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A Technological Perspective of Bringing Climate Change Adaptation, Disaster Risk Reduction, and Food Security Together in South Africa

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Abstract: As disasters and climate change risks, particularly droughts and floods, continue to affect food security globally, most governments, including South Africa, have resorted to the use of technology to incorporate climate change adaptation and disaster risk reduction to address FS issues. This is because most institutions and policies that address climate change adaptation, disaster risk reduction, and food security operate in parallel, which usually leads to the polarisation of interventions and conflicting objectives, thus leaving the issue of FS unresolved. The study aimed to investigate how food security projects are incorporating climate change adaptation and disaster risk reduction using technology. A qualitative research design was applied, whereby in-depth interviews were conducted with ten project participants from two projects, while 24 key informants were purposively selected from government and research institutions. The study's main findings revealed that both projects incorporate climate change adaptation and disaster risk reduction measures in most of their food value chains. Although the projects are different, they still face similar challenges, such as a lack of expertise, resources, and funding, and an inadequate regulatory environment to improve their farming practices. The study brings in the practical side of addressing the coherence between food security, climate change adaptation, and disaster risk reduction through technology.

Keywords: climate change adaptation; disaster risk reduction; food security; Sentinel-2 Earth observation technology; hydroponics farming technology



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1. Introduction

In recent years, many developing countries, including South Africa, have seen a rising adverse impact of climate change and disaster risk on their agricultural sectors [1–3]. Reduced output is one of the most direct ways climate change and disasters influence the food sector. This results in direct economic losses for farmers, which can ripple across the value chain, limiting agricultural growth and rural lifestyles [4–6]. Climate change and disaster risks manifest themselves in various ways, including heavier and erratic rains, rising temperatures, and prolonged and frequent droughts [7,8], all of which have a significant impact on the agricultural sector. Between 2004 and 2014, the global risks and costs related to climate change's effects on agricultural productivity—including crop and animal losses from droughts and flooding—surpassed \$100 billion USD [9]. To make matters worse, various studies have projected an increase in the magnitude and frequency of disasters, especially floods, due to continued global warming [10].

Sub-Saharan Africa (SSA) is expected to be the most negatively impacted of all the developing regions because of its high reliance on rain-fed agriculture and high temperatures [11]. For instance, only 5% of the region's total cultivated area is made up of irrigated agriculture, compared to 14% in Latin America and 37% in Asia [11]. In particular, the [12] predicted that, by 2080, agricultural productivity in SSA would decrease from 21% to 9%.

Furthermore, a lack of rainfall and drought are expected to cause the loss of around two-thirds of Africa's agricultural land by 2025 [13]. This means that South Africa is not immune to the detrimental effects of climate change and variability and the threat of disasters [14].

The Long-Term Adaptation Scenarios (LTAS) (2013–2014) for South Africa [15] estimated a 25% reduction in annual maize yields and a shift for the growing areas of field crops (e.g., sugarcane, wheat, barley, sorghum, maize, and soybean) by 2050. The LTAS further estimated that possible land degradation [16] population increase [11] and loss of growing areas to development [15] will continue to negatively impact food insecurity up to 2050. However, of all the strategies, the frameworks and themes that have been developed to interlink food security (FS), climate change adaptation (CCA), and disaster risk reduction (DRR) policies, the existing literature focuses mainly on the theoretical elements of merging FS, CCA, and DRR, with much attention paid to the commonalities and differences, convergence points, and limitations associated with addressing these issues in coherence [17,18] thus neglecting the practical actions, such as the use of technology or innovations that could help bring the CCA, DRR, and FS policy areas or mechanisms together. Hence, attempts to develop food security must consider the issue of technology to meet its growing demand for FS under increasingly severe climatic change [19] while bringing coherence to FS, CCA, and DRR. Against this backdrop, various technologies were developed worldwide, including South Africa, which is heavily dependent on weather forecasts to overcome extreme weather events and climate change disasters to improve FS [19].

The most prominent FS projects adopted in South Africa include the Urban Agricultural Initiative (UAI) Food Security Project Using Hydroponics Technology and the Western Cape Sentinel-2 Earth Observation (Sentinel-2 EO) technology agricultural project, which incorporate CCA and DRR measures to improve FS. Since some researchers might advise on the use of virtual technology trade, which is, buying cheaper imported food to compensate for technology investments made elsewhere [20] this study chose technologies that can be used by ordinary South Africans to feed themselves. In addition, these projects were selected because of their relevance to the South African environment (arid-semi arid region) [21] including the context of affordability, accessibility, and applicability [22]. Although the concepts of Sentinel-2 EO and hydroponic farming technologies are still at the inception stage in South Africa, this study first investigated how the projects are incorporating CCA and DRR measures in addressing FS in South Africa. Second, the study explored respondents' experiences in terms of the challenges and opportunities associated with the technologies in their respective areas, and, lastly, discussions and conclusions of the research are given.

2. Agriculture Technology That Incorporates CCA and DRR Measures for Improved FS: A Literature Review

The use of agriculture technology as part of the climate-smart agriculture initiative worldwide has recently gained traction [23] and is helping to bring FS, CCA, and DRR together through the creation of databases that share information across relevant sectors [24]. The findings from the [25] have shown that the Internet and Big Data technology could bridge the gaps in communication and connectivity between sectors, thus improving the interaction and access to information between farmers and DRR/CCA practitioners. According to [22], the application of agricultural technology has resulted in the creation of a single-unit system that carries multiple sub-systems for optimal performance, including farm management, seedlings, farm machinery, forecasting, the monitoring of the vegetation and risks, and irrigation. These technologies bring a synergy between all farm units, which helps address a broad spectrum of all agricultural issues, including CCA and DRR. This technical advancement is argued to be the underlying driver of economic and social growth and is projected to drive global economic and social revolution [26]. It is anticipated that the Fourth Industrial Revolution (4IR) will bring about improvements in living standards,

increased agricultural output, and increased consumption and per capita income due to the usage of technology [27].

The 4IR is a term coined by Klaus Schwab [28], who describes it as integrating computation, networking and physical processes that include Internet communication infrastructure, Big Data, 3D/4D printing, and robotics. African nations are utilising digital financial tools to enhance agricultural value chains and create more robust trading markets to adapt to the 4IR [29,30]. Examples of such initiatives include the Kilimo Salama rain-fall insurance program in Kenya, which accepts payments via mobile money, M-Shamba in Kenya, the Ethiopian Commodity Exchange, and the digital crop market known as “Kudu” in Uganda [31]. Thus, the 4IR endeavour brought about a synergy between all units on the farm, which can help address a broad spectrum of all agricultural issues [19], including CCA and DRR measures. However, adopting agricultural technology and its application in SSA, including South Africa, has been inconsistent, yielding only limited economic and social transformation [32]. Refs. [33,34] contend that this is because there are insufficient courageous individuals (entrepreneurs) who can drive innovative thinking to bring technologies to the market for the growth of the agricultural industry, as well as the costs associated with both socioeconomic environments [35]. Ref. [30] argued that, when offered the chance to implement a new agricultural technology, farmers must always convert knowledge about the technology’s performance under particular conditions to an estimate of how well it would work on their farm under the prevailing government laws. In other words, agricultural technologies should be attuned to the terrain, weather variations, climate change, and disasters, including the biological and physical peculiarities of the region [30].

The success of adopting technology in South Africa has been centred on the ability of the technology to incorporate CCA and DRR measures in its practices [36]. Therefore, this study puts more focus on how the Sentinel-2 Earth Observation technology and hydroponics farming technology are incorporating CCA and DRR measures when addressing FS. As a point of departure, the Sentinel-2 Earth Observation technology is discussed.

2.1. Sentinel-2 Earth Observation Technology

Sentinel-2 is a European Space Agency earth observation satellite mission designed as part of the Copernicus Program to make terrestrial observations in support of a variety of services, including agriculture [37]. Due to its 10–20 m spatial resolution, a five-day return frequency, worldwide coverage, and integration with Landsat expeditions, the Sentinel-2 mission widens the possibilities for global to regional agriculture surveillance [37]. Studies that have looked at the use of the Sentinel-2 Earth Observation (Sentinel-2 EO) technology in agriculture have observed that the technology provides data on vegetation phenology and growth [38], burned areas, and active fires [39]. It can also monitor agricultural activities to strengthen food production information and market transparency [40], while improving crop types and classification in both commercial and smallholder farmers [37,41]. The technology helps to bridge the gaps in communication and connectivity between sectors or farmers to improve their farming practices [25]. The report given in [42] by the Korea Institute of Planning and Evaluation for Technology in Food, Agriculture, and Forestry [22] emphasises that the transformation of the food sector using agriculture technology that uses satellites has helped farmers to communicate frequently and share information, especially with those in climate change and disaster-infested areas. In South Africa, [36] argue that the use of satellites could help farmers who practise rain-fed subsistence agriculture to have access to information that can increase their yield in the agricultural sector. This means that the incorporation of CCA and DRR measures into FS would be made easier.

However, the setbacks of Sentinel-2 EO could be the difficulties in taking images acquired for monitoring purposes if the weather is cloudy [43]. Such drawbacks could delay or affect a whole series of data that most countries, including South Africa, depend on. In addition, the technology presents the challenge of data interpretation by farmers

who have no knowledge of satellites. Thus, [19] suggests the need to train farmers and relevant stakeholders who benefit from the technology.

2.2. Hydroponics Farming Technology

According to [44] hydroponics farming technology has the capability of reducing the carbon footprint while providing a means of achieving sustainable food production for the coming years, especially in urban areas. This technology was influenced by the urban population increase, the requirement to grow food close to customers [45] and the need to supply city markets with agricultural products that are fresh to achieve FS [46]. According to [44], hydroponics agriculture is a type of farming that use artificial structures to shelter crops from the adverse impacts of climate change and disasters. In South Africa, hydroponics farming was introduced in the late 1970s by Don Bilton through the “Nutrient Film Technique” (NFT), which uses gravel in beds lined with plastic instead of purified nutrient solutions [47]. Hydroponics farming is effective under diverse climatic conditions, mostly associated with droughts, floods, and extreme weather events. By implementing CCA and DRR measures, such as water-saving irrigation technology, it limits the runoff of water and minimises evaporation while using fewer or no chemicals that could affect the groundwater table [48]. This increases the yields, performance, and ready availability of food [47,49]. Research by [50] has shown that hydroponics in a protective system is a good alternative for the preservation of water resources and the reduction of pollution in open-field farming systems. Other studies by [51,52] have found that hydroponics farming influences direct marketing networks for small- and mid-sized farmers as alternatives to mainstream channels and they form part of the multi-livelihood strategies for urban survival without the clearance of vegetation, thus adding green elements to cities. According to [44], the cost of operating the infrastructure to provide water to the plants and maintain the proper growing temperature for the crop is likely to be more than the cost of operating a typical farm unless the operators can figure out a method to use renewable energy sources to support themselves. Furthermore, according to [44], farming technology is still unable to produce a wide variety of fruits and vegetables, and obtaining the desired economic return is constantly hampered by the cost of land in metropolitan areas and the requirement for highly skilled workers.

3. Methodology

The fundamental component of the study is its methodology, which discusses the relationship between theoretical concepts and practical testing [53]. Below is a description of the methodological approach taken to collect and analyse data for the study.

3.1. Case Selection

The study was conducted with FS projects within the Johannesburg Metropolitan City and Western Cape Province in South Africa. These two cases were selected because they are locations with higher populations compared to other parts of South Africa, with increased food consumption and susceptibility to disasters and climate change [54]. In particular, Johannesburg is located in Gauteng Province, which is South Africa’s industrial and commercial hub. It has a population of about 5635 million people as of 2019 [55], and it contributes 33% of the country’s GDP [54]. The city is characterised by unequal access to land, urban poverty, rising unemployment, insufficient housing, and basic amenities, which is a significant legacy of racial segregation era [56]. Additionally, Johannesburg is prone to climate change and disaster risks such as flood risks that are frequently caused by heavy precipitation occurrence, which are expected to rise in magnitude and frequency [54]. In the end, climate change has affected the ability of people to engage in the urban economy (e.g., destruction of crops and infrastructure used to transport food to the cities), resulting in a lack of access to food [54]. However, the study was driven to concentrate on the Western Cape Province due to predictions made by [57,58] of increased impacts from climate change in the region.

The Western Cape is biophysically distinct from the rest of South Africa, which is similar to that of Mediterranean-type climate [57]. The area is subject to climate extremes such as floods [59] and droughts [60] which have affected the food sector [59]. For example, the hailstorm in August 2006 destroyed seven farms and damaged 389 hectares of fruit trees, resulting in 9.4 million Rands in direct damage costs [59]. Noticing the negative effects of climate change and disaster risks on agriculture, which would have serious implications in ensuring FS in the two regions [61], it was necessary to investigate their primary agriculture strategies to provide lessons that other provinces and the country could apply at large.

3.2. Data Collection and Analysis

This study utilised a qualitative research design, including a literature review relating to hydroponics farming and Sentinel-2 Earth Observation technology in the context of South Africa. In addition, in-depth interviews with respondents from the Sentinel-2 EO and the Urban Agricultural Initiative (UAI) projects were conducted. The interview guide comprised 20 questions which targeted the two food security projects using Sentinel-2 EO and hydroponic farming technology. Main questions were about the background of the projects including their vision in terms of food security. Other topics focused on how the technology was adopted, and benefits and opportunities brought about by the technology including the challenges associated with the technology. Purposive and snowball sampling were employed to choose respondents, whereby three project managers were chosen from each project using purposive sampling. Snowball sampling was achieved when the identified managers would be requested to recommend two suitable project beneficiaries [62].

Further, key informant interviews (KIIs) were conducted with 24 purposively selected respondents from eight institutions, including the Department of Agriculture, Land Reform and Rural Development (DALRRD), National Disaster Management Centre (NDMC), Water Research Council (WRC), Agriculture Research Council (ARC), Agri SA, and the Department of Environment, Forestry and Fisheries (DFFE), the Human Sciences Research Council (HSRC), and the South Africa Weather Services (SAWS) during the period of September 2019 to December 2019. The significance of interviewing government and research institution officials was a deliberate choice to obtain an external perspective of how the FS projects are performing in incorporating CCA and DRR measures. Both in-depth interviews and KIIs were conducted via virtual platforms, emails, phone calls, and in-person interviews, giving participants the freedom to select the method that worked best for them. The interviewees consented to having their discussions recorded.

Interview responses from in-depths interviews and KIIs were transcribed verbatim, while thematic analysis was used to analyse them. The six-phase approach was followed throughout the analysis established by [63]. The process commences with (i) becoming familiar with the data (browsing through data to obtain the meaning). Phases ii and iii (constructing and generating and codes) were skipped during the analysis because they were out of the scope of the study. Phases iv and v (reviewing potential themes, and naming and defining themes) were established based on the FS projects under study, followed by sub-themes that looked at how the projects incorporate DRR and CCA measures, including the challenges and opportunities encountered. Finally, the sixth phase produced the final report as presented below.

4. Findings

4.1. Sentinel-2 Earth Observation Technology

4.1.1. Project Overview

The Sentinel-2 Earth Observation (Sentinel-2 EO) technology in the Western Cape is operated from the Department of Agriculture in Elsenburg in Sandringham. The project is handled at a provincial level to unlock the full potential of agriculture to enhance the ecological, economic, and social well-being of the people of the Western Cape. The project uses the Sentinel-2 EO technology to incorporate CCA and DRR measures when addressing

FS. The technology is used to detect and leverage agriculturally relevant satellite data using the Sentinel-2 EO portal and remote sensing tools, which have multi-spectral data with 13 bands, a spatial resolution of 10 m and 20 m, a 290 km field of view, and a revisit time of five days [40]. The Department is experimenting with some of these cloud-based services in their geographic information system (GIS) and online application, CapeFarmMapper (CFM). This project was influenced by the need to achieve the agri-renaissance (understanding of the role of agriculture in the development process) following the 4IR initiative using technology in South Africa.

4.1.2. Project Rationale

Traditionally, the only way to obtain satellite imagery was to search through picture catalogues, pick cloud-free photos, and then download and archive each image, including all its multi-spectral wave bands. This was a time-consuming and data-intensive operation, and the subsequent analytical workflows needed specialised knowledge and costly software. To address this issue, the Western Cape Department of Agriculture has established a Sentinel-2 EO portal and remote sensing technologies to take advantage of the vast amount of agricultural satellite data available in an integrated platform that hides the technicalities from non-expert users. Once more, according to [43] the integrated platform enables the farmers to monitor crop development, and make decisions regarding the management of irrigation, fertilisation, and crop conservation. It also helps with giving feedback on operations completed, and forecast yields. To bring coherence to CCA and DRR, [40] argue that the Sentinel-2 EO technology provides rapid access to near real-time information on both crop conditions, vegetation (veld), resource use, easy information flow, and better decision-making. This information can be used in studying climate change. Through the judicious use of technology, the department promotes sustainable farming while creating a food-secure province by making these instruments available.

4.1.3. Incorporation of CCA Measures in the Project

The qualitative findings established that the sole purpose of using Sentinel-2 EO was because of the prevalence of climate change and variability and its impacts on FS, including a lack of climate change information. To address such challenges, most respondents acknowledged that the technology has helped to make the relevant data available, that allows to monitor climate change hazards and harsh weather conditions that have an impact on their agricultural seasons. One of the Sentinel-2 EO respondent's views is encapsulated in the following statement:

"The data provided by the technology has helped us incorporate climate change factors such as weather forecasting, comparing cropping seasons to see how crops are progressing to climate change." (Sentinel-2 EO, management)

The same respondent went on to say that the longer they keep tracking climate change and agricultural data for the project like that, they start building up time series of data to look at the impacts of climate change on FS over the time series. Therefore, to ensure FS in the province, it will be important to see how your seasons are progressing and identify zones or sub-regions that are underperforming and might have an impact on the food supply in the season—in response to the growing pressure of climate change on FS, one Sentinel-2 EO respondent asserted that the technology has offered better monitoring capabilities to strengthen synergies in all food value chains, including food production information and market transparency to improve decision-making during climate-related disasters. Meanwhile, the KII findings established that it is still early to evaluate the success of the technology in incorporating climate change adaptation issues. In doing this, the respondents referred to the water shortages reported in the province and how the technology seeks to address it. Such sentiments indicated a need for more knowledge on how Sentinel-2 EO works; however, the project beneficiaries asserted that the technology could give information on the extent of how water shortages could affect crops, thereby helping farmers to plan.

4.1.4. Incorporation of DRR Measures into the Project

Regarding how the project incorporates DRR measures, findings from the in-depth interviews showed that they have used the technology in monitoring vegetation and crops to determine the extent of drought and its impact on FS in the province. Consequently, the information has helped them make decisions on drought relief programmes in the form of cattle feed and drought-resistant crops as a DRR measure. One Sentinel-2 EO respondent gave an example of how they incorporate DRR when dealing with veld fires:

“We have successfully used the Sentinel-2 satellite imagery in the Western Cape area to demarcate the areas affected by fires in 2017, and this helped us advise farmers to avoid such vulnerable areas.” (Sentinel-2 EO, management)

In terms of data regarding fire hazards, one of the respondents from NDMC said that:

“We still have problems with data accuracy whereby a projection is given without information on the extent to which is expected to affect, which ends up into a disaster.” (NDMC official)

Such a statement brought about a bigger conversation regarding data accuracy (in terms of projections and early warning systems) even in the recurrent flood disasters happening in the KwaZulu Natal region of South Africa. Upon following up on how they are using the technology to monitor flood hazards to reduce the impact on FS in the province, the response from the Sentinel-2 EO project team was that they have not used the technology yet to track floods but have agreed to monitor the hazard as it also affects FS in the province. The KII findings under this section have applauded the work the technology is doing in reducing the impacts (monitoring of droughts and other extreme events to improve farmers' decisions on crop types) of disasters on the food sector. However, the NDMC and DFFE expressed concerns on the need to capture data for the whole country so that all farmers could benefit from it.

4.1.5. Challenges and Opportunities

Regarding this section, the findings from the in-depth interviews established that Sentinel-2 EO is helping farmers to optimise their production by planning to produce as best as they can when facing changing climate conditions, such as erratic rainfall or other extreme weather events. Again, the respondents asserted that farmers or any stakeholder can use the technology to see any part of a particular farm or region that is underperforming, and the farmer can adjust the crop estimate and plan accordingly. For example, when dealing with international markets, one Sentinel-2 EO interviewee alluded that the technology could inform the provincial or national government to plan or budget on what they will import or export for a certain period. One of the Sentinel-2 EO respondent's views is encapsulated in the following statement:

“The most significant opportunity brought by this technology is that the access to data is free and can be available to any stakeholder or any farmer in real time. Again, this data can be stored for up to 10 or more years, which helps in decision-making of comparing farming seasons.” (Sentinel-2 EO, management)

Another opportunity established by the study is captured in the following remarks:

“We can use this technology in a day-to-day farm operation and the good thing is we can compare notes through close links with other farmers, which aid the conduct and facilitation of agricultural business.” (Sentinel-2 EO, beneficiary)

However, the challenges alluded to by the respondents included a lack of expertise in understanding the detected information and color codes from satellite data. One of the beneficiaries explicitly said that:

“We as farmers, do not understand direct data gathered from these satellites. It will be very helpful, if the Western Cape Provincial government managing this project provide us

with training on how to interpret data from satellites especially the knowledge of different color images.” (Sentinel-2 EO, beneficiary)

In support, another Sentinel-2 EO beneficiary alluded that such training would enable us to understand the meaning of the data in terms of vegetation cover and crop performance in the farms and surrounding areas. Meanwhile, respondents from DALRRD gave an external perspective for the need to train farmers, including rural ones or relevant stakeholders, on the issue of satellites using programmers who could interpret the data into the area’s vernacular to embrace the technology’s benefits. Finally, while most respondents from DALRRD, NDMC, and DFFE pointed out that the process could be costly in terms of human and financial resources, a few from the HSRC and ARC described it as a worthy endeavour because the data provided by the technology help to reduce the impacts of climate change and disaster risk on FS in the region and the country at large.

4.2. Urban Agricultural Initiative (UAI) Food Security Project Using Hydroponics Technology

This section presents how UAI food security projects are undertaken to improve food security in Johannesburg and the rest of South Africa. Figure 1 below shows one of the rooftop farms on the Chamber of Mines building in Johannesburg owned by one of the UAI beneficiaries. This project was supported by the Chamber of Mines as a test project to determine whether it would be feasible to hydroponically produce herbs and vegetables on the rooftops of inner-city buildings and to provide space for the farm.



Figure 1. Rooftop farm situated on Chamber of Mines building in Johannesburg [64].

Figure 1 above shows one of the rooftop farms on the Chamber of Mines building in Johannesburg owned by one of the UAI beneficiaries.

4.2.1. Project Overview

The Johannesburg Inner City Partnership (JICP) developed the UAI with the collaboration of the Department of Small Business Development, the City of Johannesburg, Wouldn’t It Be Cool (WIBC), the Small Enterprise Development Agency (SEDA), and SAB Kickstart. The project is in the inner city of Johannesburg and comprises hydroponics farms situated on skyscraper rooftops around the central business district. The project aims to encourage the creation of jobs through the development of agricultural entrepreneurial

ecosystems supporting young black, urban farmers. The recipients are mainly WIBC incubator graduates—WIBC is a programme that aims to transform young individuals aged 18 to 35 into entrepreneurs. To be included in the project, they must submit a business concept, including the target market, before receiving their start-up packs, including pots, seedlings, pumps, and irrigation systems, to receive financial assistance from the WIBC. All equipment and crops are made available to them if approved and monitored for up to one year until the farmers are self-sustained. For effective returns, the small-print farms are managed in a protective artificial environment that allows plants to access all the nutrients and protect them against drastic weather conditions such as hailstorms and high or cold temperatures using plastic roof tunnels.

4.2.2. Project Rationale

The increasing population in Johannesburg has intensified the food demand, creating food access problems due to the rising unemployment rate and high level of poverty [65]. Again, poor drainage systems, paved pathways, and heavy rainfalls have precipitated the flow of water, causing frequent floods in the city. As Johannesburg is more concentrated on industries and commercial activities, agricultural businesses are not popular in the area, as land is expensive and is mostly used for residential and commercial purposes. In this regard, the UAI sought to reduce the problems of food access by locating itself within the city close to consumers, turning the sloppy paved ground into small farms to reduce the flow of water in the city that causes floods, and introducing green areas into the city through agriculture business that lowers pollution in the city, at the same time, empowering the disadvantaged to participate in the economics of the country.

4.2.3. Incorporation of CCA Measures into the Project

The findings from the in-depth interviews have shown that the major purpose of the UIA was to introduce green areas to the city, considering the amount of pollution produced in Johannesburg due to its concentrated industries and commercial activities. In addition, respondents asserted that the hydroponics-farming project has the potential to bring agriculture production closer to where the largest consumption masses are and start addressing FS challenges that most consumers face. One UAI respondent explained this in detail:

“Bringing food production to the city was a way to solve some climate change issues such as food miles that are caused by transportation of food from long distance farms, which contributes to the emission of greenhouse gases in the region.” (UAI, beneficiary)

Again, the respondents shared that, in the event of severe weather, like hailstorms and the cold in winter, their production system is carried out under a protective environment, and they use that to protect their crops while obtaining more returns by producing out of season. For example, one respondent mentioned that they grow basil in winter while no commercial farmer is growing it across the region, which, in the end, brings more profit, as there will be a high demand from retailers.

Sentiments emphasised by some of the in-depth interviewees suggest that there was more to gain when using hydroponics farming in a protective environment than in a natural environment, such as open-field farming. In contradiction, one respondent from the DFFE reiterated that:

“We cannot feed the whole nation with produce from greenhouses, what about staple foods such as maize and wheat. What do you suggest we do?” (DFFE, key informant)

The answer to the question prompted a discussion from both government and research institution officials. These officials argued that, although the incorporation of CCA measures in open-field farming would require more resources on agriculture innovations, including a turnaround strategy on the entire agricultural system to achieve this, the adoption is long overdue. In addition, respondents from the HSRC and ARC suggested that more attention and resources should be put into the agriculture industry to design innovations that are affordable at a larger scale. Although this study did not collect much

data on open-field farming, the emphasis of the above assertions was on the necessity of strengthening policies on the agricultural sector and inventiveness as suggested by the [19,22,66], where hydroponics farming technology lies.

4.2.4. Incorporation of DRR Measures into the Project

Under this section, the in-depth interviews reviewed that the UIA project incorporates DRR measures through the slowing down of running water because what was hard surface or a slope rooftop is now turned into agriculture and can now consume or reduce the flow of water, which could have instigated floods in the city. Again, on the issue of protecting crops from disaster events such as drought and storms, the respondents asserted that, in the event of drought, their water loss does not increase that much. Hence, they are able to maintain a full productive output amid high drought conditions as compared to open-field farming. However, findings from the KIIs established that incorporating DRR measures is more feasible in small-scale farming like the UIA, where the cost is low, unlike when the project is carried out at a larger scale. The following statement reflects the response to that argument:

“Hydroponic farming technology seems to be effective at a small-scale rather than at commercial level as the equipment used is expensive to someone with more than one hundred hectares of land.” (DALRRD respondent)

One respondent from the UAI agreed with the assertion above but suggested that commercial farmers should start incorporating CCA and DRR measures from one hectare and use the available resources further. The same respondent went on to say that the environment is changing, and it is high time that all farmers, both commercial and subsistence, incorporate DRR and CCA initiatives into addressing the South African FS concerns.

4.2.5. Challenges and Opportunities

This section presents findings that reflected the opportunities and challenges experienced by the UAI project. The findings from the in-depth interviews established that the UAI gives young black people the opportunity to turn into entrepreneurs to develop new agricultural value chains in places where agriculture is not active. Another opportunity recognised by respondents was the project’s ability to recycle waste from their farms and turn it into bioenergy so that the project would be eco-friendly and renewable in nature and reduce the emission of greenhouse gases. Conforming to this assertion, DALRRD, NDMC, and DEFF respondents applauded the UAI for the initiative of contributing to the food system in Johannesburg where the food demand is high, especially with its high population and increasing informal settlements. The in-depth interviewees described another opportunity brought about by the UAI to the city as bringing “green” to the city considering the amount of pollution produced from industries, thus making farming a significant contributor in lowering the city greenhouse gas emissions.

However, the in-depth interviews disclosed that a challenge still exists is market access, which is engraved in traditional marketing channels built for what was the 17th century agriculture system that favoured commercial farmers. Both KII and UAI respondents shared that the problem with that system is that it contributes to food miles, whereby farmers travel long distances to one centralised market, which contributes to air pollution. Thus, one UAI respondent had this to say:

“There is need for decentralisation of market access whereby farmers can access markets in their own regions to reduce greenhouse gasses emitted while transporting food.” (UAI, beneficiary)

Another challenge cited, as with the Sentinel-2 Earth Observation project, was the costs associated with incorporating CCA and DRR measures into the projects. The expenses included the training of people to familiarise them with the technologies. One respondent from the UAI asserted that it takes one full year to train individuals to use the technology. To make matters worse, the UAI respondents alluded that the lack of support from the

government through funding or supporting policies that promote agricultural innovation makes the incorporation of CCA and DRR measures difficult and more expensive as they end up funding themselves. Such a scenario was argued by [67], that SSA governments, including South Africa, need to prioritise innovation and technology in their national development policy frameworks, the lack of which is limiting agriculture business [68]

5. Discussion and Conclusions

The findings presented in this paper showed that both the Sentinel-2 EO project and the UAI project, although different in nature, incorporate CCA and DRR measures to reduce the impacts of climate change and disaster risk impacts on FS. The use of the technologies has revealed that, when considering the linkages between FS, CCA, and DRR, it is important to realise that FS is not simply about the provision of food to all people [69], but it is about considering the risks associated with it by trying to reduce the impact through CCA and DRR measures to keep up with food demand. The KII and in-depth interview findings established in this paper have convincingly shown that both projects are at the high end of considering CCA and DRR measures in most food value chains.

The findings highlighted that, while the Sentinel-2 EO project is mostly focused on reducing climate change and disaster risk impacts on food production, its area of divergence from hydroponics farming is its unique digital technology feature, which benefits economic growth by giving farmers more access to markets through e-commerce and may eventually lessen the shortage of food [70]. However, reports from the UAI showed struggles in the food supply system due to the centralisation of markets, whereby most respondents called for the decentralisation of markets to include smallholder farmers in the food supply system. The findings further showed areas of convergences where the Sentinel-2 EO project bridges the gaps in communication and connectivity between farmers through the sharing of CCA and DRR information through one database, while the UAI brings synergies across all farming units, which helps to address a broad spectrum of all agricultural issues, including CCA and DRR measures. Although it is too soon to determine whether the projects will be successful or not, the ability to incorporate CCA and DRR measures into one platform (dataset or farm unit) has been regarded by [71] as the best way to solve incoherence issues between FS, CCA, and DRR.

While both projects use different tools to bring CCA and DRR issues together, Sentinel-2 EO respondents illuminated that the integrated online platform has given farmers the chance to detect extreme events, such as droughts and veld fires, follow crop development and seasons, and make decisions regarding irrigation fertilisation and predicting yields. Findings from the UAI respondents revealed that the hydroponics farming technology is a system that focuses more on creating structures that are optimised for agricultural systems to unite DRR and CCA measures in production (sustainable water use, reduction of land degradation through the use of soilless systems, and using plastic tunnels to protect crops in harsh weather), distribution (reduction of food miles by choosing a location close to markets), and consumption (providing fresh and nutritious food and using the waste for bioenergy to maintain the economic return), as suggested by [44]

However, the findings cited in this study revealed that both projects experience similar challenges such as the lack of information, institutional competence, funds, or personnel such as a lack of financial or human resources, institutional capacity, and information, the cost of training farmers to use the technology, and a lack of policies to support the initiatives. Various scholars have also identified these challenges ([23,72,73] and have stressed the need to analyse them before adopting any technology for successful implementation. In addition, the findings further revealed that the current policies do not support agriculture innovation in terms of the localisation of the agriculture industry, or funding upcoming entrepreneurs, which, in a way, could make the country a net importer if the sector needs to respond to the changing environment. In the end, the study findings inform further research to focus on reviewing policies that address the agriculture industry in South Africa to create inclusion, efficiency, and integrated innovation with policies that address DRR

and CCA. In addition, the findings of the study have revealed how technology can be used to bring a coherence to CCA, DRR, and FS, thus informing other studies to investigate how other technologies can be used in the agricultural industry to reduce the impacts of climate change and disaster risk. The limitations of the study were that the technologies are still new; thus, the evaluation of the success from external perspectives was limited. Therefore, there is a need for further research that could evaluate the successes and failures of the projects.

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