes to long-term community adaptive capacity (Larson & Dahal, 2012). In the same way, the adverse impacts of climate change on land use have effects on various livelihood practices such as agriculture, water management, forestry, and food systems, rendering human populations vulnerable to climate-induced changes (Sahana et al., 2021). Another essential point, is the abundance of scientific evidence highlighting climate change as a developmental challenge in various African sectors, despite Africa contributing less than 4% of factors (e.g., global greenhouse gas emissions) exacerbating the climate change crisis (African Union, 2022). Chigbu (2023a) noted that these sectors encompass agriculture, transport, energy, real estate, mining, and forests. Addressing the climate change challenges faced by these sectors necessitates the establishment of appropriate frameworks for land governance, with a focus on tenure issues, to facilitate both mitigation and adaptation efforts.

5. IMPACT OF CLIMATE CHANGE ON AGRICULTURE

The agricultural sector in Namibia contributes to the majority of the country's GDP, accounting for 7%- 10% of total GDP (World Bank, 2021). A sum of 70% of Namibia's population relies on rain-fed crop production for a living, while some rely on subsistence farming (GIZ, 2022). Climate change effects, such as low participation, drought, and shifting seasonal rainfall patterns, makes Namibia's agriculture sector vulnerable to climate change. Moreover, agriculture, faces high vulnerability to climate variability and change, particularly in low-income countries such as Ethiopia where it contributes a majority to GDP. Climate change impacts soil erosion, pests, diseases, and crop yields (Yohannes, 2016). The link between temperature change and crop productivity is evident, with changing precipitation patterns exacerbating water scarcity and creating difficulty in planning agricultural systems. On a global scale, climate change is projected to significantly reduce yields of staple crops by 2050 (Yohannes, 2016). In Sub-Saharan Africa, agriculture is central to livelihoods and economies, with increased variability threatening food security and economic stability. Urgent mitigation and adaptation strategies are imperative to safeguard agricultural sustainability and the welfare of millions worldwide (Siyambango et al., 2022). According to the Namibian National Farmers Union (2008), about 2% of Namibia's land receives adequate rainfall for crop production. Rain-fed agricultural output is heavily relied on, particularly by smallholder farmers in Namibia, who live in vulnerable areas susceptible to water constraints and environmental degradation. This makes farming systems more vulnerable, putting rural communities at risk of food insecurity and gradual poverty.

6. IMPACT OF AGRICULTURE ON CLIMATE CHANGE

According to the literature, agricultural activities are a significant source of emissions, directly accounting for 10-12% of global totals, which increases when land clearance for agriculture is considered (Andersson et al., n.d). The food and agricultural industry's energy use and transportation generate significant emissions. Therefore, agriculture contributes significantly to anthropogenic greenhouse gas (GHG) emissions, accounting for 30-40% worldwide (Yohannes, 2016). For example, agriculture alone accounts for approximately 80% of Ethiopia's GHG emissions. Directly (fertilized soils, livestock) and indirect (deforestation, fossil fuel) emissions are common and exacerbated by excessive tillage and fertilizer application. Nitrous oxide (N2O) and methane (CH4) emissions, from fertilizer use, are significant contributors to agricultural emissions, which has consequences for climate change mitigation methods. There is a need to reduce the environmental impact of agricultural operations while maintaining food security and sustainability (Yohannes, 2016).

7. UNVEILING GEO-AGRICULTURE

The concept of geo-agriculture is fairly new which is defined as the study and application of cultivating seeds to maturity in geological formations (rocks) with or without the use of soils and fertilizers (Pratt et al. 2020). Van Straaten (2002), provided a detailed explanation of the chemical composition of bedrock types that can be sources for nutrient supplements in farming practices. Subsequently, Edwards and Lim (2017) reviewed the potential of utilizing crushed volcanic rocks inter alia to mitigate against the effects of climate change. This is through the weathering of these rock types which results in the forming of minerals carbonate phases, taking up CO2 from the atmosphere, and can benefit agriculture. However, these studies do mention that these practices have drawbacks like environmental impact from mining and increased sedimentation during heavy rains. The Kunene Region in Namibia is characterized by distinctive agricultural geology, where geological features significantly influence the local farming landscape (Kunene Regional Development Profile – KRDP, 2015). The geological composition, including various rock types, like igneous, metamorphic, and sedimentary rocks, plays a pivotal role in shaping soil fertility and nutrient content and the region's well-drained soils range from sandy to loamy, offering varying degrees of fertility (KRDP, 2015). Moreover, mineral resources found within the rocks, particularly those rich in essential nutrients like potassium (K) and phosphorus (P), contribute to soil fertility when weathered over time. Understanding the distribution and composition of these minerals in the geological formations is essential for sustainable agricultural practices. In many African developing countries, replenishing the nutrients necessary for crop production is a significant challenge, driven by climate change-related vulnerabilities, cost constraints, and complex supply chains for chemical fertilizers (Ciceri & Allanore, 2019). Soil nutrient audits reveal a troubling trend of essential nutrients being depleted faster than they are replaced, which is unsustainable. To address this, a study by Manning & Theodoro (2020) mentioned that the use of crushed silicate rocks as a source of plant nutrients offers a promising solution. These rocks can slowly release essential nutrients like potassium (K) and mitigate issues of rapid leaching, making them especially suitable for deeply leached soils prevalent in the global south (Manning & Theodoro, 2020). However, the effectiveness of crushed silicate rocks depends on factors such as mineralogical composition and grain size. Studies have shown that in temperate zones with existing silicate minerals in the soil, peer-reviewed research has yet to definitively demonstrate the agronomic benefits of using crushed rocks (Manning & Theodoro, 2020; Ciceri & Allanore, 2019). This is in contrast with observations by farmers who often note positive effects. Nonetheless, in tropical soils, particularly in regions like Brazil, the use of crushed silicate rocks, especially when combined with organic sources, has exhibited the potential to enhance nutrient availability and crop growth (Manning & Theodoro, 2020). These findings emphasize the intricate relationship between rock-based soil treatments, mineral composition, and their impact on agriculture. It also suggests the potential of utilizing the geosphere as fertilizer for crop production instead of utilizing traditional and costly fertilizers. Thus, emphasizing the importance of considering geological factors when exploring sustainable practices for crop production in Namibia and beyond.

8. NEW OPPORTUNITIES FOR GEOSPHERE FERTILISER RESERVES AND CLIMATE CHANGE MITIGATION

Desonie (2007) defines geosphere fertilizer reserves as rocks and minerals such as nitrogen, phosphorus found in the earth's geosphere. These minerals can serve as nutrients for agricultural purposes (Desonie, 2007). There is a need for considerable adjustments in agricultural methods as a result of the concerns of climate change and soil degradation. Traditional fertilizers like nitrogen (N) contribute to environmental problems like ammonia emissions, nitrous oxide release, and nitrate leaching. Similarly, there is a large carbon footprint due to the energy needed for production. (Leng et al., 2015). Natural nitrogen sources from rocks and minerals could help address these issues. Certain rocks contain nitrogen-rich minerals that could be used as supplements to traditional fertilizers. These minerals have the potential for slow-release nitrogen. Likewise, traditional phosphorus comes from phosphate rock deposits, but these may be depleted within the next century (Manning & Theodoro, 2020). Certain types of rocks like granite and basalt naturally contain phosphorus and thus extracting phosphorus from rocks which usually involves using acids or heat. Another promising alternative to traditional phosphorus reserve is a mineral struvite, which can be found in natural deposits or created from waste streams (Pratt et al., 2020). Notably, geological amendments are widely available and less expensive than conventional fertilizers. Thus, minerals have the potential to address specific agricultural issues (Pratt et al., 2020). For example, olivine can store CO2 emissions and boost resilience to drier and warmer circumstances, whereas zeolites and iron oxides can minimize nutrient contamination in rivers and improve soil climate resilience. The significance of water retention and drought-resistant measures, such as the usage of zeolites, can improve soil water retention and boost drought resistance (Xiubin & Zhanbin, 2001). This is significant within the context of climate change, as extreme weather events, such as droughts, become more common and severe. These findings suggest pathways for mitigating greenhouse gas emissions from agricultural practices while also potentially improving soil fertility and thus improving agricultural practices.

8.1 Practical examples from Cameroon

Below is an example from the University of Bamenda in Cameroon wherein a novel approach was taken to improving food security and public health outcomes using geo-agriculture. This pioneering project is consistent with Sustainable Development Goal (SDG) 2 and 3, which aims to eliminate hunger and improve nutrition worldwide.

Source: Queen's Commonwealth Trust, 2021

Geological Agriculture (GeoAg), pioneered by Richard Campbell, offers a revolutionary approach to cultivating plants and vegetables without soil and fertilizers, aiming to reduce food costs and promote health. Driven by the vision of Dr. Ndamsa Dickson from the University of Bamenda (UBa), GeoAg has gained momentum globally, particularly in Africa, with partnerships formed with institutions like RADA (Reconciliation and Development Association). Collaboration with academic institutions across Africa and the United States has facilitated knowledge sharing and research advancement in GeoAg. Despite initial challenges, the project saw success in 2020, with the implementation of distance learning programs and practical training sessions. The Ministry of Agriculture in Cameroon has embraced GeoAg, leading to its successful implementation, with RADA urging collective effort for nationwide adoption. RADA, as a non-governmental organization, advocates for sustainable development through community problem-solving and employment creation, underpinning the transformative potential of Geo-Agriculture in Cameroon and beyond (Nsoh., 2021).

8.2 How geo agriculture assists with SDGs

The Sustainable Development Goals (SDGs) are a set of 17 linked global goals approved by United Nations Member States in 2015 as part of the 2030 Agenda for Sustainable Development. These goals aim to address global concerns such as social, environmental, and economic. While encouraging prosperity and conserving the environment. These goals aim to alleviate poverty, and enhance access to excellent education and healthcare, attaining gender equality, fostering economic growth and combating climate change. The diagram in figure 1, illustrates how geo-agriculture contributes to achieving several Sustainable Development Goals (SDGs) outlined by the United Nations. Through the implementation of geo-agricultural practices, such as utilizing rocks and minerals to enhance soil fertility and adopting innovative techniques like hydroponics to grow plants without soil, various SDGs can be addressed. For example, geo-agriculture promotes economic prosperity and poverty reduction by providing opportunities for income generation through the sale of geo-agricultural products and services. Additionally, it contributes to achieving zero hunger by increasing agricultural yields and improving nutrition, particularly in regions affected by climate change. Furthermore, geo-agriculture supports climate action by providing sustainable fertilizer options that reduce environmental contamination and help crops withstand drought conditions. Moreover, by promoting cost-effective agricultural production with minimal fertilizer use, geo-agriculture contributes to the goal of affordable and clean energy. The diagram highlight how insecure land tenure may act as a barrier to long-term climate change adaptation efforts. Overall, the diagram demonstrates how geo-agriculture serves as a multifaceted solution to address global challenges while aligning with the SDGs, thus highlighting its potential for sustainable development and environmental conservation.

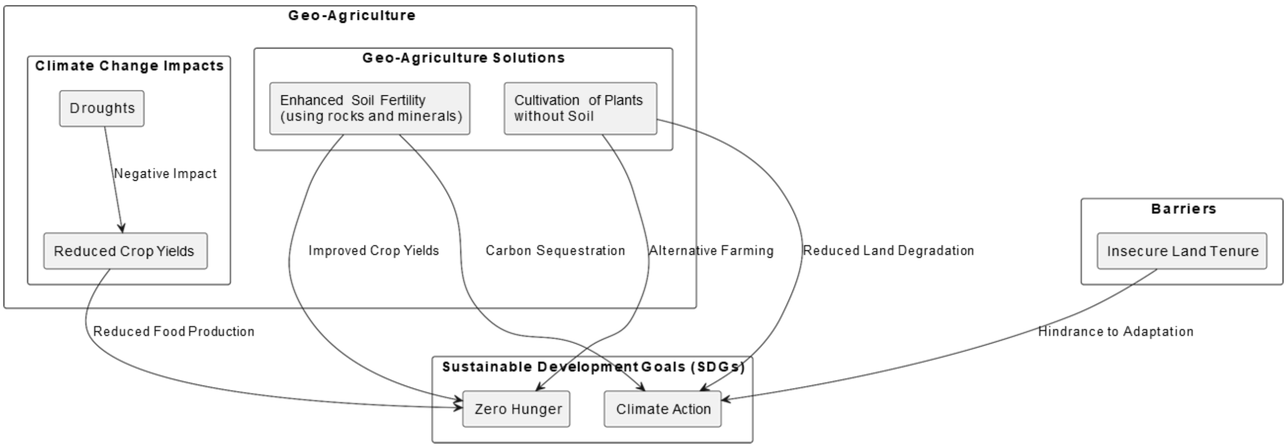

Figure. 1. Geo-Agriculture, SDGs, and Climate Change Adaptation
Source: Author

In reference to the pilot project in Cameroon, which aimed at promoting food security by reducing food costs and promoting health, therefore achieving some of the SDGs listed below.

- No Poverty: Educate on the skill of geo-agriculture and leverage geo-agriculture plant products and related services from home and earn income.
- Zero hunger: Potential to increase agricultural yields affected by climate change simultaneously enhancing nutrition.

- Climate Action: Offering new viable fertilizer options that reduce environmental contamination and assist crops to cope with drought stress such as the use of zeolite minerals.
- Affordable and Clean Energy: Cost-effective agricultural production with the use of less or no fertilizer.

8.3 The climate change benefits of geo-agriculture

Source: Queen's Commonwealth Trust, 2021

- No Soil Use
- No fertilizer Use
- Less watering requirements
- Auto-composing
- Improving organic ecosystem
- Attractive
- Durable lifelong use
- Capable of growing many plants types
- Cost efficient
- Sustainable
- High nutritional values
- Scalable

9. CONCLUSION AND RECOMMENDATIONS

Climate change constitutes negative impacts in Namibia. Among the effects experienced is droughts and long-term soil degradation which affect imperative sectors such as agriculture. As a result, countries like Namibia experience gradual reduce in crop production. This leaves small scale farmers vulnerable to food insecurity. Consequently, the geosphere abundantly consists of minerals that are essential for agricultural production. Certainly, for successful integration of geo-agricultural practices, possible barriers must be confronted. Firstly, these include land tenure, as previously demonstrated, lack of tenure has proven to cause the unwillingness of farmers to adopt long-term adaptation strategies such as soil conservation. Secondly, farmers may lack access to information such as soil/rock types, compositions and structures. And thirdly, farmers may lack or may be unwilling to educate on understanding of geo-agriculture and how it influences agricultural productivity. Hence, it is important for collaborative approaches such as government bodies, NGOs and local communities to streamline education of geo-agriculture. As well as offer training and workshops on practical implementation of geo-agricultural practices. Finally, geo-agriculture has the potential to assist with the SDGs, such as zero hunger, climate action and affordable and clean energy. In this way, the adoption of geo-agriculture promises a pathway towards enhancing climate resilience, assuring food security and promoting sustainable development in Namibia and Africa at large.

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