Professional Practice 2

Digital Earth Africa with South Africa Food Security

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Executive Summary

There is enormous potential buried in South Africa territory, not only does it have the power for elimination of hunger, but also play a vital role in the global food market. The potential mainly lies in soil, water, and land, in Africa people and huge markets. However, despite its unique geographical environment and the ability of food self-sufficiency, South Africa has encountered agricultural production decline issues, especially during recent decades.

This project has conducted investigation on existing possible risks that threaten socio-ecological sustainable development. Three aspects have been defined: uneven food production, natural disaster, and soil issues.

In order to provide government with data support to ensure food security and agriculture indemnification on the basis of maintaining socio-ecological sustainable development, this project has collaborated with Digital Earth Africa (hereinafter called DE Africa), aiming to use Earth observations and analysis tools to deliver decision-ready products, to further develop a socio-ecological system for innovation.

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1. Introduction

Digital Earth Africa (hereinafter called 'DE Africa') is an organization that aims to use Earth observations and analysis tools to deliver decision-ready products to ensure food security in Africa and develop a socio-ecological system for innovation.

South Africa has a good but still face food security issues including food inequality, natural disasters and land policy. This project aims to analyse and put up some possible solutions to ensure the food security and agriculture development of South Africa on the basis of maintaining socio-ecological sustainable development by taking DE Africa as a typical method.

1.1 Purpose

The purpose of this report is to analyse how Digital Earth Africa uses innovative technologies to help the South Africa government ensure food security as well as considering socio-ecological sustainable development. This report would include a brief introduction, literature review, methodology, empathy, ideation, prototyping and the conclusion.

1.2 POV

The South African government needs to ensure food security and agriculture development on the basis of maintaining socio-ecological sustainable development because they lack the ability to scientifically and systematically make analysis and decisions.

1.3 Scope

This report and the professional project of our group includes an overview of the issue and provides possible solutions for the South African government. Our job does not contain the implementation of the solutions.

- Team Number: Workshop 4 Group 3

1.4 Definitions, Acronyms, and Abbreviations

- DE Africa: Digital Earth Africa
- SDG: Sustainable development goals
- EO: Earth observation
- stats SA: statistics South Africa

2. Literature Review

South Africa is experiencing persistent food insecurity [1]. Some cases point to the negative impact of climate change on agricultural food production, as well as impact of scientific and political factors on South African agriculture. In order to achieve zero hunger, promote food security and improve nutrition, attention should be paid to the sustainable development of agriculture. South Africa needs several control measures to help change its food system [2]. Some analysis indicates that South Africa's ability to adapt and protect its food items depends on the understanding of risks and the vulnerability of various food items to climate change. However, this poses a challenge in developing countries, including South Africa, because such countries have weak institutions and limited access to technology [3]. As a result of the COVID-19 pandemic, informal traders were negatively affected, which was detrimental to the food security system, as businessmen played an important role in food security and other economic and social commodities in South Africa [4]. According to the survey, rural families in South Africa are vulnerable to food and income adversity. About 52% of households have severe food insecurity, while others are either mild or moderate food insecurity. Only 16% of households have food safety [5]. And food nutrition in South Africa can lead to chronic dietary diseases. While food insecurity among rural households also contributes to food sustainability by expanding credit services, non-credit services, and non-agricultural activities, owing to irrigation facilities and educational literacy [6]. Food insecurity among rural households is also due to lack of irrigation facilities and education. Food sustainability is facilitated through the expansion of credit services and non-agricultural activities.

In summary, there are problems with agricultural security in South Africa due to natural factors (e.g. climate), socio-economic problems (e.g. credit and education), political strategies (agricultural food policy), and scientific and technological problems (lack of high-tech technology and talent). Thus, it is worth exploring how to promote sustainable agricultural development in South Africa.

3. Methodology

3.1 Research Design

Our project is based on DE Africa's existing data for further analysis. We selected some satellite and farming distribution maps of South Africa in DE Africa. Based on the existing analysis tool of DE Africa - Sandbox model analysis, and the related methodologies: quantitative and qualitative analysis, our project further analyses the available arable land and soil related information. In order to better understand the requirements of stakeholders, we use the method of stakeholder analysis and ecosystem mapping to research the relationships between issues and stakeholders. To rethink the core and project goal, our team decided to use KWHL_chart analysis [Appendix A], HWM [Appendix D] and Project Client Map [Appendix B] to improve our understanding and learning. For solutions integration, we apply 6-hat methodology [Appendix E] and LotusBloom [Appendix F] to generate ideations from the requirements. At the same time, meeting with our mentor also gives us help in the proposed design.

3.2 Participants

Mentor (Chad Burton) from the DE Africa group provides us with DE Africa-related technology and product concepts. Since our direct stakeholders are the South African government. and the ultimate beneficiaries are farmers and society, it is more important to get people's satisfaction and feedback. After the discussion of the team, we decided to use the form of questionnaires to collect relevant data. The questionnaire will be distributed online, and all those who answer the questionnaire will provide us with corresponding feedback and suggestions.

3.3 Data collection

In our project design, our data collection is divided into three categories: technology related data, design related data and feedback related data.

- Technology related data: the project uses the Sandbox model analysis (provided by DE Africa) to get real-time data of South Africa. The relevant technical support used in the project includes: water resources and soil moisture analysis, crop health tracking. The method of big data collection and real scene simulation is combined to integrate relevant data.
- Design related data: to deepen the understanding of client's requirements, we apply several design thinking tools in the data collection. For example, the KWHL_chart [Appendix A], Project Client Map [Appendix B] are used to define the current issue. Stakeholders' analysis and ecosystem mapping are used to find the relationships between issues and stakeholders.
- Feedback related data: combined with the interview of DE Africa group and questionnaire survey of ordinary people, the relevant expectation and suggestions survey results will be collected and used for future improvement [Appendix I].

3.4 Data analysis

Based on the collected data, our team used the corresponding data analysis methods to conduct quantitative and qualitative analysis:

Quantitative analysis:

- Factor analysis: construct our own benchmark to measure whether different factors meet the requirements. Find the potential factors and estimate the impact of potential factors on measurable variables.
- Cluster analysis: the data are classified according to their characteristics to find a reasonable statistic to measure the similarity of things. It is used in land classification and disaster prediction.
- Discriminant analysis: according to a batch of samples with clear classification, the discriminant function is established to minimize the cases of misjudgement. (Use of non-recommended cultivated land)

Qualitative analysis:

- Stakeholder / Client analysis: stakeholders mapping, and client matrix are used to broaden the scope of the problem. At the same time, check whether the customer’s needs are met.
- Correlation analysis: study whether there is a certain dependency relationship between phenomena and discuss the relevant direction and degree of the specific phenomenon with dependency relationship.
- Reliability analysis: check the reliability of the measurement, such as the authenticity of the questionnaire. Use broader and more random selection.

3.5 Ethical considerations

One of the ethical considerations will be the environmental problems caused by over reclamation. One of the preconditions to achieve sustainable development of society is the sustainable development of the environment. Although the reasonable development of land resources has little impact on the environment, it is still difficult to balance the trade in relationship between reclamation and environmental protection.

4. Empathy

To empathize with the South African government and understand the present food security situation, our group used a variety of tools to carry out a background research work. Synthesizing the results, we mainly focus on the following three aspects to understand the issue of food security in South Africa:

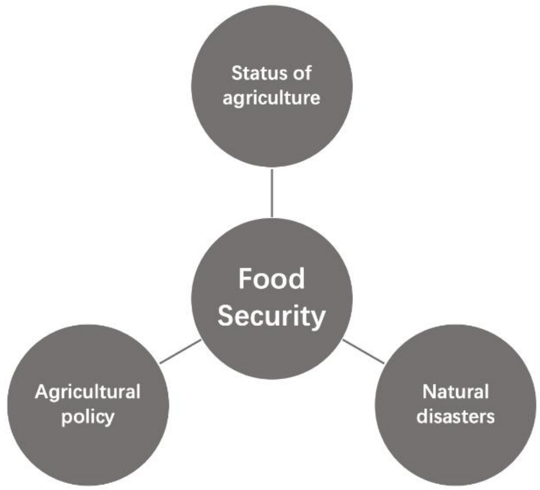

Figure 1: Radiogram outlining the three aspects around food security issue

4.1 The status of agriculture in South Africa

By reviewing government data and various research papers, we found that although South Africa's overall national strength compares favourably with other African countries, its agricultural production clearly shows a shortage of supply. It has further led to an uneven distribution of agricultural products in different regions of South Africa, deepening the gap between the rich and the poor and aggravating the problems of agricultural financial and technical support, and insufficient agricultural production in the regions with lower economic capacity, creating a negative circular effect. The reasons behind insufficient production are twofold:

Firstly, South Africa has insufficient agricultural employment, which causes the problem of decreasing agricultural products, making unequal distribution of agricultural products available. Based on a report of stats SA about 2020 mid-year population estimates, South Africa's midyear population will increase to 59 million in 2020 [7]. However, with the huge population, the employment of agriculture has sharply decreased. Less numbers of the population are devoted to agriculture works, making unequal distribution of agriculture products become more severe. The figure [8] in Appendix J clearly shows that the largest population are working for services, less numbers of population works for agriculture in South Africa. As of 2020, the number of agriculture employees glides into only around 5% of the total population. Therefore, not enough numbers of agriculture workers will become harder and heavy pressure to provide high agriculture outputs to support the huge population of South Africa.

Secondly, South Africa suffers from a shortage of tillable land for agriculture. Because of shortage of rainfall and water, the arid climate is the main problem to influence the agriculture of South Africa. When diamond, gold mining industries rise, the area for agriculture becomes less and less. Although the development of urbanization is fast in South Africa, agricultural acreage shortage cannot support a large population and urbanization also occupies more land. Based on Stats SA report about census of commercial agriculture 2017[9], On land use, the survey shows that in September 2018, the total land used for commercial agriculture was 46.4 million hectares, which represents 37.9% of the total land area of South Africa (122.5 million hectares). Grazing land (36.5 million hectares) is used for livestock and game farming, and arable land (7.6 million hectares) is used for crop production. In a number of farms, Gauteng, Mpumalanga, and Limpopo provinces do not provide enough land areas for farms, which will cause the shortage of agricultural products for their cities and population.

Additionally, the land policy in South Africa also brings a far-reaching impact on the issue of arable land area. The main race of population in South Africa is black race [10], detailed information in Appendix K. Large commercial farms run by whites coexist with traditional subsistence farming by blacks. Large areas of fertile soil only belong to few people, and most of the high-quality land is occupied by whites, and the main agricultural products also come from white farms. And the black areas are overpopulated, lacking in capital and technology, with poor infrastructure and low crop yields. In a word, huge numbers of the population are still facing no land for agriculture or high rent for land from others which lead to the situation that they only get less benefits and agricultural products.

4.2 Natural disasters in South Africa

According to our research and recent news reports, food security in South Africa is still largely affected by natural disasters. In order to better understand the impact of natural disasters on food security, our group decided to analyse the problem from drought, insect disaster and other aspects.

- Drought

According to the research, the average annual rainfall for South Africa is about 464 mm (compared to a global average of 786 mm) but large and unpredictable variations are common. Overall, rainfall is greatest in the east and gradually decreases westward, with some semi-desert areas along the western edge of South Africa [Figure 2]. The uneven distribution of precipitation leads to the difference between agricultural output and agricultural type, and sometimes drought. The La Nina climate and the rising sea surface temperature in the Western Pacific have resulted in the decrease of precipitation, serious drought, reduction of grain harvest and increase of price. The detailed explanation of the Vaal River example is given in In Appendix N.

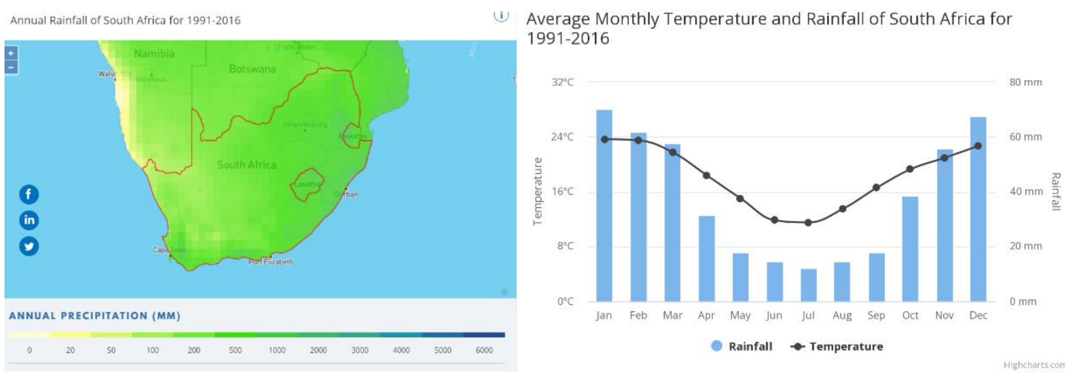

Figure 2: the average annual rainfall for South Africa [11]

- Insects

Presently, some emerging Agricultural Pests (such as Fall Armyworm and Tuta absoluta) have caused enormous damage to crop and have not yet been resolved. Crop losses in African countries due to insect pests are estimated at 49% of the expected total crop yield each year, according to the Centre of Agriculture and Biosciences International [12]. But some crop losses can be even worse, and the effects of the changing climate are expected to increase the damage done by insects. And the South Africa government pointed out the problem of fall armyworm in Appendix O. Oftentimes, the purchase of pesticides is much higher than the output of agriculture. So far, the government needs to invest a lot of money on the prevention and remediation of pests every year.

- COVID-19

Recently, the COVID-19 has had a great impact on the actions and activities of humanity, and agriculture is not outside this impact. Food demand and thus food security are greatly affected due to mobility restrictions, reduced purchasing power, and with a greater impact on the most vulnerable population groups. With the increase in infectious disease cases, the government has taken more stringent measures to prevent the spread of the virus, which has also affected the global food system. Furthermore, specific agricultural issues arising from the COVID-19 described in detail in Appendix P.

4.3 The agricultural policy in South Africa

We reviewed government websites, work reports, and current political messages and selected two areas to analyse the impact of policy on food security.

The first part is economic policy. With the global epidemic, South Africa's economic vulnerability is gradually affecting more agricultural production and the country's agricultural economic policy is facing great challenges. The Land and Agricultural Development Bank of South Africa (hereinafter as 'Land bank') is the South African government's state-owned bank that was established to safeguard the needs of the farmers for financial resources, as well as multiple loan support for the advancement of black economic rights. Due to poor agricultural conditions in South Africa, the bank issued loans to farmers at a preferential interest rate, which was lower than the market interest rate. Also, the bank provides financial support to all sectors of the agricultural economy, and to be the economic backbone of sustainable rural development planning. We reviewed Land Bank's recent news around loan and credit, financial annual and interim financial audit reports, and found out that Land Bank has been exposed to liquidity shortages currently due to the long-term operation of some poor business models and the negative impact of today's epidemic on the macroeconomic situation [13][14]. More information can be found in Appendix L. The unfavourable operating conditions of the Land Bank have also led to credit difficulties and business continuity difficulties for farmers, which also means difficulties for carrying out stable agricultural operations, as well as to increase food production, leaving a huge potential danger for food security.

The second aspect is about import and export policy. The agricultural economy in South Africa is market-oriented and highly diversified, including major grains (except rice), subtropical fruits, sugar, and most vegetables. In the financial year of 2018, South Africa imported $7.7 billion in agricultural food products, which remained the same level as in the financial year of 2017 (International Trade Administration, 2019).

Agricultural Products	**Imported Value (USD)**
Rice	437 million
Wheat	395 million
Chicken cuts and offal	389 million
Palm oil	305 million
Corn	208 million
Whiskies	181 million
Soybean meal	173 million

Table 1: South Africa imported agricultural products in FY2018

However, when South Africa decided to follow the global rule of free trade post 1994, the country's agricultural sector has been in a difficult position since then. Although it was expected to compete against the best in the world, the support has been taken away from facilitating the current food import situation. This means that new individual farmers would have a hard time compared to existing farmers who had been supported previously.

Low-cost foreign imported food is one of the vital factors restricting the agriculture development in South Africa. For example, the price of rice imported from China and Thailand is much cheaper than native rice produced in Africa. Developed countries have subsidies for imported agricultural products, and this is the reason for imported products being so low-priced. For example, the EU's economic policy is to make their export prices lower than production costs through subsidies, further, to ensure the interests of European agricultural producers. And so do the United States and Argentina (USDA, 2016). As a result, South Africa's local agricultural products are not competitive in price and attain a low availability to develop local agriculture. See Appendix M for details.

There is a big difference between South Africa's population needs and local production. This gap must be filled by imports, and the country has a large network of food importers and distributors. According to the World Bank collection of development indicators, food imports as a percentage of merchandise imports in South Africa was reported as 7.2342% in 2019 (World Bank, 2021). However, due to the impact of COVID-19 in 2020, many countries in the world have imposed restrictions on exports due to the priority of securing their own food reserves, and this action has brought risk to South Africa food security. Hence, in order to cope with this hardship, they need to achieve self-sufficiency in food as soon as possible.

To sum up, although there are several existing agricultural policies that are beneficial to local development, such as the emphasis on water conservation, increasing the purchase price of agricultural products, reducing transport prices, and establishing tariffs to protect agriculture, South African agricultural policy has revealed a few failed decisions and mismanagement at present. Although the government is now actively addressing the weaknesses of black agriculture in the country, increasing investment in rural areas, and seeking ways to alleviate the food security crisis in the wake of the epidemic, there is still a long way to go to change the situation.

5. Ideation

Our group first used How-Might-We (HMW) questions to help us better understand the case and identify the questions in different aspects. After working in small groups on the full range of food security issues in South Africa, we gained a more comprehensive understanding of the whole issue at a macro level. During our regular meetings, we brainstormed the current state of the problem in terms of low food production, inadequate prevention, control of natural disasters and epidemics, shortcomings in decision-making, and discussed solutions to each of the problems listed. (The detailed information of our HMW questions and solutions can be found in the Appendix. D.)

After that, we used the Six Hats Thinking method to take a deep look at our drafted solutions. Four of our team members chose one of the 6 coloured hats and followed the instruction of the chosen hat to make further analysis based on the solutions we drafted, and the one remaining helped to record all of our thoughts together. After conducting this we found more useful information in deciding the final solutions. (The detailed information of our Six Hats Thinking record can be found in the Appendix. E.)

Then, we used the Lotus Bloom Analysis method to conclude our final solutions. This method helped us to think through all the solutions we propose layer by layer, including the problems they cover and solve, the technical requirements involved, and the breakdown of solutions into smaller solutions. The detailed description of our Lotus Bloom Analysis can be found in the Appendix. F. After finishing this analysis, we selected 4 best solutions to take part in the Dot Voting Activity.

The Dot Voting Activity is a voting among all 25 project participants to help decide one of the best solutions for making a prototype in the next stage. We provided four solutions and finally got a top voted solution from the activity. The detailed information of the voting result can be found in the Appendix. G. Those participants also provided a lot of useful information on the reason for their choices, which also spread our thinking and provided valuable insights. Taking into account the results and our team's thoughts, we also believed that Sandbox technology could be a good way to cover a number of issues that we want to detect or monitor, including soil moisture, crop health levels, climate issues, agricultural land conditions, etc. Therefore, we finally choose the solution of using Sandbox simulation technology to make the final prototype.

Finally, we spoke to the mentor of our project, Chad Burton, about the details of Digital Earth Africa's Sandbox technology, and noted that it does do what we need in terms of monitoring soil moisture, crop health levels and other issues, and that we could easily access the technology's platform to see some of the technical information available to help understand exactly how the technology works. Based on our practical exploration and understanding of the technology, we were able to successfully develop the prototype.

6. Prototyping

In general, our prototype will be based on how to better help the South Africa government utilize technical innovation like the Open Data Cube to promote solving food security issues and social-ecological sustainable development. DE Africa is a good practice in this area. The core mission of DE Africa is to produce decision-ready products through the processing of openly accessible and freely available Earth observation (hereinafter as 'EO') data. These EO data products help the South Africa government better understand our natural resources and the human and climate impact on them.

South Africa can have cooperation with DE Africa. The South Africa government can observe the map of the target city from satellite to understand and analyse the geography to improve agricultural outputs. DE Africa can provide and map the distribution of agriculture for South Africa. Based on monitoring satellites, it can give more useful information to the South Africa government to solve the problem about unequal distribution of agricultural products and urban planning. DE Africa can provide city maps by satellite and monitor land distribution around cities. It can show the distribution of the target city about land, infrastructure, and urbanization. Based on the map, the government can exploit the land for agriculture and improve transportation infrastructure which shortens the time to transport agriculture from suburb to city.

Polokwane, the largest city in Limpopo province of South Africa, is used below as an example of how the South African government can cooperate with the DE Africa to address issues in poor food productivity. Polokwane has a serious problem about unequal distribution of agricultural products. DE Africa's satellite maps can help show the current distribution of agricultural land in this city and identify tillable land for reclamation and cultivation. The Figure.6 is from DE Africa which maps the distribution of the city Polokwane. In this figure, the red squares show the agricultural land in which there are different crops in different colours with some regular shapes. In blue squares, it clearly shows that there are not any crops for agriculture which should be exploited. Moreover, DE Africa's satellite maps can also help show traffic in the city and confirm whether current traffic distribution around the agricultural land is conducive to crop trading. From Figure.3, the number of highways in Polokwane are not enough. Most crop farms share only one highway to transport.

Figure 3: Polokwane satellite map from DE Africa

DE Africa is free for any country in Africa and provides open data to these countries, so it is easy to access the data about mapping and get authority to monitor. Using this DE Africa data to monitor or analyse target fields for increasing agricultural outputs is simple and easily used. Government only needs to organize less numbers of people who have experienced urban planning or land usage and involves less manpower to monitor and analyse, then can get know how to rationally use land for agriculture and improve infrastructure. DE Africa provides an easy approach to help the government monitor and point problems about agricultural crops, land reclamation and infrastructure. It greatly improves the efficiency of collecting related information locally. It not only helps the government easily to understand the characteristics of cities, lands, and states of urbanization to reclaim agricultural lands and provides related policies, but also easily for the government to monitor the process of developing infrastructures and highways.

Using the Sandbox of DE Africa can detect the crop health to increase crop yield. This technology has the Ability to scout for disease damage. It’s able to investigate poor performing fields and undertake management action such as soil testing or targeted fertilizing to improve yield. Furthermore, satellite imagery can be used to measure plant health over time and identify any changes in growth patterns between otherwise similar fields. In this way we can find out where the land is suitable for this crop. As shown in the figure 4, NDVI data from two areas over the past two years can be compared to find abnormal crop areas. The Normalised Difference Vegetation Index (NDVI) describes the difference between visible and near-infrared reflectance of vegetation cover. This index estimates the density of green on an area of land and can be used to track the health and growth of crops as they mature. Comparing the NDVI of two similar planting areas will help to identify any anomalies in growth patterns. For example, the government can work with companies to develop a mobile phone app. Farmers input the relevant soil area information, and then, the app will obtain some data from the SandBox and through scientific analysis to provide the intuitive conclusions to farmers. In this case, people can grow crops more effectively and increase production.

Figure 4: NDVI data from DE Africa

The South African government has been exposed to a lack of more transparent and timely information on the agricultural policies, which has had a negative impact on decision-making. The utilization of technical innovation like DE Africa can therefore help in providing more effective data and making scientific and systematic decisions.

The South African government needs to balance between short-term demand and long-term development goals in the agricultural import and export perspective. In order to achieve the target, the South Africa government can utilize DE Africa for local production analysis.

DE Africa has the technology of Cropland Mapping Services, which rely on continental-wide satellite imagery to provide users the understanding and analysis tool for spatial footprint of food crops across South Africa annually. Providing local farmers and agricultural scientists with accurate information about land health, crop development and water availability, scientists and farmers would have the ability to select the best geographical locations for crop growth. Moreover, the technology-based mapping food crops facilitates stakeholders to understand the importance of how crops are related to climate change, geographical factors, and farming methods, so that there will be an inevitable increase of local production capacity with the guidance of Cropland Mapping Services.

Decision makers can formulate relevant import and export policies based on annual crop production capacity, rather than deciding policies beforehand. DE Africa not only benefits scientists and decision makers, but also farmers who lack professional knowledge for current agricultural policies. Local farmers can have the advantage of watching transparent policy information with the guidance from DE Africa, so that they will produce crops based on current policies, which will further facilitate South Africa's food import and export.

7. Recommendations

As stated in this report, the South African government is sparing no effort to think about efficient and high-yield farming methods for local farmers, and to find suitable land resources for farming. They joined a protective agricultural policy to promote the healthy growth and harvest of agricultural products. These policies meet the basic requirements for the development of South Africa's agriculture, but they are far from our goals. We aim to establish a long-term cooperative project and set an example for similar projects in the future. Therefore, we propose to use the DE Africa Sandbox to optimise existing solutions. The DE Africa Sandbox is a cloud-based user computational platform that can provide users, such as the South African government, with a platform to detect the health of crops, thereby increasing crop yields.

Our recommendation is to utilize the DE Africa Sandbox to provide the South African government with a platform for data monitoring as well as data analysis, for the purpose of making feasible decisions based on the results of the analysis. The sandbox can measure the growth of plants over a period of time through satellite monitoring and identify changes in other areas of the specific plant. In addition to this, the sandbox can be used to detect the crop health and analyse data to increase yields. This technology also possesses the ability of disease detection. It can conduct soil disease prevention control and management measures by investigating land with low yield by comparison, such as area-targeted fertilisation and sample soil testing. Using this technology can achieve the purpose of rational use and distribution of land. For example, the government can visualise the data provided by the sandbox and create dashboards so that scientists can more efficiently analyse the data that can bring opportunities to South Africa's agriculture. Meanwhile, the government can develop mobile applications through Sandbox. If farmers enter relevant crop and soil information, they can get advice on scientific planting methods and soil management. In this case, people can grow crops more efficiently and increase yields.

Hence, our prototype will design a plan for utilizing DE Africa's sandbox technique focusing on tillable land usage, water source and soil moisture, natural disaster and crop health which seriously affect South Africa agricultural products and provide related suggestions to improve agricultural development of agriculture for solving food security.

- Tillable land usage

People can analyse the usage rate of land for agriculture by using the sandbox. Its satellite monitoring provides real-time information about South Africa land.

Figure 5: Polokwane satellite map from DE Africa

The figure above shows that our project can detect the land usage in Polokwane of South Africa which can show the proportion of land for agriculture and information about Polokwane city planning. The blue square is an unexploited area and red square is about land for agriculture. Based on this information, our prototype will give the South Africa government the suggestions about how to plan the land for agriculture and the estimation about whether this city has enough food to supply its population to avoid the risk of food dearth. We will mainly focus on the areas with serious food security, to analyse their tillable land usage to efficiently use and exploit its land for agriculture, and judge whether it can be used for agriculture.

- Water resource and soil moisture

Our prototype also will use data from DE Africa to create data visualization about water resource distribution and spatial data to show the river distribution of South Africa and estimate soil moisture to judge whether the area fits for agriculture, or for which crops. In addition, the other purpose of this sub goal is to help locals to access safe drinking and using water in South Africa which improves the security of agriculture products and using water in food. The technique can help the South Africa government to monitor and manage its water resources efficiently for agriculture.

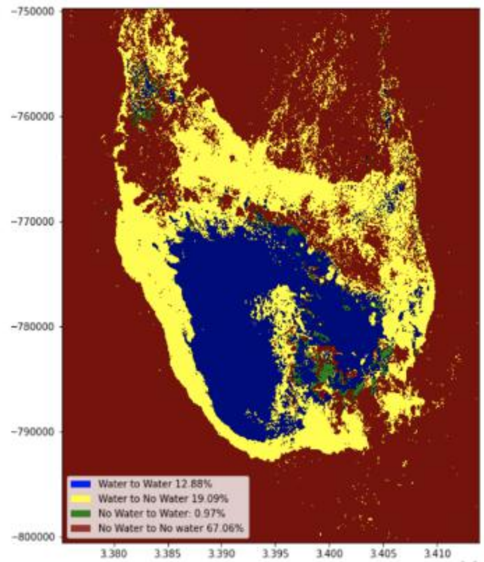

Figure 6: Data visualization for water distribution in South Africa from DE Africa

The above figure is an instance for data visualization for water distribution in South Africa. Which clearly shows that the centre of South Africa has plentiful water. The water distribution will indirectly affect the distribution of different kinds of crops. Like glutinous rice, swamp cabbage and maize etc crops should be in an area with more water, potatoes, and tomato etc should be planted in an area with less water. The technique can help analyse the water resource distribution and soil moisture to help the South Africa government in deciding suitable crop plantations in different areas. Furthermore, based on spatial data provided by DE Africa, our prototype will also analyse river distribution.

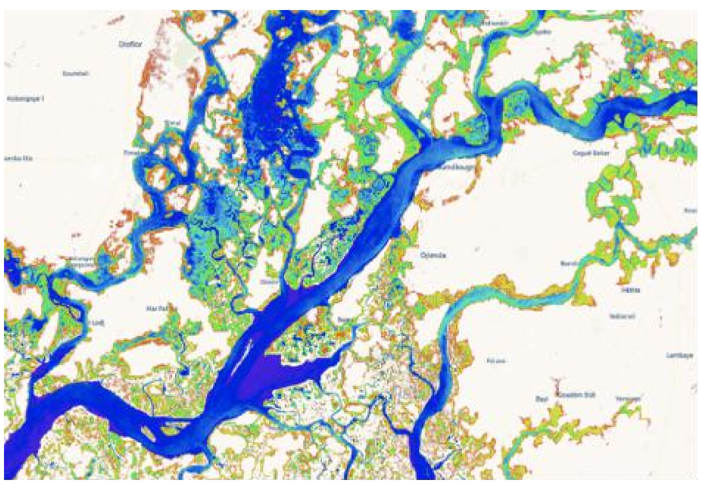

Figure 7: River distribution from DE Africa

Above figure shows the details of river distribution, therefore, out prototype can provide details analysed about how to allocate water resources to the surrounding area and for locals to access and analyse the suggestions about crops and the approaches to solve using water in food, which can help the South Africa government to make policy to improve agriculture development and food security.

- Natural disaster

DE Africa’s sandbox platform allows for the detailed tracking of weather changes across South Africa. Therefore, our prototype also can provide and predicate the influence of extreme weather to agriculture. The DE Africa can provide data visualization about the environment and climate of South Africa in a period. Our prototype will give the South Africa government the prediction of extreme weather to avoid crop losses and keep track of the environments of agriculture.

- Crop health

The DE Africa also provides us with a range of additional analysis tools to monitor agriculture crops by satellite imagery. Our prototype will use a normalized difference vegetation index to describe the difference between visible and near-infrared reflectance of vegetation. This index estimates the density of green on an area of land and can be used to track the health and growth of crops as they mature. Comparing the NDVI of two similar planting areas will help to identify any anomalies in growth patterns.

Figure 8: Plant health visualization from DE Africa

The above figure is about measuring four different parts of plant health. Our project will compare the NDVI index to judge these plants' health. Based on our analysis, our prototype will give the South Africa government related information about crops health and crop situation to keep track of crop development and suggest how to promote or optimize crops living.

8. Proposed budget

Our budget is based on 100 farms and estimates the total benefits from these selected farms.

Subjects	**Priority**	**Unit**	**Measurement**	**Cost (-) / Income (+)**
Cost				
1. Hardware facilities	L1	3	$437 * 3 = 1311	-1311
2. Labour cost	L1	10	$5000 * 10 = 50000	-50000
3. Natural calamities protection (per farm)	L2	100	$30000 * 100 = 3000000	-3000000
4. Investigation - validation	L1	4	$300 * 4 = 1200	-1200
5. Backup facilities	L2	1	$11250	-11250
			Total Cost	-3063750
Income				
1. Production gain	L1	100	$184000 * 0.2 * 100 = 3680000	+3680000
2. Reduce the investment cost for social support	L2	10000	$50 * 10000 = 500000	+50000
			Total income	+3730000
			Balance	666250

specific calculation presented in appendix Q.

9. Project plan

Our solution to the problem of food safety in South Africa is to recommend that the Government use DE Africa's sandbox techniques to analyse factors such as the soil, crop, and environment to develop policies for South African farmers to improve the sustainability of South African agriculture. (Gantt chart: Gantt chart of programme implementation)

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Appendix A: KWHL chart

K-What I know	W-What I want to know	H-how I will learn	L-what I learned
South Africa has food security issues, and the government is intended on addressing those issues. Digital Earth Africa is a kind of technical innovation as the Open Data Cube to promote solving South Africa's food security issues and benefiting social-ecological sustainable development.	How can an innovative technique be applied to help solve the food security issues? What the government considers to be the most important issues and influence in addressing food security and what kind of measures it would accept?	Our team will learn by doing research on a wide range of topics, including papers, official statistics, government reports, international news, and reports on the work of international organizations, etc. Our team will brainstorm at regular meetings to synthesize findings and develop subsequent directions for the project.	South Africa's food security issues will mainly appear in those aspects: poor food productivity, natural disasters and the current epidemic, the impact of adverse policies. Digital Earth Africa has some products and measures to help ease those issues.

Table 2: KWHL chart

Appendix B: Project Client Map

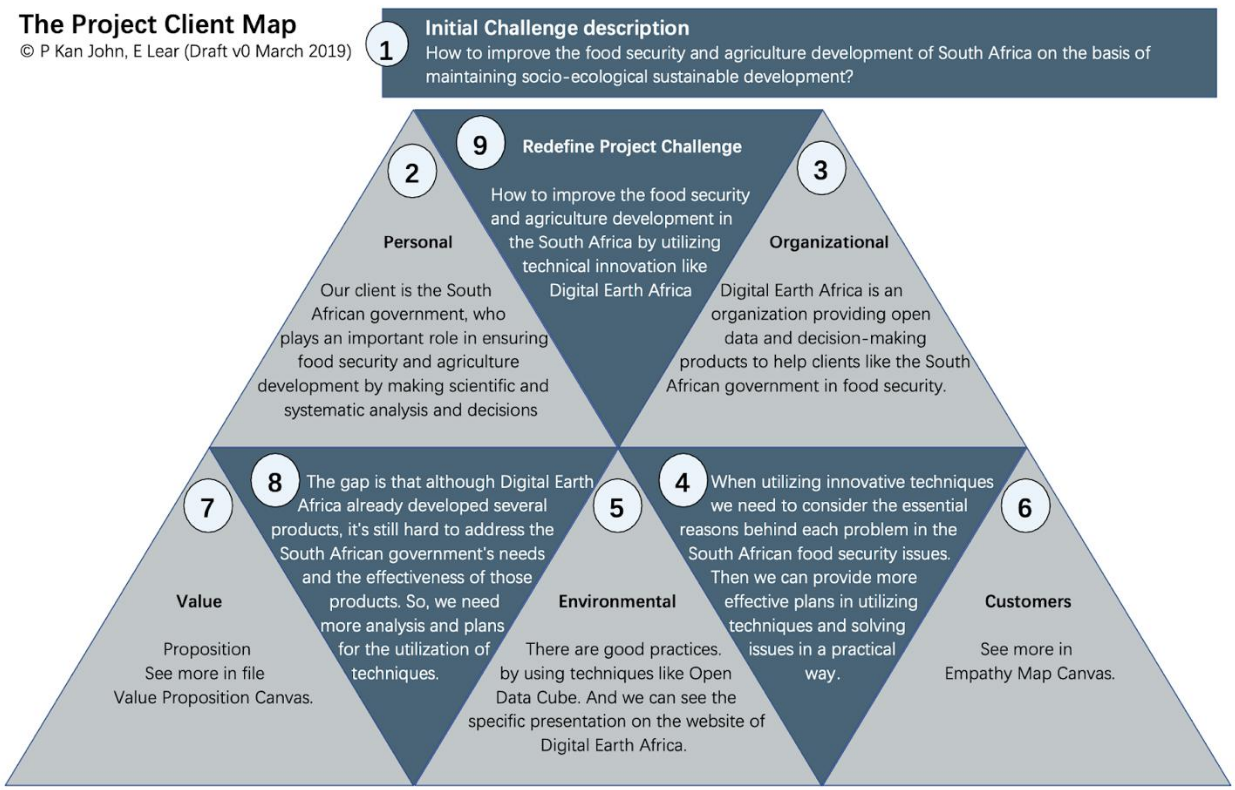
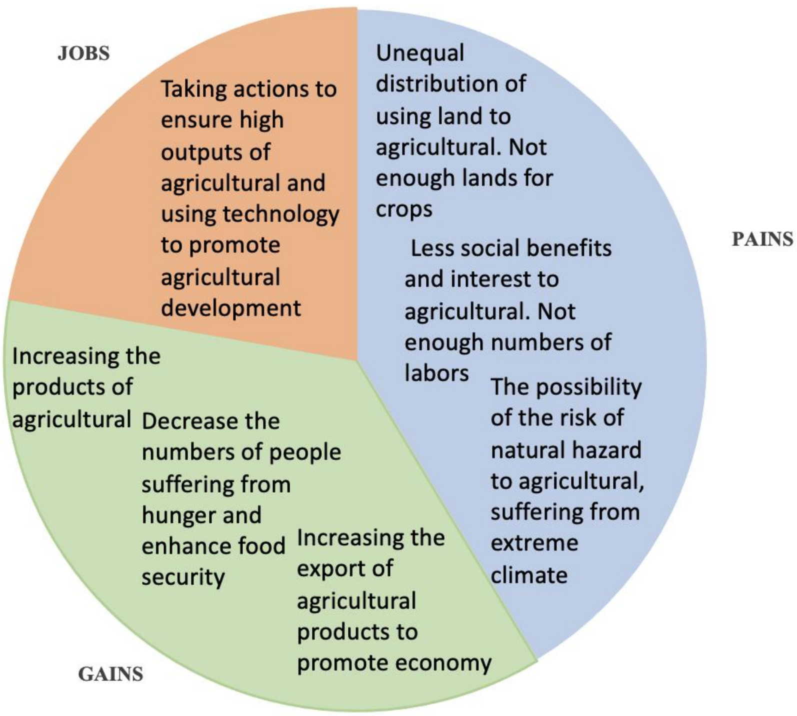


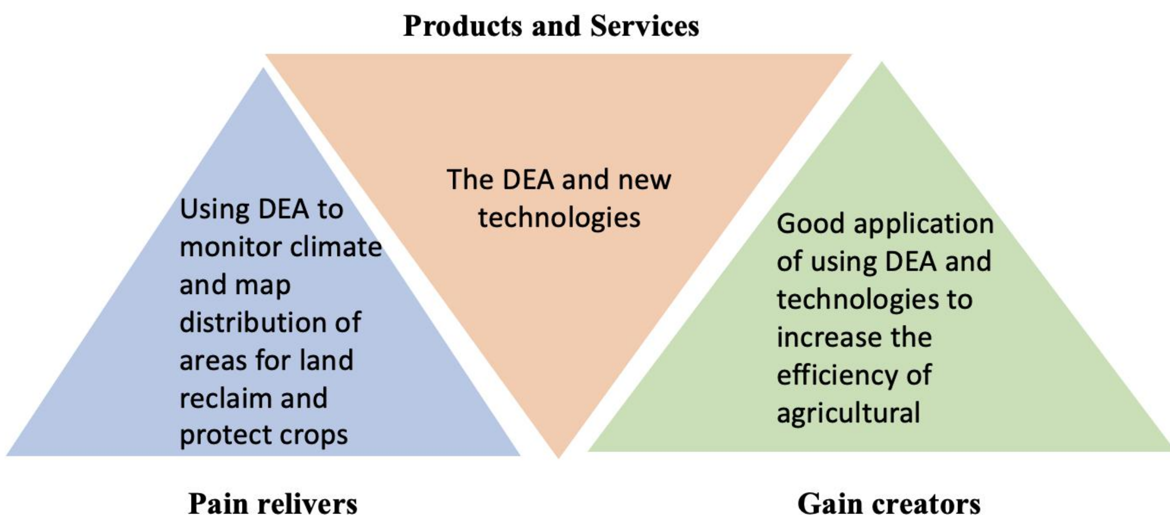
Figure 9: Project client map

Appendix C: Value Proposition Canvas

Customer Profile



Value Map



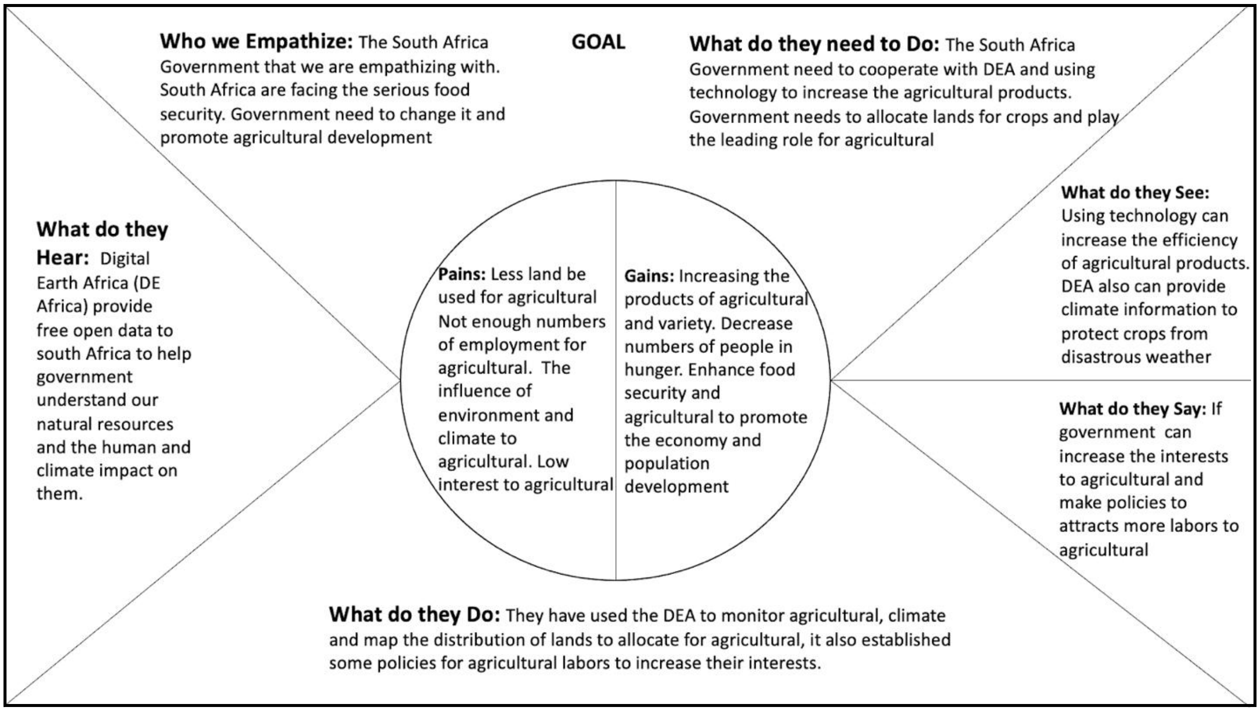


Figure 10 - 12: Value proposition canvas

Appendix D: HMW questions and solutions

POV

The South African government needs to ensure food security and agriculture development on the basis of maintaining socio-ecological sustainable development because they lack the ability to scientifically and systematically make analysis and decisions.

HMW

1. How might we make accurate and specific presentations of the full range of food safety issues in South Africa?

2. How might we give solutions for the poor agricultural productivity in South Africa?

3. How might we give solutions for the natural disasters and the epidemic influence in South Africa?

4. How might we use technical innovation to help improve scientific decision making?

5. How might we develop a systematic plan for the South African government to utilize Digital Earth Africa and other similar techniques?

Solutions

1. Our group splits up to carry out different aspects of research activities, brainstorming at regular meetings and integrating our findings into a final outline. – Question 1

2. Using Digital Earth Africa's current techniques including Sandbox and satellite map to monitor and analyse the agricultural situation in a certain area. – Question 2 & 4

3. Using techniques like Crop health monitoring by Digital Earth Africa and other crop quality test techniques. – Question 3

4. Considering the Global Root-zone moisture Analysis & Forecasting System (GRAFS) produced by the ANU Centre for Water and Landscape Dynamics – Question 3

5. Once the solution for each aspect has been identified, a comprehensive view of what needs to be integrated and leads to the final plan will be held by our group in regular meetings. – Question 5

6. Identifying the customer’s needs for the solution, determining the feasibility of the solution. Prioritizing the solution according to the urgency and feasibility. – Question 5

Appendix E: Six Hats Thinking

White Hat:

Digital Earth Africa currently has crop health detection, soil moisture monitoring, satellite maps, sandbox simulation with products, and these existing technologies and products can be used in agricultural production in South Africa.

The South African government is also open to the use of technology in agriculture.

Yellow Hat:

Positive impact on the survival and livelihood of future generations, and easy sustainability.

Black Hat:

Even if the plant health data is collected, how it will be analysed and how the results will be applied to the farmers' farming process will become problems.

Blue Hat:

The project has now reached the point where Digital Earth Africa is being used to detect and ensure food security in South Africa, and the question is how to integrate Digital Earth Africa's analysis tools across different stakeholders.

Apart from the already secured Digital Earth Africa analysis tools, are there other potentially available digital analysis methods, or how can Digital Earth Africa analysis be referenced to give users a clear visualization of food security and changes (e.g., BI dashboard)?

Appendix F: LotusBloom Analysis

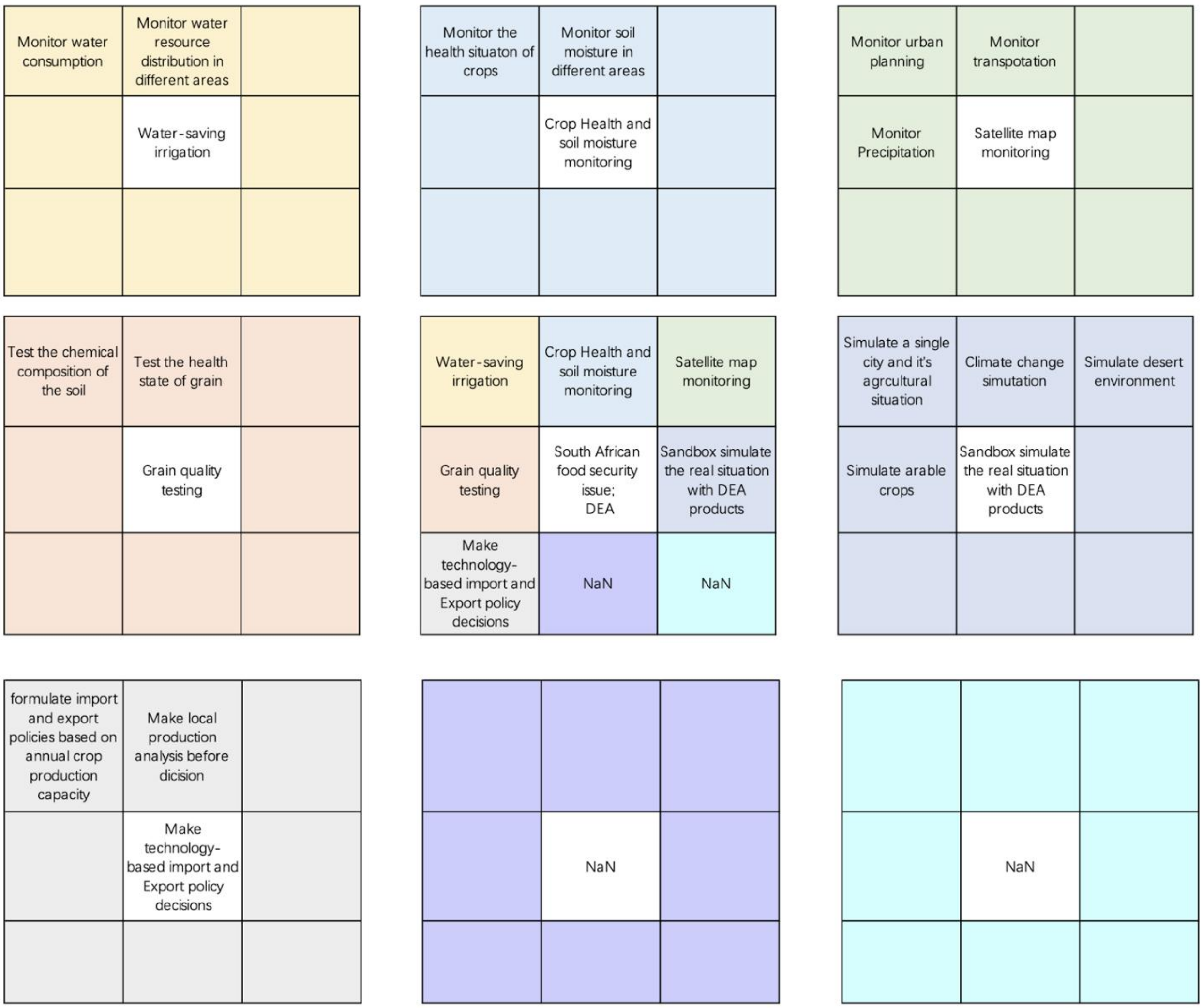


Figure 13: Lotus bloom analysis

Appendix G: Dot Voting Results

WS4 Group 3:

Problem Statement: Our project overview is: The South African government needs to ensure food security and agriculture development on the basis of maintaining socio-ecological sustainable development because they lack the ability to scientifically and systematically make analysis and decisions. We mainly focus on the food security problem in South African.

Solution 1: Using Sandbox simulation technology provided by DE Africa to rationally use and allocate land resources, and further increase food production.

Solution 2: Using Satellite mapping technology to monitor the farming distribution and food security.

Solution 3: Testing crop health and soil moisture to ensure food security of the crop growing environment.

Solution 4: Making technology-based import and export policy decisions to maintain sustainable development.

Solution Votes

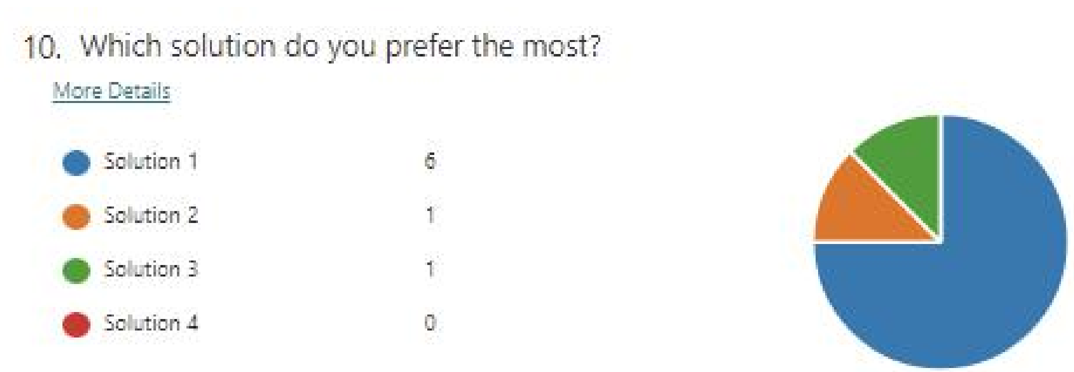


Figure14: Pie chart for dot voting results

Which solution do you prefer the most?	Was there a particular reason for your choice? What was it?	Do you have other suggestions, comments, or ideas for the group 3?

Solution 1	it is helpful to improve local agriculture	focus on water resource, land desertification
Solution 1	Seems like an advanced approach.	No.
Solution 1	Yes, it said the specific technology of DE Africa.	They can explain more.
Solution 1	Null	Null
Solution 1	The production of food must be guaranteed before further development in other areas, such as food safety and exports	Analyse the soil composition and structure to find the most suitable crops and fertilizers
Solution 1	The first solution is the most feasible. In contrast, it is difficult to implement the other solutions.	I think they should combine the other provided data with the technology, which may be more precise.
Solution 2	Since DEA is mostly based on satellite technology, I think this solution utilizes DEA the best.	I am not sure how solutions 3 and 4 are related to DEA.

Table 3: Dot voting feedback

Appendix H: Gantt Chart

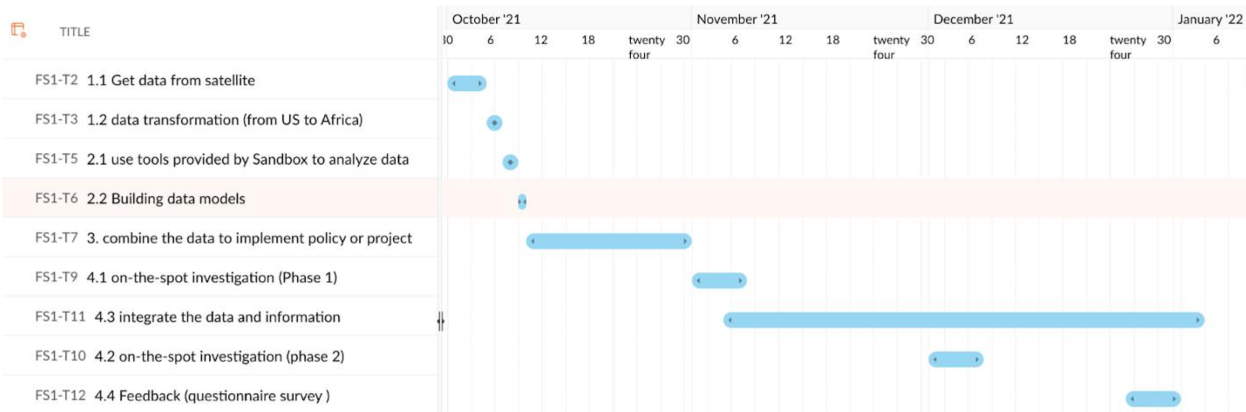


Figure 15: Gantt chart for prototype

Tasks	Estimate time cost	Start time	End time	Progress
Project - Digital Earth Africa with South Africa Food security				
1. Collect data	1 week	2021.10.1	2021.10.7	
1.1 Get data from satellite	5 days	2021.10.1	2021.10.5	
1.2 Data transformation (from US to Africa)	2 days	2021.10.6	2021.10.7	
Milestone - 1	collect data through satellite and pass data to Africa			20%
2. Analyse data	3 days	2021.10.8	2021.10.10	
2.1 use tools provided by Sandbox to analyse data	2 days	2021.10.8	2021.10.9	
2.2 Building data models	1 day	2021.10.10	2021.10.10	
Milestone - 2	analyse date by sandbox, and build data models			45%

3. combine the data to implement policy or project	3 weeks	2021.10.11	2021.10.31	
Milestone - 3	implement policy or project and put it into agriculture production			80%
4. Validation	2 months	2021.11.1	2022.1.4	
4.1 on-the-spot investigation (Phase 1)	1 week	2021.11.1	2021.11.7	
4.2 on-the-spot investigation (phase 2)	1 week	2021.12.1	2021.12.7	
4.3 integrate the data and information examined	2 months	2021.11.5	2022.1.4	
4.4 Feedback (questionnaire survey)	1 week	2021.12.26	2022.1.1	
Milestone - 4	examine the effects of the project or policy implementation, integrate information, and get some feedback			100%

Appendix I: Content of Questionnaire

1	What is your age?
	▢ under 20 ▢ 21 - 35

	▢ 36 - 50 ▢ 51 - 65 ▢ above 65
2	Does your work involve the following agricultural areas?
	▢ Agriculture ▢ Forestry ▢ Animal husbandry ▢ Aquaculture activity ▢ Others (please specify): ▢ None of those, I don't work in agricultural area
3	Are you familiar with/Have you ever used or heard any agricultural information technique? (e.g. Data Analysis, Automation, Remote sensing, Satellite monitoring, ...)
	▢ Yes, I have used some of these. ▢ Yes, I am familiar with some of these, but never used. ▢ Yes, I heard some of these, but not very familiar. ▢ No, I never heard them before.
4	If we supply a new agricultural information technique which can help you perform daily agricultural activities with higher efficiency or lower losses, to what extent will you accept?
	▢ I will definitely accept the technique and use it immediately. ▢ If the benefits outweigh the costs, I will accept the technique. ▢ I will accept the technique if most people accept it. ▢ I cannot decide unless it has successful real practice in local area.

	▢ I won't accept any technique even if it can help me. ▢ Others (please specify):
5	What is your income per year from working in agriculture (in USD)?
	▢ under 1,000 ▢ 1,000 - 10,000 ▢ 10,000 - 20,000 ▢ 20,000 - 50,000 ▢ 50,000 - 100,000 ▢ above 100,000 ▢ I don't work in agricultural area
6	What percentage of your income would you be willing to invest in agricultural technology?
	▢ under 5% ▢ 5% - 10% ▢ 10% - 20% ▢ 20% - 30% ▢ above 30%
7	What principles do you think should be followed in the promotion of those innovative agricultural information techniques?
	▢ Respect for the wishes of agricultural workers and no compulsory use ▢ Do not cause ecological damage or waste resources ▢ Government/department/organizations should give support, guidance, and encouragement ▢ Local adaptation, experimentation, and demonstration

	▢ Others (please specify):

Table 4: Questionnaire

Appendix J: Distribution of employment in South Africa

The figure is from stat SA. It describes the distribution of employment in South Africa by economic sector from 2010 to 2020. In 2020, around 5 percent of the employees in South Africa were active in the agricultural sector, around 22 percent in industry and around 72 percent in the service sector.

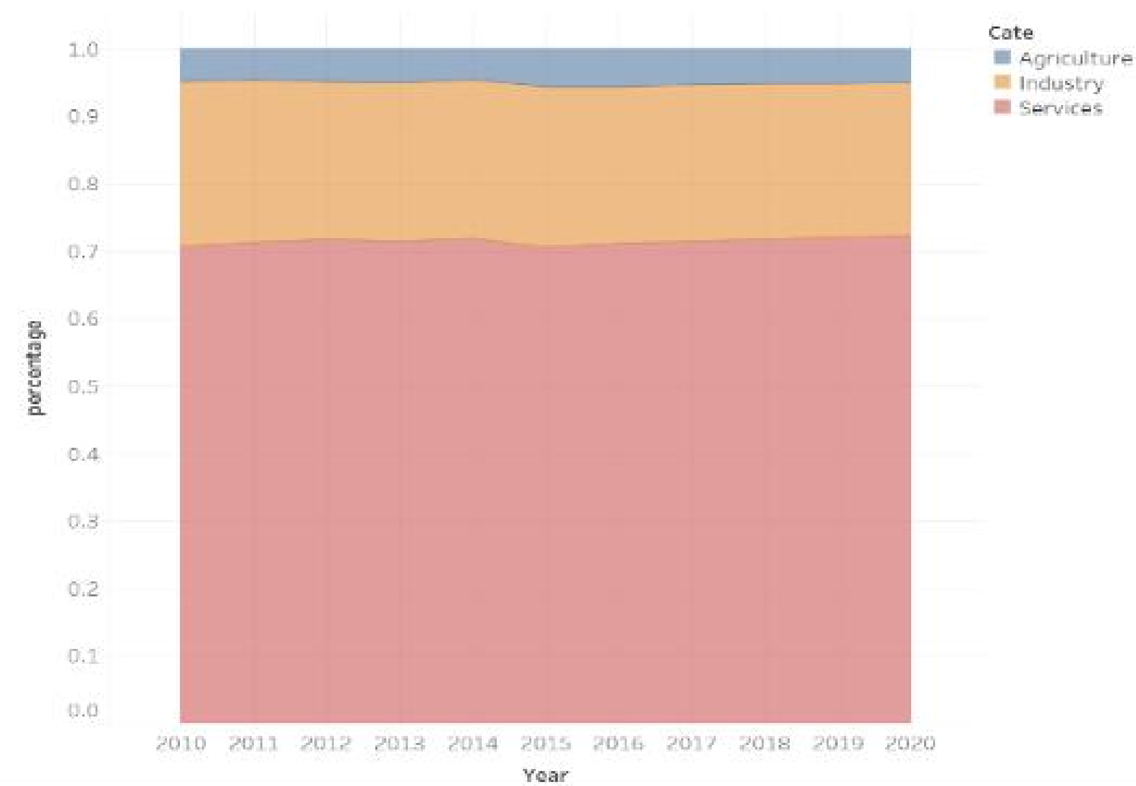


Figure 16: Distribution of employment in South Africa

Appendix K: Race distribution in South Africa

As of 2019, South Africa's population increased and counted approximately 58.4 million inhabitants in total, of which the majority (roughly 47.4 million) were Black Africans. Individuals with an Indian or Asian background formed the smallest population group, counting approximately 1.45 million people overall.

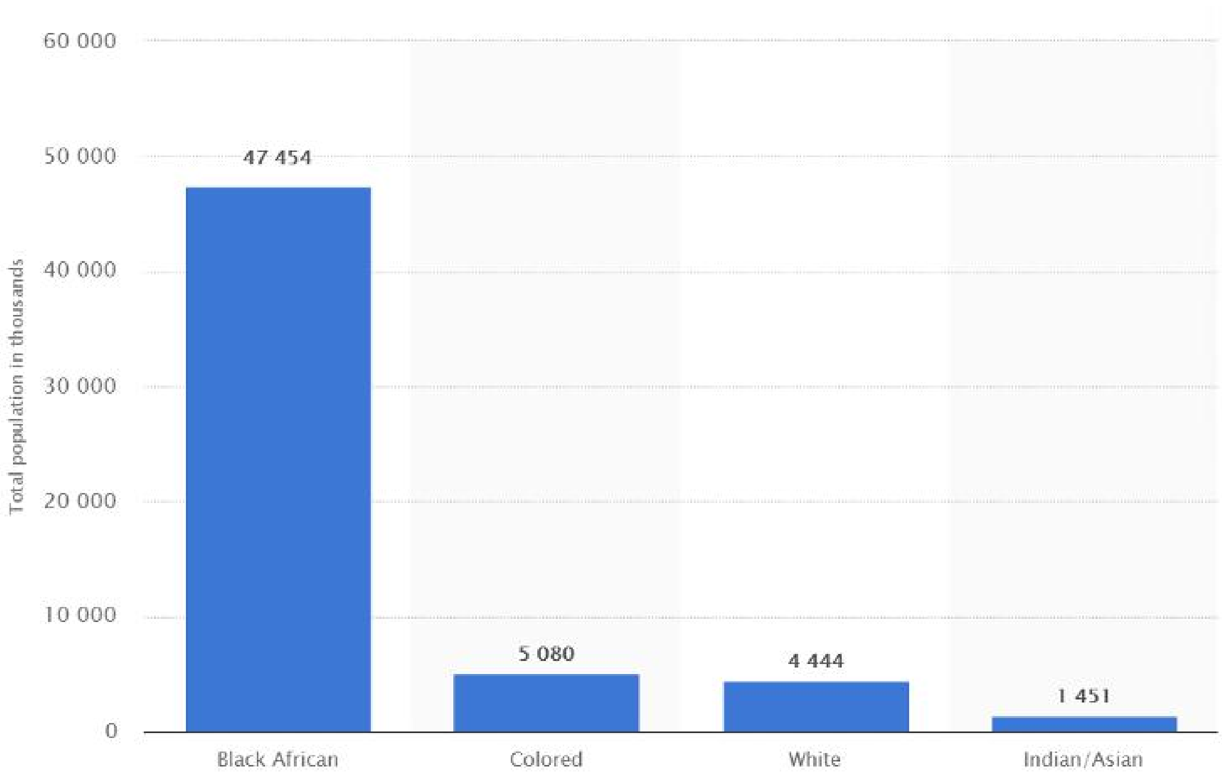


Figure 17: Race distribution in South Africa

In the following figure, the x axis is percentages of land ownerships for different races in some provinces, the y axis shows different races in some provinces of South Africa. Except for NW province, white people got ownership of over 50% land areas in other provinces.

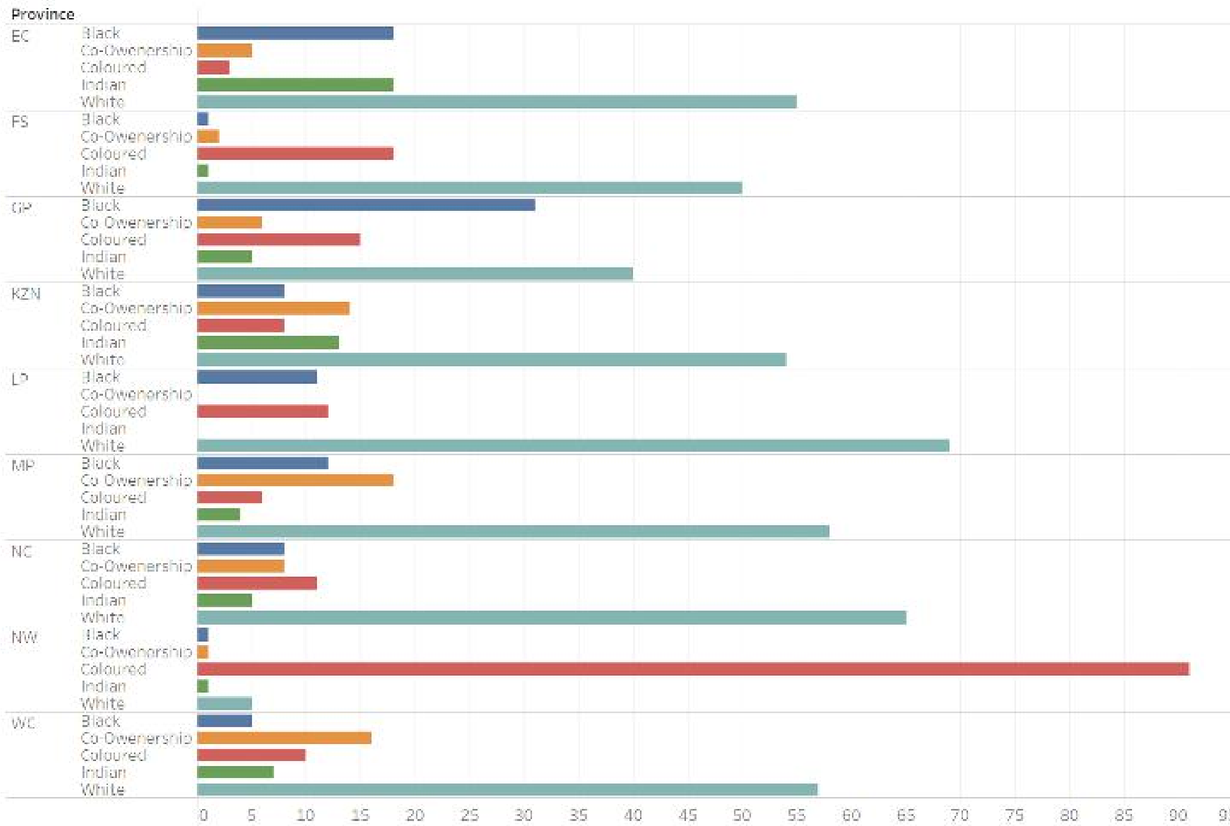


Figure 18: Percentages of land ownerships for different races

Appendix L: Land bank financial reports

The bank failed to make repayments in April 2020 on a revolving credit facility, leading to a default event being triggered on debt worth R13.8bn (US$754m). In addition, the bank's credit rating has been declining and appears to have a negative rank since February 2019 [14]. As the following two figures showed, in Land Bank's interim financial results as of 31 March 2020 and 30 September 2020, the loss/profit for the year continues showing losses. And its loss from continuing operations for the six months ended 30 September 2020 was 172 million South African Rand. The net interest income and additional funding costs for banks continued to decline over this financial period due to margin compression and declining loan books, as well as credit rating downgrades and events of default.

	Notes	Group 2020 R'000	Group Restated 2019* R'000	Bank 2020 R'000	Bank Restated 2019* R'000
Continuing operations					
Net interest income		651 138	1 102 877	646 822	1 097 938
Interest income	25	4 698 792	4 927 160	4 692 661	4 920 302
Interest expense	26	(4 047 654)	(3 824 283)	(4 045 839)	(3 822 364)
Net impairment charges, claims and recoveries	11.6	(1 807 700)	(1 188 033)	(1 807 700)	(1 188 033)
Total (loss / income from lending activities		(1 156 562)	(85 156)	(1 160 878)	(90 095)
Non-interest expense	27	(125 231)	(262 667)	(120 556)	(251 361)
Non-interest income	28	99 407	113 977	93 589	105 452
Operating (loss) / income from banking activities		(1 182 386)	(233 846)	(1 187 845)	(236 004)
Net insurance premium income	29.1	143 126	156 826	-	-
Net insurance claims	29.3	(131 261)	(165 886)	-	-
Other costs from insurance activities	29.4	(32 497)	(20 085)	-	-
Investment income and fees	30	91 138	104 645	314 243	21 299
Interest on post-retirement obligation	23	(26 672)	(22 533)	(26 672)	(22 533)
Interest on lease liability	16.2	(5 249)	(6 703)	(5 218)	(6 686)
Gains and losses on financial instruments	31.2	(19 153)	(4 912)	(19 153)	(4 912)
Fair value (losses) gains	31.1	(142 468)	90 208	(21 714)	83 275
Operating (loss) / income		(1 305 423)	(102 286)	(946 359)	(165 561)
Operating expenses	32	(712 777)	(697 008)	(688 550)	(673 934)
Net operating (loss) / income		(2 018 200)	(799 294)	(1 634 909)	(839 495)
Non-trading and capital items	33	(40 951)	(26 968)	(40 951)	(26 969)
Net (loss) / profit before indirect taxation		(2 059 151)	(826 262)	(1 675 860)	(866 464)
Indirect taxation	34	(65 764)	(73 170)	(65 622)	(73 045)
Net (loss) /profit from continuing operations		(2 124 915)	(899 432)	(1 741 482)	(939 509)
Net profit / (loss) from discontinued operations	24	363	12 930	363	12 930
(Loss) Profit for the year		(2 124 551)	(886 502)	(1 741 119)	(926 579)

	September 2020
Net interest income	223
Impairments	(73)
Operating expenses	(272)
Profit / (Loss) from Continuing Operations	(172)
Cash	7 306
Investments	2 184
Net loans and advances	37 510
Total assets	**47 678**
Capital and reserves	5 352
Liabilities	42 326
- Funding liabilities	*41 047*
- Other liabilities	*1 279*
Total equity and liabilities	47 678

Figure 19 & 20: Land bank financial reports as of 31 March 2020 and 30 September 2021

Appendix M: Average share of world total corn and soybean production and exports

The data of the following table is from USDA, Economic Research Service calculations in 2014. As data shown in the table, the average production share (2.7%) of corn in Argentina is much less than the share percent in exports (16.9%). Brazil, Argentina, the US have been important producers and traders of these crops in the world markets.

	Corn		Soybean	
	Production	Exports	Production	Exports
	Percent			
Argentina	2.7	16.9	18.0	9.5
Brazil	7.6	14.0	28.1	36.8
United States	36.5	42.2	34.5	41.8
Total	**46.8**	**73.1**	**80.6**	**88.1**

Table 5: Average share of world total corn and soybean production and exports (marketing years 2008-12)

Appendix N: The fall in the water level of the Vaal River led to drought

In November 2020, due to severe drought, the water volume of the Vaal River, known as the “mother river of South Africa”, continued to decline. The water level of the Vaal River reservoir has dropped to 28% of the total water level. The Vaal River is one of the most important rivers in South Africa, which is the main source of water supply and irrigation system in northern South Africa. Unreasonable irrigation enlarges the effect of drought on grain production. According to the reports, a serious multi-year drought in parts of South Africa’s Northern and Eastern Cape provinces has seen a number of small towns threatened by total water supply failures and livestock farmers facing financial ruin.

Appendix O: The question about fall armyworm raised by the South Africa Government

In 2017, the fall armyworm invaded South Africa's northern province of Limpopo - just months after the worst drought. In South Africa, the white maize is the main source of food for many South Africans, and the sorghum can also be used in animal feed and alcohol. As stated by the South African government, "Fall Armyworm is a disastrous exotic pest with a wide host range and if not properly controlled it may lead to damage of the host crop and or yield loss. Fall Armyworm is present in all the provinces in South Africa, however; the level of infestation varies per province, district or area." The invasion of insects not only greatly reduces the output value of agriculture, the government and farmers also need to invest a lot of labour and funds to solve the pest problem.

Appendix P: Specific agricultural issues arising from the Covid-19

Firstly, the demand-side shock. A recent survey in South Africa found that 24 percent of respondents had no money for food. For people living in informal settlements, that number rises to 55 percent. Additionally, as incomes contract, depreciating currencies and increasing logistics costs may drive up the cost of goods, putting pressure on people's ability to afford food. Secondly, production shock, COVID-19 may disrupt upcoming planting seasons. Moreover, many farmers in South Africa may still be emerging from debt caused by droughts in previous years which may cause ongoing financial challenges for upcoming production seasons, which in turn affects agricultural production. Thirdly, the labour force. By Coronavirus Case Analysis [Figure 21], we can see the great impact of the epidemic on South Africa. This can affect the safety of farmers, and shortages of labour and protective materials can affect the efficiency of agricultural cultivation thus affecting food security in South Africa.

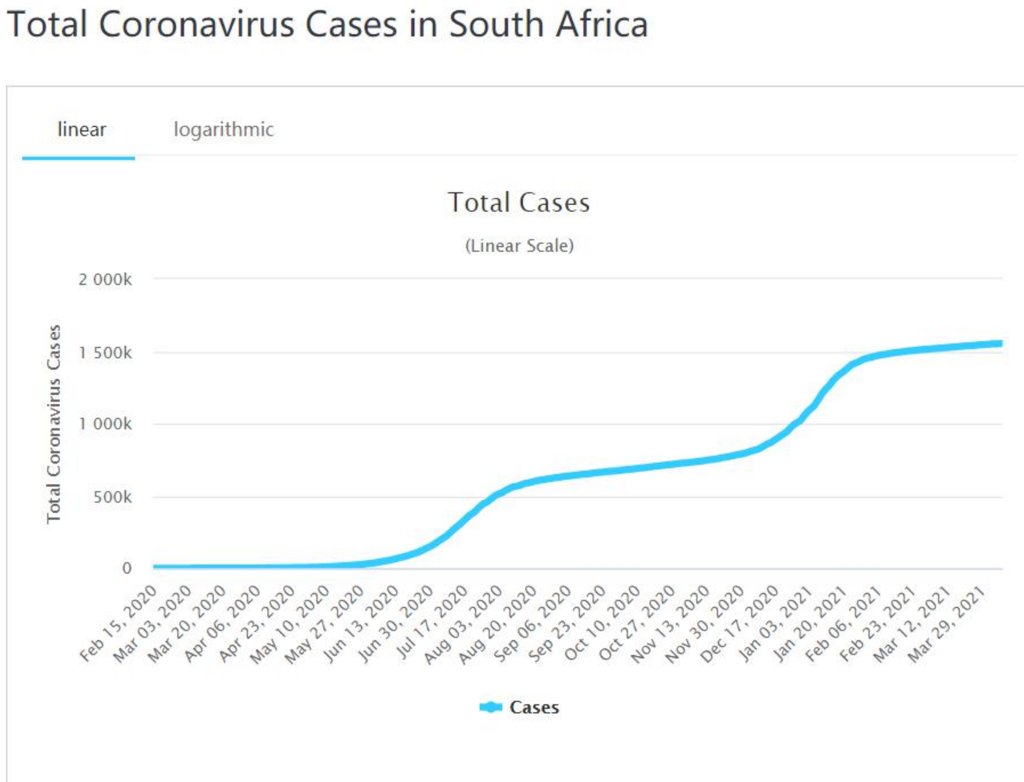


Figure 21: Total Coronavirus Cases in South Africa (ref.15)

Appendix Q: Specific calculation of proposed budget

- The data collected by the DE Africa group is open source. Thus, we consider the cost of data collection is free.

C1: cost of computer maintenance, estimate 3 computers enough. 199 + 138 + 100(accessories) = 437

C3: cost of pesticides, drought, and water flow protection (115 + 285 = 300) * 100 unit = 30000

C4: cost of investigation: questionnaires and travel related cost -> 100 + 200 = 300, we estimate 4 times investigation to collect feedback from clients

I1: each farmer’s average pure income per unit is 400

benchmark of 30% gain in production