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Effective Strategies to Encourage the Cultivation of Sorghum and Corn in the African Sahel: An Analysis of Chad

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Abstract

The research explores traditional sorghum and corn cropping systems in the Guera region of the Sahel, focusing on social, economic, and ecological criteria. The region faces challenges due to its tropical climate, droughts, and land characteristics, affecting sorghum and corn cultivation. A comprehensive framework, developed in collaboration with national and international organizations, is needed to improve agricultural production in infertile land. Chad's smallholders use a low-tech, risk-averse rainfed system, but diversified techniques and new cultivation patterns can increase profits. Modern technologies and innovations can increase diversity and create new cultivation forms, involving scientific, commercial, credit, and industrial organizations. Chad faces severe water stress and crop yield issues, with up to 95% of water resources lost due to evapotranspiration. Proper water management techniques, assisted irrigation, efficient rainwater harvesting, and effective seed selection and crop management are crucial for improving agricultural production, reducing poverty, and ensuring the survival of the region's agricultural sector. Chemical poverty complicates crop management, but fertilizers and skips can improve soil and provide good cereals. Urea can be added to legumes to increase plant growth and nitrogen fixation, while microorganisms and mycorrhizal fungi can strengthen rhizobia and enhance plant recovery. Handling tradeoffs is crucial, as environmental shocks can lead to social consequences like hunger and unemployment. The Sahel region's sorghum and corn plant species face food production stagnation and chronic insufficiency due to increasing population and pests. Integrated pest management strategies and market access are crucial for smallholder farmers, but quality standards are weak. Public-private partnerships can improve value chains and market linkages, leading to increased farmer income, traders' income, and consumer prices.

Keywords

Sorghum, Corn, Guera Region, Sahel, Chad

1. Introduction

As in other parts of the world, a primary goal of African countries is the efficient exploitation of local resources and the improvement of crop yields, not only to ensure sufficient quantities of food and livestock feed but also to increase their income from the sale of the surpluses produced. In sub-Saharan Africa, most crops, such as cereals, are produced by family farms that are implemented at times of the year in which they have no off-farm occupation. These lines of work can ensure food security, improve the nutritional quality of the diet (detection of the causes of malnutrition and the development of strategies to combat them), and assess the productivity of the resources covering labor, land, water, and variability, among others. This knowledge is essential to ensuring not only the welfare of the population but also the sustainability of the ecological systems envisaged [1] [2].

The main objective of this research is to make a detailed examination of the traditional sorghum and corn cropping systems cultivated in the Guera region, defined according to social, economic, and ecological criteria, to propose to agricultural public bodies an improvement in the production and marketing of crops produced. Specifically, the objectives of the present study are: 1) the identification of the main cropping systems in the Guera region of the Sahel; 2) the identification of the agronomic practices in use in the traditional cropping systems of sorghum and corn; 3) an analysis and description of water use in traditional sorghum and corn cropping systems; and 4) an analysis and description of the related economic and social aspects of water use in traditional sorghum and corn cropping practices used in the Guera region.

1.1. Background and Significance of Sorghum and Corn Cultivation in the African Sahel Region

Globally, cereals are the most widely cultivated crops. Toward the end of the 20th century, most cereal production in the African Sahel region was subsistence without being treated as a marketable commodity. However, in the 21st century, the African Sahel region is in the midst of vast demographic changes, with a growing consumer market driving agriculture to produce for profit. This signals a transformation in the role of African Sahel agriculture, from providing food for oneself to producing crops for the market. Food security issues have become a national concern for Sahel countries. Against this backdrop, it is impossible to ignore the importance of cereal crops such as sorghum and corn, which form the backbone of African Sahel agriculture. These crops are daily necessities that provide critical nutrition and are the primary source of income for the majority of local smallholder farmers. It can be said that maintaining food security in the African Sahel

region directly hinges on the success of these cereal crops.

1.2. Background and Significance of Sorghum and Corn

Cultivation in the African Sahel Region Cereals are the most widely cultivated crops in the world. Animal husbandry, which utilizes cereal crops as the primary source of food, is also widely conducted. Today, as countries around the world work to improve their food security to keep up with a growing population, nearly 60% of arable land is being used to produce cereals in order to avoid food deficits. The region also includes the African Sahel, where the population is increasing rapidly. At the end of the 20th century, cultivation in the African Sahel region was largely subsistence, with little regard for marketable production. However, the poverty reduction framework of world institutions has driven African Sahel agriculture to produce for profit. National concerns over food security issues have grown, and African agricultural transformation is accompanied by substantial demographic changes.

1.3. Challenges Faced in Sorghum and Corn Cultivation in Chad

Chadian households rely heavily on sorghum and corn for their food, providing over 50% of their intake. However, production is declining due to factors such as unimproved seeds, lack of research, vulnerability to climate variability, pests, diseases, high costs, and lack of access to fertilizers. Small producers cultivate varieties that they can tolerate and accept, ensuring sustainable productivity without environmental or food security issues. Over 80% of harvested grains are alive, causing fungal damage, germination delays, and loss of quality. This business syndrome, coupled with sensitivity to mycotoxins, necessitates seed health and quality control. The lack of resources and support negatively impacts food security due to the high moisture and humidity of the grains.

2. Climate and Soil Conditions in the African Sahel

In the middle of the African continent, there is a belt of savannah called the Sahel. The region stretches from the Atlantic to the Red Sea, including southern desert areas and portions of central tropical Africa. The region enjoys a tropical continental climate in which two very distinct seasons occur: the prolonged dry season and short rainy season. Most of its countries are underdeveloped and rely primarily on agriculture and animal husbandry for both food and income. With the limited water resources that are available in the region because of climatic and geological characteristics, frequent droughts occur, and the region can only grow drought-resistant crops such as sorghum, millet, and cowpeas. Gross harvests in agricultural production are influenced by only water availability due to climate characteristics and land characteristics such as lithology, topology, hydrology, and soil type [3] [4].

This chapter discusses the current agricultural activities that are taken into account in the region and introduces a comprehensive framework that will improve gross agricultural production in infertile land with available land resources. The

rest of the chapter is structured as follows:. In Sect. 2, we present the current climatic and soil conditions of the region. In Sect. 3, we show the study area and then proceed to explain the rationale for the cultivation of sorghum and corn. In Sect. 4, we present the comprehensive framework of measures developed in collaboration with national and international organizations in terms of local conditions. In this work, we use remote sensing environmental change data to exhibit the feasibility of the comprehensive framework in the study area of Chad in Africa. Finally, Sect. 5 concludes the paper [5].

2.1. Characteristics of the African Sahel Region

The African Sahel is not only composed of semi-arid zones; it also includes Sudanian and Sudano-Sahelian zones, which have the ability to provide the required conditions for achieving the concept of rural development. The climate consists of two main seasonal periods when water is alternately abundant or rare. In most of the plains, rainwater is evaporated, whereas in wadis, rainwater flows and carries potential water and soil fertility with it. When properly managed, run-off water enables crop cultivation, and regeneration of dying vegetation and partially or completely fills the groundwater table to recharge wells. Though having the required ability to naturally produce, support and indirectly manage the conditions for achieving development, the African Sahel is extremely often mistakenly considered as needing to be developed [6].

The scarcity of water resources in the Sahelian zone of Chad resulted mainly from the 3 (drought) to 8 (normal period) temporary inter-basin surface and underground flow of water scarcity. This water scarcity promotes the predominance of destructive surface and sub-surface flows over constructive infiltration and transpiration flows. To achieve sustainable water resources management and reach the nearby unreachable United Nation's Millennium Plan of cutting by half the number of extremely poor people living on less than 1 USD/day and 65% of the population in rural areas who are poor, sustainable use of rainwater complementary to sustainable technique use is required. Success in agriculture is not only linked to plant tending but mainly to water control efforts [7].

2.2. Impact of Climate Change on Sorghum and Corn Cultivation

The African Sahel region, where the climate is already semi-arid, is prone to drought due to its geographic location in the northern hemisphere, located at approximately 15 to 18 degrees latitude. In the African Sahel region, it has been reported that residents have observed a decrease in rainfall and various changes in weather and climate. As a result, the region's agricultural management methods relying on traditional knowledge have been damaged, and cultivation has become difficult. African Sahel residents have experienced more climate change than people in other parts of the world. In Chad, March 20 is the day to sow sorghum and corn, considering the timing of the rainy season. However, it is becoming difficult for the people of the African Sahel to decide when to start cultivation due to the

impact of climate change [8] [9].

In 2007, for the people of Chad, who depend on rain for agriculture and livestock, year-end rain lowered the water temperature. As a result, an abnormally frozen rainy season began as precipitation. More unusual weather has occurred annually, including more frequent occurrence of irregular rainy weather, higher intensity rainfall, stronger winds from the north and south, early rain, and delayed rainy season. As a result, seasonal temperature and precipitation, which depend on the influence of the rainy season, also change [10].

3. Traditional and Modern Agricultural Practices

3.1. Current Agricultural Practices of Chad

Sorghum and corn are the major cereal crops in Chad, with other cereals grown in a rainfed system in northern Chad. Socioeconomics and agroecology are the two limiting factors in this study. Traditional farming systems in the Sudanian climate region often use rotational cropping with animal manure to enhance soil fertility. This method is profitable for crops, with low yields but regular positive marginal returns. Traditional root plows were produced by blacksmiths, and animal traction constrains seasonal labor. A single plow machine with one plow was efficient, allowing 1 ha of land to be plowed in three days [11] [12].

The majority of smallholders in Chad operate in a rainfed system with low technology and risk-averse practices. However, a case study showed that seasonal workers in the cereal rainfed system can benefit from diversified techniques and new cultivation patterns. These leaders showcased their products to neighbors, demonstrating the entire process from seed to sorghum production and the price they could charge for the grain. Managers had the right to select both experienced and relatively young seasonal workers, and the most profitable agricultural certification was awarded to cultivators working as laborers. Unique personnel wages, leadership programs, and long-term mentoring were provided to these workers. The profile of a vital partner was essential for corporate farming, supplemented by long-term mentoring or on-demand support and the attainment of commendable wealth, privileges, and designated posts. The case study also highlighted the importance of social farming, having sincere leaders from the most prosperous community, and a woman making key decisions. Household livelihoods are often entrusted to independent workers, considering the sustained growth of the younger generation's eating environment and national education media. The availability of programmers and additional measures during the first rain is a justifiable business investment to encourage devotion and extension of the land. Close links were found among other potential facilitators, including support for sustainable agriculture. Addressing the contributions of the female workforce requires valuing women and improving working conditions [13].

3.2. Traditional Farming Techniques in Chad

The soil in Chad is poor, contains very little organic material, and often suffers

from drought. Traditional farming techniques have evolved over centuries so that agriculture can continue even in these poor environments. Traditional farming methods have successfully utilized the texture and chemical properties of soil and adapted them to suit the natural environment and local conditions without using artificial inputs. Some of these methods can be analyzed scientifically and may be better suited for producing crops under such harsh conditions than Western practices. In order to raise agricultural productivity and contribute to the stability of agricultural management systems, it is important to understand the principles of survival that have produced these techniques [14] [15].

In Chad, soil preparation at the beginning of the dry season is carried out in preparation for sowing. The level ground is first weeded to remove unwanted vegetation. Since there is very little organic matter in the soil, any collected weeds are scattered directly on the ground. The soil in Chad becomes very hard, and it has relatively high concentrations of aluminum and manganese compared to neighboring countries, which have an aspect of Alansols. In other words, aluminum and manganese accumulated over a long period during which water dissolved silicates and leached out the silica, so that the resulting materials recrystallized as sheet silicates. In Chad, a gray soil surface layer about 20 to 30 cm deep is found atmospherically. One can extract proximity sometimes without pulling the soil [16].

3.3. Modern Technologies and Innovations for Sorghum and Corn Cultivation

Modern technologies and innovations for sorghum and corn cultivation. Despite the large share of the GDP and the considerable proportion of farmers engaged in traditional agricultural activities, sorghum and millet, which are grown in the African Sahel, largely remain household crops. The technology of their cultivation can be classified as traditional due to their productivity and labor intensity. Within the traditional technology of cultivation, household plowing tools such as a hoe, a ripper, and a plow are traditionally used. It is possible to increase diversity and create new forms of cultivation in household holdings largely by improving the intensiveness and efficiency of equipment use rather than acquiring new equipment: reducing the cost and labor intensity of agricultural operations, freeing up family labor for non-agricultural work, improving the quality, timing, and weather restrictions of agricultural work and seeding density, and improving agricultural production while maintaining a low level of production saturation [16] [17].

International experience shows that by involving scientific, commercial, credit, and industrial organizations and by using innovations and modern knowledge and technologies, it is possible to achieve a considerable increase in product productivity in the agricultural activities of rural households in African countries. At the same time, in developed countries, the collective efforts of farmers are aimed at solving strategic problems associated with the constantly growing world

demand for food products. This can increase the role of agriculture in the development of countries and the well-being of their residents. The rural family should be the driving force behind this process, using the most modern knowledge and innovations in production [18].

4. Water Management Strategies

In Chad, crop yields and water productivity are among the lowest in the world. Water is available to the majority of Chad's farmers only a few months each year; in the remaining months, water stress is extreme. Water stress is further accentuated by poor water management during the growing season. Up to 95% of water resources are lost by evapotranspiration after the crops are harvested [7].

4.1. Results According to the Focus

The BagréPôle could improve grain yields and water productivity by implementing proper water management techniques. This would enable better resource management and poverty reduction. The Pôle should focus on basic supports for sorghum to overcome constraints and increase productivity. Assisted irrigation techniques can enable income-generating activities during the dry season, reduce damage from floods and water erosion, and increase agricultural production. Flooding agricultural land with untreated water would improve water availability during the dry season. Sandbags should be replaced with sand, as it raises fluoride in the subsurface layer, negatively impacting soil quality and productivity. Experimenting with sorghum in the Bogho season could improve production. Cultivating maize and adding carbon to the land could also contribute to food security [19] [20].

4.2. Rainwater Harvesting Techniques

It is difficult to predict the nature and severity of the information gaps in existing information and data frameworks. Food production is, however, clearly at risk. A combination of techniques could overcome this situation, provided the performance of the techniques is carefully monitored and assessed. Long-term research and observations show, for example, that millet responds very little to inputs; there is no response to fertilizers and only a small response to water in deep soils. There are, however, opportunities for increasing adaptation and resilience by using long-term water storage techniques that reflect high rainfall variability. Such techniques are all based on variations or combinations and/or the timing of available water or the response of millet's activities [16].

That is the reason why the techniques of rainwater harvesting need an update in order for the smallholders to achieve adaptive measures to climate change that are robust between the random variations of the rainfall. Indeed, without the harvesting of rainwater, the early season will be dry and the level of the water table will remain low, while in the late season, when it does rain, the level of the water table will drop quickly under the use of soil moisture, making even the last rain un-useful [21] [22].

4.3. Irrigation Methods for Sorghum and Corn Fields

In the proposed region, the annual rainfall amount is about 500 mm, whereas the annual rate of evaporation is 2500 mm. The difference between the two values is an index of the water shortage. Although only drought-resistant crops such as sorghum and corn are cultivated in the region, the problem of insufficient crop production has not been completely solved. In this paper, we examine methods to efficiently cultivate fields and obtain abundant crops. Particularly, we focus on companies that support farmers in purchasing and utilizing water pump systems [23].

In the proposed region, the pipeline can be installed using small amounts of electric power obtained from a battery system charged with solar panels. There are three important factors for success: a reasonable price of water, running the water pump system 24/7, and the establishment of a company. Even when all conditions are satisfied, if the total price for the year cannot be repaid to the company due to bad harvest conditions, this business cannot succeed. Therefore, guaranteeing the functioning of the water pump system, *i.e.*, extending the years when total sales are performed, is an important duty for the company. The maximum sales are achieved when the water pumps are utilized not only from the time when the rain stops to the harvest time but also during the growth period from sowing time. They can provide irrigation services during this period [24]-[26].

5. Seed Selection and Crop Management

Selecting and storing good-quality seed depends on the farmer's resources and storage conditions. Traditional farmer-selected seeds are recommended, but commercial seeds may be used if low yields or other issues occur. Tests are recommended to detect and eliminate soil pathogens causing plant diseases. The best quality seed is large, good endosperm, and free of external damage. An average of 300 non-fodder seeds is recommended. Seed quality deteriorates more quickly when stored at high moisture content and temperatures. Low moisture content (10% - 11.5%) is effective for preserving seed longevity, as sorghum seeds typically last longer at 11% moisture content [27].

The Sahel region faces challenges in crop management due to chemical poverty, which can be addressed through various methods such as herbicides, hand weeding, and green mulches. Herbicides can kill or damage crops, while hand weeding is more beneficial for small farms with sufficient labor and community support. A scalping solution may be more desirable for larger fields. Combining both methods can be the most effective way to earn income. Cover crops or forage plants can also be beneficial. Green mulches are best suited for small plots under humid conditions. Fertilizers and skips can improve cereals' undernourished soils and provide good cereals. Urea can be added to legumes to increase plant growth and nitrogen fixation. Adding microorganisms and mycorrhizal fungi can strengthen rhizobia and enhance plant recovery. Handling tradeoffs is crucial, as environmental shocks can have social consequences like hunger and unemployment. Old tools and basic

planning can help bridge the gap and tackle the situation [28] [29].

5.1. Choosing Resilient Sorghum and Corn Varieties

In Chad, several projects are contributing to the renewal of seed systems and seeds' sustainability. They generally provide for the evaluation, dissemination, and use of improved varieties and hybrids. The first family of varieties to check is that of local seeds. They must be made more robust and improved thanks to more professional selection, by forming strong regional federative professional organizations in permanent collaboration with technical services, young rural technological enthusiasts, and naturally by developing a professional and modern approach to agro-meteorology, which is the future of agriculture on a planetary scale [30].

Choosing resilient lines for food crops in general and sorghum, in particular, is the best possible solution to plan and implement adaptation projects. These key suggestions must adapt and develop climate services and make them available to their members. It is also important to train permanent trainers to adapt themselves and to make this knowledge and knowledge-intensive to provide more professional services and build new cooperative enterprises, especially through service cooperatives [31].

5.2. Best Practices for Soil Preparation and Planting

To prepare the land for planting, the local farmer should sow at least two rows so that one can compare germination and yield on different soils. The neighboring stems (both ears or tassels) should be covered with bags or netting to prevent natural as well as artificial nearby cross-pollination. If the container is an ear, then the larger, male-line tassel should be detasseled before it develops (beginning at around V7seven leaves plus a few more). This would not be the case for the self-pollinated lines, but these should also be placed in groups of 5 to 7 stalks or more. When both the B (female) and R (maintainer) lines are present, the maintainer line can be used to both cross with the B line and produce the S1 seed [32] [33].

Because this paper is aimed at the non-breeding community, the protocol emphasizes savings in resources and labor and surveys practicable techniques. Although specific to sorghum, the methodology is similar in corn, except the receptor plants are usually corn plants with signs of corn earworms. Small, dark pupae on the ground in the area of the ears are a sign that earworms are present. Stations should, therefore, be placed at least 500 meters from neighboring plots. Also, they need to be marked and checked after every rain if the life stages of the earworm are to be estimated. If the goal is simply to cultivate seed, then all of these precautions would not be necessary [34] [35].

6. Pest and Disease Management

In general, the incidence of major pests and diseases is typically low in Chad, and

sorghum and millet have minimal fertilization requirements. "It is considered unnecessary to use fertilizer on sorghum in Chad, often even on millet too, because the aim is to have crops that can flourish in poor soil." However, the same crop would manifest different growth patterns in areas where water was available. There is some research showing evidence of a reversion of the green revolution; e.g., a survey of Chadian commercial farmers revealed that the first generation of farmers to receive government assistance in the form of subsidized inputs felt they had been pushed to grow hybrid plants without having had the opportunity to adapt them to local constraints [36].

For aid to have an impact, it is important to work with local solutions that are well-adjusted, as well as tools that allow the identification of resistance to pests and diseases in cultivated plants that have a big potential for use. Mbow and Sensi from ICRISAT showed results from a project to develop resistance to ergot (a disease normally associated with wheat), as well as photosynthate partitioning, which could explain how the resistance was expressed, which would correlate with mycorrhizal inoculation. As many completely safe adaptations can be applied, such as breeding for broad-spectrum resistance, altering planting times, and changing growth durations, it is important to assess potential agricultural harm if the products would be sufficiently widespread to affect other areas [22] [37].

6.1. Common Pests and Diseases Affecting Sorghum and Corn

Andropogon sp. (sorghum) and *Zea mays* sp. (corn) are two plant species cultivated by the majority of the Sahel's farming population. Their major importance is based on the food value of their grains. In Chad, the opposing pressure of increasing population on the one hand and food production stagnation or even decrease on the other hand leads to chronic alimentary insufficiency despite great efforts. Several reasons may account for stagnation and yield decreases: delayed onset of the rainy season in the sub-equatorial zone of the South, fear of an early wet season, lack of variety, even of tillering plants [38].

These two species are exposed to many parasites. The variety of these pests and the high percentage of attacks by them are not only explained by a lack of plant health care at the farming level (tillage) or by the microclimatic habitat of these parasites (high humidity in May–September or even until November), but also by the extensive use of the same morphology for planting by humans. This latter observation is evidence of the quality of the cereal. Based on original field observations made in many places in the Guera and Salamat Subdivisions and also from reading the works of other authors from the same region, an analysis of these two pest families is made, and particular emphasis is given to their reducing-action methods to preserve harvests [39] [40].

6.2. Integrated Pest Management Strategies

One of the solutions to reduce damage and capitalize on the genetic efforts promoting the traits for resistance to maize and sorghum pests may be to promote

integrated pest management based on available knowledge validated and proposed to producers in synergy with disease- and insect pest-tolerant genotypes. If negative correlations between grain diseases, stem borers, and reduced stem lodging damage have been observed by breeding programs, and damage is still too high in farmers' fields. Among the broad approaches to integrated pest management, the use of intercropping, trap crops, and early maturing varieties were the recommended strategies to reduce pest damage and infections on cereals in the mixed cropping system, which is largely practiced in the region [41] [42].

For grain diseases, we have no data or information on the importance and damages that these diseases could induce, such as the damages caused by stem borers. We observed an abundance of grain diseases at the flowering and grain maturity stages, causing variable degrees of symptoms. No clear differences in disease severity have been noticed between the cereal species involved or between proximity effect and variety in the farmers' fields where the experiment has been established. The high abundance and potential severity of the disease observed in these fields and the symptoms presented could impact variety in evaluation trials, underestimating treatment effects. It is necessary to include grain diseases in a variety of evaluations through the screening of both grain diseases and pests because resistance to lodging traits is linked [43].

7. Market Access and Value Chain Development

Market access and developing demand are central elements to the success of smallholder farmers. A strong market is essential to further strengthen the potential of the productive capacity of the food system and to mobilize further investment and economic growth in the agricultural sector. The sorghum and millet market is not only important for the economy but also helps provide food security for Chad by giving households access to essential agricultural commodities. Strategies aimed at improving the production and marketing of these products in the country are essential. Chad's millet and sorghum markets are important because of increased demand from consumers, high household consumption, climate risk tolerance by producers, and competitive pricing compared to wheat and rice [44].

In the 1980s, Chad's cereal economy underwent major policy reforms affecting all stages of a cereal production enterprise. These strategies were implemented through coordinated efforts by various groups, such as agricultural consultants, government agricultural agencies, and public health programs. Technical advice and financial support from international organizations have played a key role in achieving this. Processing businesses are in less developed clusters in the Nile Valley, and as a result, even though the FCA moved up to the border with the Republic, the business relationship between producers in Chad and Sudan can be considered weak at best. In 2004, the main businesses on the border were the gross markets, handling Khartoum's trading activity, where merchants sold about 80% of the initial shipments [45].

7.1. Market Opportunities for Sorghum and Corn Farmers in Chad

This review of sorghum and maize revealed that both value chains in Chad are largely informal. Quality standards are less stringent, are largely defined by cross-border trade policies for maize, and do not include herbicide use. Quality controls are weak in both staple value chains, and much of the staple produced is for subsistence purposes. The main target markets for both cereals in Chad are Senegal, the Central African Republic, and Nigeria. Yet the preference for maize and sorghum produced in the country is for and benefits the consuming countries, such as Nigeria [46] [47].

Findings from the recent value chain study in Chad, topped up with our limitations of the current research, highly recommend policies that enhance backward and forward linkages among market participants. These participants include producers, processors, other market intermediaries, and service providers. Such linkages are essential for enhancing the creation and sustenance of competitive markets, the effort to promote sorghum and maize production in Chad, and the move to a more inclusive development of the agricultural sector in the country. In light of the predominance of participants in the cereal value chains taking place in Chad, public-private partnerships would have to play a key role in the implementation of such targeted policies [48].

7.2. Improving Value Chains and Market Linkages

In Chad, sorghum and corn value chains present opportunities for poverty reduction. It is, therefore, necessary to increase the efficiency of these chains. This can be achieved through the following approaches: 1) Improve the storage at the production level; 2) Implement targeted and integrated support for the promotion of sustainable and profitable agricultural enterprises; 3) Reduce the losses incurred by grain collectors and traders; 4) Modernize transformation techniques through the use of more efficient equipment and better-mastered mechanization; 5) Improve the structuring of value chains by promoting collective marketing; 6) The promotion of agricultural insurance should be supported; 7) Links with international markets should be fostered [49].

This article demonstrates that business development services and support for collective marketing of agricultural enterprises are the keys to increasing the efficiency and competitiveness of these value chains. The findings indicate that strengthening the productive capacities of agricultural enterprises and creating an enabling environment for entrepreneurship and cooperative organizations result in gains in terms of price and revenues for farmers, higher income for traders, and lower prices for consumers. This article shows that through these strategies, countries can induce the development of the entire value chain, in which resources are allocated to the most efficient enterprises and the wealth generated is distributed in an equitable manner [50] [51].

8. Gender Inclusivity in Agriculture

Efforts to transform the agriculture sector to be more productive and inclusive

not only require ensuring access to resources and knowledge sharing for smallholders and agripreneurs, but they also need to unlock the potential of female farmers, who represent a significant but mostly untapped portion of the agri-food value chain. The socio-cultural aspects of agricultural activities are still very linked to gender roles that lead to an unequal distribution of crop value along the agri-food value chain. To overcome this, effective communication, technical information, and training should be developed and made available at the right place, at the right time, and in the right format to better meet the needs of target end-users, taking into consideration women's education, experiences, access, and control over resources [4].

Specific extension services that train women to acquire new ICT/solar equipment maintenance and repair skills may be developed, and approaches targeting all family members leveraging the peer-to-peer effect of innovation may be adopted to facilitate gender inclusivity in agricultural productivity increases. E-participation and e-inclusion will increasingly become the focus of the participatory monitoring and management of the agriculture intervention to support agri-women coop and "self-help group" transformation, as well as to enhance the awareness and proactive participation of agri-women in decision-making processes. E-mentoring, voice, and access to finance and market services for women may also be facilitated by taking care of digital literacy and user experience and improving e-communication and e-transaction security. To ensure sustainability, women's social and personal highly motivating needs or preferences related to natural resource preservation and the fight against climate change may be addressed by introducing a social dashboard that highlights successful gender inclusion practices [52] [53].

8.1. The Role of Women in Sorghum and Corn Production

Cereal production in Chad is a challenge due to rain scarcity. Only 5% of the cultivated surface is supported by irrigation. The principal crops have low active-water requirements to adapt to the drought. Of these, sorghum is the crop that is best adapted to the demands. Sorghum responds to adverse climatic conditions and the degree of fertilization by reducing the productive cycle and producing an acceptable yield [36].

Rain-fed sorghum is generally considered to be a woman's crop, whereas sorghum produced under irrigation is a major crop. The labor of men and women is necessary at various stages of sorghum and corn cultivation, in traditional practices as well as modern practices. This includes land preparation, sowing, watering, fertilization, weeding, sorting, harvesting, and storage [54].

It is important to deliver an effective irrigation method to maximize the yield of sorghum or corn. In Chad, during a drought period, using water effectively is important because only the traditional rainfed agricultural practices have been used for sorghum production until now.

The water footprints of sorghum and corn plants were evaluated to determine

the most suitable sorghum to plant with different types of corn. Water-use strategies suitable for sorghum and corn were determined using a combination of qualitative and quantitative experiments [55].

8.2. Empowering Women Farmers through Training and Resources

Playback can be considered an area in which women have more experience, but mechanization is in its infancy, and it is more and more likely that cereal production is mechanized. It is essential that all family members make efforts to take charge of this activity in order to promote greater production and respond better to market needs. To do this, work sessions to implement the best methods must be organized together. This is an opportunity for the development of the E.P.A. to develop the roles of each family member involved in this activity (husbands, wives, students, unemployed, farm workers, etc.). If one of the spouses does not wish to take charge, the other spouse must explain to him the importance to the family of ensuring that the mechanization of sorghum production is carried out on time. It is therefore essential to help everyone ensure an equitable division of labor in the practice of mechanization, planting, and harvesting [56] [57].

This can also be implemented in a group: women alone or men alone, especially if the workers in the port are not practical and if their mechanisms leave something to be desired (implements of tines or low-quality rakes, work done by untrained workers, etc.). In this case, these groups could have a gender orientation, training course, and performance (mechanization work, soil preparation, planting, weed tilling, and maintenance of the machinery). The main advantage of this group of services would be the opportunity to cover a portion of a farm for all households to be involved in these significant activities. It also provides the possibility of creating social tailoring mechanisms for women or men who need them, with career paths consistent with the members of the identity group [58].

9. Policy Recommendations and Government Support

Chad's government supports efforts to grow and distribute improved sorghum and corn seeds, which are grown at various research stations in the desert country. As rainfall in Chad's Sahel region decreases, farmers are moving to rain-fed areas. As climate change impacts farming, NGOs and host country governments must offer additional support to farmers. A study analyzed how historical DEnKF soil moisture predictions are linked to crop failure in Chad's Sahel region. The researchers found that using land for sorghum was the best use for land considering economics, stakeholder preference, ecosystem services, and independence from major agricultural systems. The DEnKF results indicated that genetics and the environment are the primary factors affecting cereal yields. Using ethnobotany to identify climate impacts on targeted populations of Jeanes' sorghum and traditional corn through the DEnKF may provide a reasonable method to help predict occurrences of the international refugee crisis.

9.1. Existing Agricultural Policies in Chad

The Chadian government needs to intensify efforts in developing agriculture to increase food security and meet the needs of the sorghum and millet grain-producing population. This can be achieved by encouraging financing and establishing reliable representation programs. The focus should be on addressing issues like lack of organic and inorganic fertilizer, tools for improving crop conditions, and lack of agricultural development policies. Despite the government's privileged position in agriculture, results are timid, with only support for small producers and inadequate financing for agricultural sector activities.

9.2. Proposed Policy Interventions to Support Smallholder Farmers

Chad's low input and subsistence cereal production necessitates traditional methods to increase yields without expensive fertilizers and genetically modified seeds. Traditional beliefs promote the intercropping of sorghum with Benne and Vigna unguiculata and a balanced diet. However, corn and sorghum failure rates are high, and more efficient farming practices are not explored. Traditional knowledge may be lost with each generation, and the increasing use of pharmaceutical artificial medicine may obscure ancestral health knowledge. In Chad's Sahel region, this hinders public ambition and championing of traditional knowledge.

10. Conclusion and Future Directions

The Sahel and Savannah ecologies are increasingly important for global food security and climate change adaptation. Pilot activities in Chad have identified practical solutions for sorghum and corn production, using innovative plant breeding and data tools. These adapted varieties offer pathways to improved food and nutrition security and poverty alleviation. The pilot experience has led to discussions with potential actors, including seed companies, financial institutions, public-private partnerships, and international investors. The focus is on simplification and better quantification of risk-benefit relationships, improved communication, and targeted scenario-based future studies. Constructive feedback from a larger community of stakeholders is crucial for consolidating and scaling-up activities.

10.1. Key Takeaways from the Study

Crop calendars in semi-arid regions like the African Sahel are crucial for crop growth and maturity before interannual droughts. These calendars are not just about farming but also serve as risk management strategies for households living at the subsistence level. Early cash collected from cotton can be used to purchase essential goods and services for agricultural activities, reducing vulnerability more effectively than increasing spending on subsistence items. Support for agricultural production mechanisms specific to the region is needed for small-scale farmers, and even simple changes in seasonal agricultural support schemes can yield better returns from agricultural investments.

10.2. Areas for Further Research and Development

This chapter discusses the African Sahelian region's agricultural systems and natural resource manipulation, focusing on Chad, Mali, and Burkina Faso. The region's farming systems are flexible but lack conservationist support. The chapter examines the role of sorghum and maize in Chadian agriculture, highlighting population growth, land use, diversification, technical opportunities, and conflict with natural resources. African agricultural areas must adapt to rapidly expanding populations through sustainable agro-ecosystems.

Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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