Hochschule Konstanz – Technik, Wirtschaft und Gestaltung

Fakultät Maschinenbau

Wirtschaftsingenieurwesen Maschinenbau

Hochschule Konstanz
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Bachelor Thesis

Conception of smart farming solutions in the context of Botswana's digital development:

Identifying and evaluating potential innovations that enable smallholder farmers in Botswana to access data, connecting them to new resources, knowledge, and markets, based on a federated digital framework to advance Africa's transition to a digital economy.

Hannes Borgwardt

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Bachelor Thesis

For the attainment of the degree Bachelor of Engineering (B.Eng.)

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Identifying and evaluating potential innovations that enable smallholder farmers in Botswana to access data, connecting them to new resources, knowledge, and markets, based on a federated digital framework to advance Africa's transition to a digital economy.

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Abstract

Botswana serves as a role model for other African countries due to its rapid development in recent decades. Since the country is sparsely populated and a large part of the rural population depends on agriculture, especially livestock, this sector forms the backbone of the national economy. The digitization of this sector offers promising opportunities for economic growth and driving Botswana's evolution to a digital economy, while real value is being created for smallholder farmers. To support this process, an ITU research project made the key recommendation for the development of a digital crowdfarming tool and marketplace to create a digital ecosystem for smallholder agriculture. Within the research project, infrastructural challenges such as the creation of rural electricity supply and internet access, as well as the smallholders' need for remote monitoring, management, and better connectivity, were identified.

Based on the findings of the ITU research report, this bachelor's thesis aims to identify potential innovations for the digital development of smallholder agriculture in Botswana and to conceptualize proposals to address the identified challenges and needs of smallholder farmers. To achieve this, solutions were developed through literature research, technology analysis and expert involvement. These included the design of a decentralized mini-grid for power supply, proposals to create internet access, and the graphic visualization of a conceptual app. The latter addresses smallholder farmers' needs for remote monitoring, market access, knowledge enhancement, and connection to colleagues, buyers, and investors.

The proposed solutions and developed concepts provide impulses for further research and can serve as a basis for an extended evaluation through further involvement of experts and stakeholders.

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II. List of abbreviations

GB .... *Gigabyte*
GEO .... *Geosynchronous Earth Orbit*
GPS... *Global Positioning System*
ICT... *Information and Communication Technologies*
ID .... *Identification*
IoT .... *Internet of Things*
ITU.. *International Telecommunication Union*
LEO .... *Low Earth Orbit*
LoRa... *Long Range*
LoRaWAN... *Long Range Wide Area Network*
LPWAN... *Low Power Wide Area Networks*
SMS.. *Short Message Service*
TV .... *Television*
TVWS .... *Television White Spaces*
USD... *United States Dollar*
WiFi .... *Wireless Local Area Network*

1. Introduction

1.1 Problem definition

Over the past decades, Botswana has developed from one of the poorest countries in Africa to one of the most prosperous countries on the continent, serving as a role model for many African countries. Much of Botswana's rural population depends on smallscale agriculture, which forms the backbone of Botswana's economy. Digitization of this sector offers tremendous opportunities for economic growth in the country and can make a significant contribution to Africa's transition to a digital economy.[1] To lay the foundation for such an innovative and trusted digital economy, the entry barriers for smaller digital players may be lowered through the concept of digital federation, by promoting new digital services.[2]

Implementing digital applications for rural smallholder farmers requires overcoming some infrastructural barriers, such as providing access to electricity and the internet. In addition, smallholder farmers themselves face various challenges in managing their farms, as access to information, markets, and resources are limited by their remote location. Ultimately, the core problem is determining how smallholder farmers can be provided with the necessary technological infrastructure and how it can be used in a meaningful way, to provide real value to smallholder farmers through a new digital service.

1.2 Objective

This work aims to examine potential innovations that will enable smallholder farmers in Botswana to access data and connect them to new resources, knowledge, and markets, based on a federal digital framework to advance Africa's transition to a digital economy**.**

In doing so, the following research questions are derived and answered in this thesis:

[1] Cf. Elsäßer, Hänsel, & Feldt, 2021
[2] Cf. Bühler, et al., 2022

1. How can smallholder farmers in Botswana be provided with technological infrastructure in the form of reliable electricity and internet supply?

2. What can a digital platform look like that meets the needs of Botswana's smallholder farmers and allows them to get started with digitization and access to data?

1.3 Methodology

Starting with chapter 1, the topic, the problem definition, as well as the objective of the thesis are pointed out and concrete research questions are derived.

Chapter 2 puts the thesis in context by providing some background information. It outlines the current situation in Botswana in terms of the economy, agriculture, and digital infrastructure, as well as it presents the ITU research project, on whose findings this work is partly based. In this context, the challenges and needs of Botswana's smallholder farmers, which were identified in advance, are categorized.

In chapter 3, the thesis focuses on the meaning of a digital economy to emphasize what needs to be done to create such an economy. In addition to a general definition, smart farming and digital sovereignty are discussed.

Chapter 4 explores innovations with potential to solve fundamental infrastructural challenges for the implementation of digital applications. The focus lies on ensuring a reliable supply of electricity and internet access through literature research and the conceptual design of a mini-grid through an expert interview. It also examines which device is suitable for accessing the internet, making it affordable and user-friendly for smallholder farmers.

Chapter 5 explores technological solutions to the previously identified needs of smallholder farmers in Botswana. In the course of this, technology analysis will identify opportunities for implementing remote monitoring, as well as for creating connectivity for smallholder farmers. In addition, a conceptual app is designed, representing a suggested solution for addressing the identified needs.

The sixth chapter is dedicated to a concluding review of the thesis. In addition to summarizing the results and answering the research questions, the methodology of the work is critically reflected and the need for further research is outlined.

2. Background

This chapter sets the background for this bachelor's thesis by first outlining the current state of affairs in Botswana and then presenting the grant-winning research project in the field of digital inclusion, that provides fundamental findings for this thesis. Of particular importance is the categorization of challenges and needs identified in smallholder agriculture in Botswana.

2.1 State of affairs in Botswana

The Republic of Botswana is located in southern Africa, bordering South Africa, Namibia, Zambia, and Zimbabwe (see figure 1). The landlocked country lies about 1,000 m above sea level and covers an area of about 582,000 km^2. About 80% of this area is covered by the Kalahari Desert, which extends mainly over the southwestern part of the country.[3] The northwest of the country is dominated by the Okavango Delta, the largest inland delta in the world, known for its pristine nature and great biodiversity. The northeast is home to the Makgadikgadi salt pans, which cover an area of over 8,000 km^2.[4]

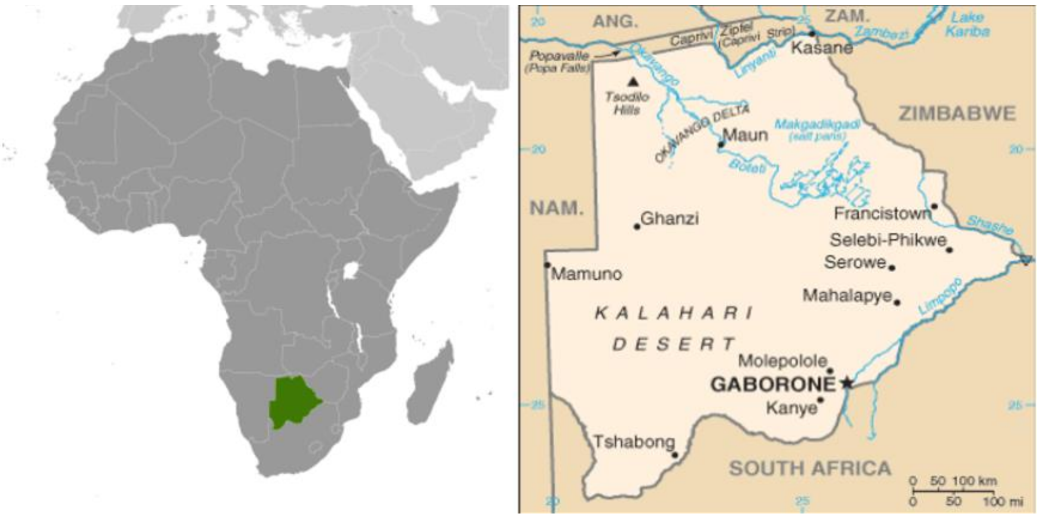

Figure 1: Geography of Botswana[5]

About 2.3 million people live in Botswana, a tenth of them in the capital Gaborone alone, in the southeast of the country. Botswana thus has one of the highest urbanization rates in Africa. At the same time, Botswana is considered one of the most

[3] Cf. Ramm, 2022
[4] Cf. Wagenfeld, 2019, p. 3
[5] Wagenfeld, 2019, p. 3

sparsely populated countries in the world, with an average of only about 4 people per km^2.[6]

2.1.1 Economic development

Botswana became an independent, democratic republic in 1966, making it the oldest democracy in Africa. However, the economic situation was so bad at that time that Botswana was considered one of the poorest countries in the world. In recent decades, Botswana has experienced significant economic growth, averaging about 9% annually, and has become one of the most prosperous countries in Africa. This rapid development and political stability make Botswana a model for other countries on the African continent. This development is because shortly after Botswana's independence, rich diamond deposits were discovered, and the funds gained were purposefully invested in the development of the country.[7]

Despite remarkable successes in recent years, Botswana faces several challenges. These include great social inequality, which manifests itself in widespread poverty among the population. In addition, Botswana is heavily dependent on its diamonds and trading partners.

2.1.2 Agricultural situation

Botswana is heavily dependent on imports from surrounding countries, especially South Africa, for food. About 90% of food is imported, while national agriculture provides only a fraction of food needs. Nevertheless, the national agriculture and livestock sector is of immense importance, especially for the rural population.[8] A large proportion of Botswana's citizens depend on the food, employment, and income that local agriculture and livestock provide. Smallholder farmers play a fundamental role in the food security of many rural households and form the backbone of Botswana's economy.[9]

[6] Cf. Eglitis, 2022
[7] Cf. World Bank, 2022
[8] Cf. Kashe, Kolawole, Moroke, & Mogobe, 2019, p. 4
[9] Cf. Elsäßer, Hänsel, & Feldt, 2021, p. 7

More than 20% of the workforce in Botswana is employed in the agricultural sector, which mainly comprises grain cultivation and livestock farming, but is dominated by the latter. The most important cereals are sorghum, maize, and millet. Since in large parts of Botswana, due to dry periods, there is no reliable water supply for irrigating fields and soil quality is often inadequate, cereal production suffers (see figure 2).

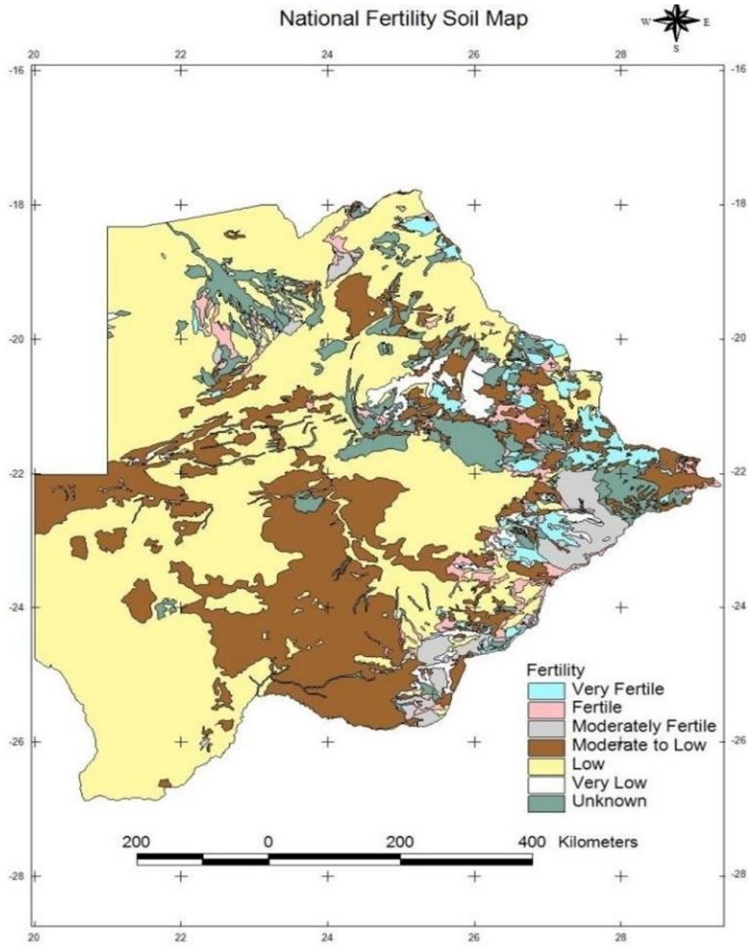

Figure 2: National fertility soil map of Botswana[10]

Not least because of the often inadequate quality of arable land for agriculture, about 70% of the land is used for livestock, which is thus the predominant agricultural activity in Botswana.[11] Livestock farming is mainly used for the production of beef, which is the most important agricultural export product. Besides cattle, mainly smaller ruminants such as sheep and goats are kept, which cope relatively well with the climatic conditions. In addition to the climatic challenges, other problems weaken the farmers'

[10] Kashe, Kolawole, Moroke, & Mogobe, 2019, p. 8
[11] Cf. Moreki, Moseki, & Kopano, 2022

production. These include a lack of infrastructure, technical equipment, insufficient financial resources, poor market access and integration, and animal diseases.[12]

These problems are particularly pronounced in traditional agriculture, which is prevalent in rural areas of Botswana. One of the characteristics of traditional livestock farming is, that unlike commercial farming, animals are not kept on leased, fenced land. Instead, animals graze on open, natural pastureland to which ranchers have no ownership rights. The labor force is typically low-skilled and has few resources and financial means, making traditional agriculture highly crisis-prone and inefficient. Commercial livestock farms, on the other hand, operate on their own fenced land and feed their animals supplemental feed. This can lead to greater efficiency as the animals are healthier and rearing can be managed more selectively. Such commercial farms produce exclusively for the market, while traditional farmers often produce only for their own needs or just beyond.[13] The traditional approach exposes farmers to the risk of inadequate food security, as they often produce only for their family's daily needs, repeating this day after day, without realizing their full potential.[14]

2.1.3 Digital infrastructure

A country's digital infrastructure is the infrastructure that enables digital services and network-based business models and thus forms the basis of a country's digitization. The two most critical prerequisites for this are firstly, the nationwide supply of electrical energy, and secondly, a reliable internet connection.[15]

2.1.3.1 Electricity access

The Republic of Botswana has one of the highest electrification rates on the African continent, at about 70%, but access to electricity is unevenly distributed. As shown in figure 3, in rural areas, only about 30% of the population has access to electricity.[16]

[12] Cf. Moreki, Moseki, & Kopano, 2022, pp. 332-374
[13] Cf. Bühler, et al., 2022, pp. 11-12
[14] Cf. Bambokela J. , 2022
[15] Cf. Hofmann, 2020, p. 2
[16] Cf. World Bank, 2022

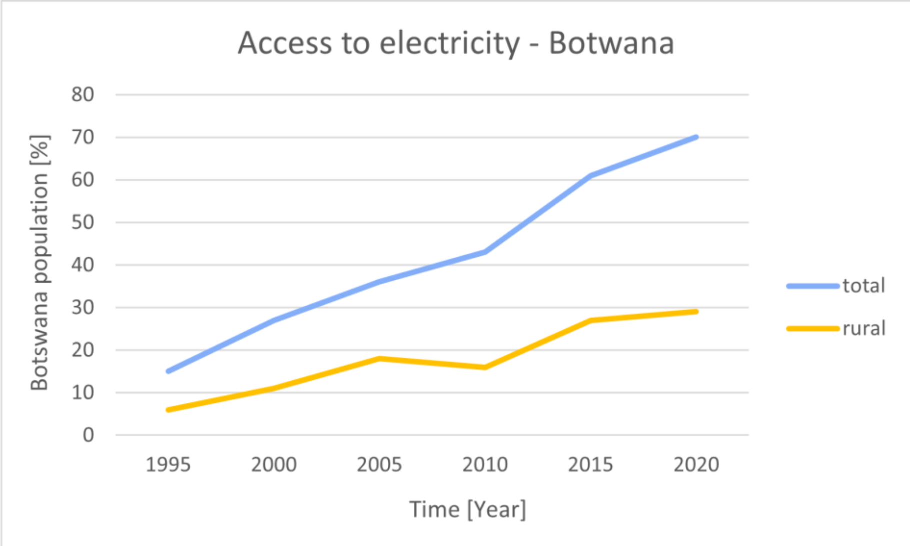

Figure 3: Access to electricity for the population in Botswana[17]

Botswana's annual electricity consumption is 3.64 billion kWh and averages 1500 kWh per capita.[18] To cover this, the country relies mainly on coal for electricity generation. However, as can be seen in figure 4, national electricity generation is not sufficient to cover the country's electricity consumption. As a result, a large part of the annual electricity consumption is covered by imports, mainly from South Africa.[19]

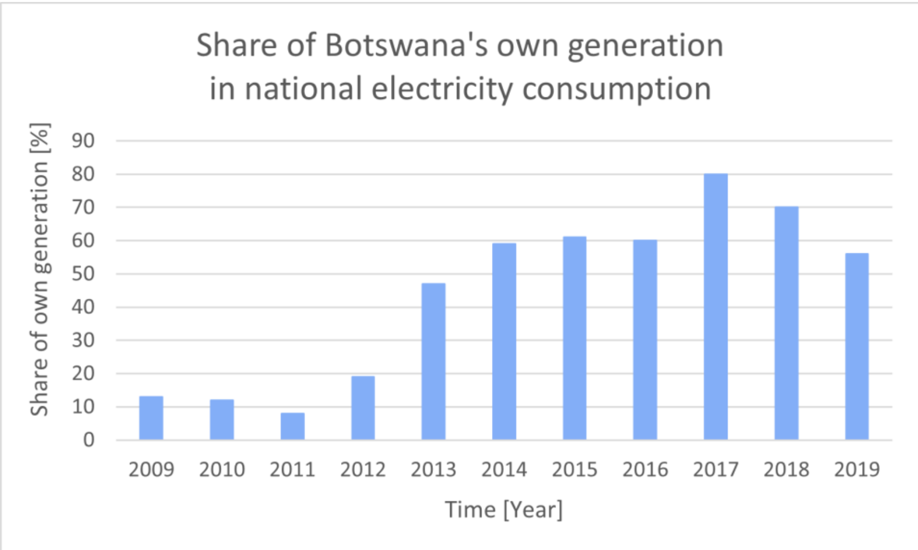

Figure 4: Share of own generation in electricity consumption in Botswana[20]

However, policymakers are working to advance national self-sufficiency in electricity. Part of the plan is to relax the monopoly that the Botswana Power Corporation has on

[17] Own illustration based on World Bank, 2022
[18] Cf. Eglitis, 2022
[19] Cf. Knupp, 2020
[20] Own illustration based on Knupp, 2020

electricity generation. This will make it easier to operate independent power generation plants, which will then be allowed to sell their surpluses. There are also plans to switch to renewable energies for power generation. The focus is on solar energy to achieve the goal of generating 50% of electricity from renewable sources by 2030.[21]

2.1.3.2 Internet access

At the beginning of 2022, there were approximately 1.48 million internet users in Botswana, representing about 61% of the total population and an increase of 1.9% from 2021. Just over half of the pages accessed online were accessed via cell phones, while around 47% of the pages accessed were opened using laptops and desktop computers. Tablets and other devices account for only a vanishingly small percentage of the devices used for web browsing. There were around 1.2 million active users of social media at the beginning of 2022, which corresponds to a share of 49.6% of the total population, roughly the same as in the previous year. A large proportion of these social media users, 96.4% to be precise, access them via mobile devices, mostly with the aid of the Android operating system, while the most frequently used platform is Facebook.[22]

2.2 ITU Connect2Recover research project

In the course of the research project described below, findings were made in the run-up to this bachelor thesis, which are taken up in this paper to further explore the digitization of smallholder agriculture in Botswana.

2.2.1 Research competition

As part of the "Connect2Recover" research competition, organized by the International Telecommunication Union, the Constance University of Applied Sciences has won funding for the title "Federated Digital Platform: Pilot Project Botswana". The detailed research title of the successful proposal was: "Creating a Blueprint for Africa's Transition Towards an Inclusive and Competitive Digital Economy: Identifying Potential

[21] Cf. Knupp, 2020
[22] Cf. Kemp, 2022

Industries, Stakeholders, and Use Cases for the Development of a Federated Digital Platform and Advanced Services with a Focus on Botswana".[23]

The Connect2Recover competition is a global initiative that aims to build a global research community of think tanks and academics. They will share knowledge and conduct research to support the development of a resilient digital infrastructure for meaningful connectivity.[24]

2.2.2 Overview of the final ITU report

The research team's final report is titled "Advancing Smallholder Agribusiness in Botswana through Smart Digital Innovation." The key recommendation here is the "design and deployment of a digital crowdfarming tool and marketplace to create a digital ecosystem for smallholder agriculture as a blueprint for Africa."[25] This report highlights the potential of federated platforms in the context of the Republic of Botswana's digital transformation. In addition, the report offers insights into the reality of smallholder farmers in Botswana who have been identified as potential users of such a federated platform and for building digital resilience.

The focus on a pilot project forms the main outcome of the ITU Connect2Recover research study presented. This pilot project defines the first phase of a longer-term transformation roadmap, which consists of the three phases shown in figure 5.[26]

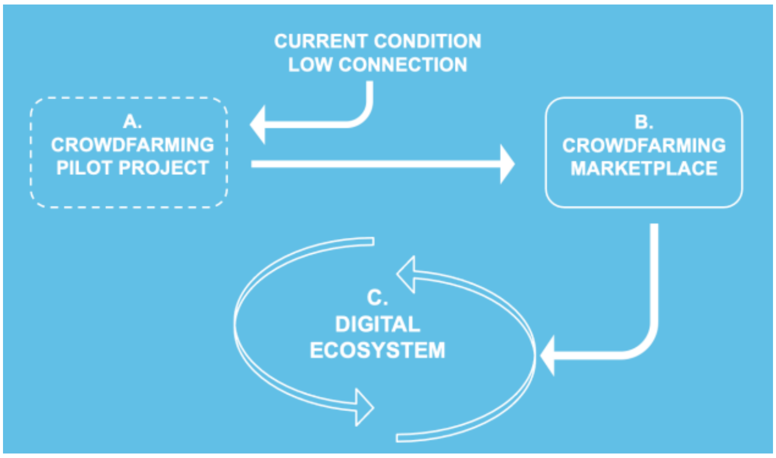

Figure 5: Roadmap to Digital Ecosystem for smallholder agricultural sector[27]

[23] Cf. Bühler, et al., 2021, p. 13
[24] Cf. Bühler, et al., 2021, p. 1
[25] Cf. Bühler, et al., 2022, p. 2
[26] Cf. Bühler, et al., 2022, p. 23
[27] Bühler, et al., 2022, p. 23

The first phase, the crowdfarming pilot project, aims to develop a minimally functional digital crowdfarming marketplace that connects selected farmers with consumers in Botswana. As a result, smallholder farmers should be able to better plan their harvests, increase yields, and improve their financial security. Consumers become virtual crowdfarmers and investors and benefit from transparency regarding the production and origin of the products. In addition, crowdfarming aims to make the supply chain more efficient, reduce food waste, and reduce the risk of inflation and supply chain disruptions.

The findings from the pilot project will be used in the second phase, the crowdfarming marketplace, to expand the pilot project and set up a larger marketplace with a higher number of participants. This will consist of an online store, mobile applications, ordering and fulfillment processes, and financial transactions.

In the third phase, the crowdfarming marketplace will then evolve into a digital platform where the focus expands from agricultural production and marketing to a data and technology-driven approach to farming. The focus will be on collaborative connectivity among participants.

2.2.3 Development roadmap for the crowdfarming pilot project

The realization of the first phase of the transformation roadmap, described in the previous chapter, requires several steps. The research team of the ITU report suggests the following three stages for the implementation of the crowdfarming pilot project.[28]

1. Analysis and stakeholder selection

   In this first phase, a market definition, alignment, and analysis will first be conducted. A service provider and technology will also be selected to develop the marketplace. Stakeholders will also be selected during this phase, with a focus on pilot farmers, traders, and consumers. The analysis of needs will be conducted as part of an ideation workshop with farmers, farmer associations, traders, and consultants.
2. Design and implementation

   The second phase will focus on designing and adapting digital marketplaces and the necessary processes related to logistics, payments, and customer service for

[28] Cf. Bühler, et al., 2022, p. 25

business models between farmers and consumers. In addition, a blueprint for digitally supported long-distance animal husbandry will be created and agricultural goods will be selected for crowdfarming. Furthermore, the organization and coordination of the marketplace and network will be established, and a microfinance mechanism for smallholder farmers will be set up to bridge financing gaps.

3. Launch and operations

   In the third phase, the pilot project will be launched with confirmed participants, initially for one harvest season and one production and sales cycle of live cattle. After that, it is planned to scale up by attracting new market participants and expanding the regions. Improvement projects will continue to grow the project so that the conceptualization of a fully functional crowdfarming marketplace, farming-as-a-service business model, and precision agriculture platform can occur.

2.2.4 Identified challenges and needs

Through research and interviews, conducted with various experts, as part of the ITU report, it was possible to identify some challenges and needs that exist in the agribusiness sector in Botswana.[29]

In the following, the challenges and needs mentioned are addressed, categorized, and summarized in order to explore potential innovations to solve selected issues in the course of this work.

- Infrastructural challenges
  - Access to water
  - Access to land
  - Access to electricity
  - Access to the internet
- Need for remote monitoring and management
  - Use of electric ear tags
  - Animal location tracking
  - Animal health monitoring
  - Animal theft prevention

[29] Cf. Bühler, et al., 2022, p. 15

    - Digital livestock management
- Need for connectivity
    - Contacts and communication
    - Access to markets
    - Fair market prices

The focus of this paper lies on technological and data-based solutions regarding agriculture in Botswana, therefore basic requirements, such as access to water and usable land, are not explored in detail. Instead, the focus lies on prerequisites for digitizing the agricultural sector, such as access to electricity and the internet, remote livestock monitoring capabilities, and connecting farmers to partners and fair markets.

3. Digital Economy

In order to drive Africa's transition to a digital economy, it is first necessary to clarify what is meant by a digital economy or what constitutes such an economy. In the following, a definition will shed light on this. Additionally, the findings will be placed in the context of the agricultural sector and smart farming. Furthermore, digital federation will be explained, in order to assess the positive contribution, it could have later on.

3.1 Definition

A digital economy is a network of economic activities enabled by information and communication technologies, or ICT for short.[30] However, this is more than just about using a computer to perform tasks that were traditionally performed analogously or by hand. Rather, it is about using digital technologies to perform tasks better and often differently than before. Moreover, in a digital economy, completely new tasks can be performed, or advanced technologies can be used in such a way that new products and services can be developed, that would not be feasible without digital means.

The pure digitization or automation of tasks forms only a small part of a digital economy. Rather, it is about using ICTs to network technologies, individuals, and organizations, thereby creating new connections and opportunities for exchange. The foundation for such a trustworthy digital economy is sovereign and secure data exchange.[31]

3.2 Smart Farming

When ICT is used in agriculture and this sector of the economy is digitalized accordingly, this is referred to as smart or precision farming.[32] Some of the most important digital technologies that can be deployed are devices such as mobile phones, sensors, cloud computing, and low power wide area networks, short LPWAN. Especially in rural areas of Africa, agriculture and livestock are the basis for a large part of the local population. For these remote farmers, smart farming offers valuable

[30] Cf. Pratt, 2022
[31] Cf. Bühler, et al., 2022, p. 13
[32] Cf. Bacco, Barsocchi, Ferro, Gotta, & Ruggeri, 2019, p. 1

opportunities for further development, as it gives them access to resources, knowledge, and data to which they would otherwise not have access. [33]

3.3. Digital sovereignty

Sovereign and secure data exchange is the foundation for innovative and trustworthy digital economies. By promoting new digital services and business models, the barriers to data exchange entry can be lowered. In this way, smaller digital players who cannot develop their own digital services due to limited resources can also gain access to shared data spaces.[34]

3.3.1 Definition

In modern understanding, the concept of sovereignty means the general ability to act self-determined and independent of foreign domination. The sovereignty of a state, for example, consists not least in guaranteeing the framework conditions for the self-determination of its citizens. It thus enables every human being to act independently and to be respected in his rights.[35]

The prefix "digital" refers to sovereignty and the self-determination it implies in the digital space. Digital sovereignty is therefore understood as the ability to use digital technologies and data in a self-determined and secure manner.[36] This involves enabling and promoting the generation, sharing, and reuse of data, as well as creating open and trustworthy data alliances within industries and countries. The concept of digital sovereignty has the potential to ensure the innovativeness, integrity, and trustworthiness of a digital economy.[37] Particularly in low- to middle-income emerging markets, digital sovereignty offers the opportunity to lower the barriers to data sharing, where a lack of resources and data makes it difficult for digital players to develop their own digital services, making data spaces for sharing particularly attractive.[38]

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[33] Cf. Elsäßer, Hänsel, & Feldt, 2021, p. 5
[34] Cf. Bühler, et al., 2021, p. 4
[35] Cf. Pohle, 2020, p. 2
[36] Cf. Pohle, 2020, p. 3
[37] Cf. Bühler, et al., 2021, p. 14
[38] Cf. Bühler, et al., 2022, p. 4

3.3.2 Federated digital platforms

The increasing demand for digital sovereignty has led to a technological architecture enabled by advances in cloud computing. Digital federation has evolved into such a technology architecture. As part of digital sovereignty, digital federation provides a collaborative framework for using shared data spaces without compromising ownership of the shared data.[39] The digital federation thus has significant potential to lay the foundation for a trusted digital economy.[40]

A federated digital platform can be used to increase collaboration, efficiency, and innovation. The key participants here are data owners, providers, consumers, and users.[41] As shown in figure 6, federators act as intermediaries between participants without collecting or owning the data exchanged. Together with the main participants, app-, service-, and other providers, they form a federated digital platform environment.

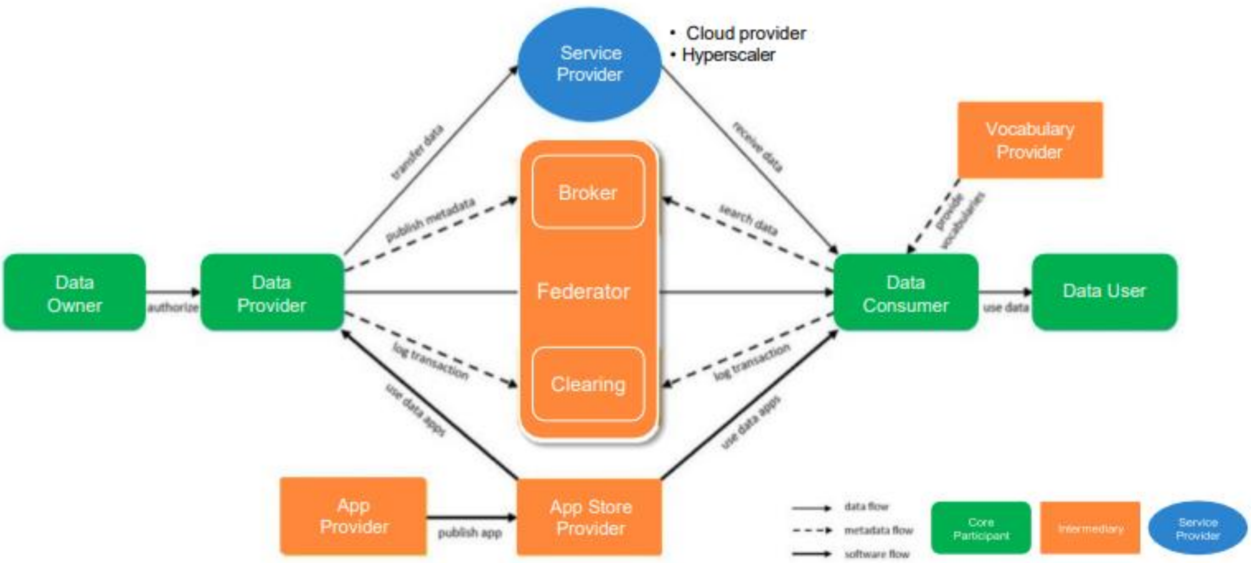

Figure 6: Federated digital platform[42]

To realize such a platform, the initial focus is on data sharing with scalable and marketable use cases. Following the bottom-up approach, these will then transform the shared data into common data spaces, data alliances, and increasingly complex ecosystems.[43]

[39] Cf. Nübel, Bühler, & Jelinek, 2021, p. 8
[40] Cf. Bühler, et al., 2021, p. 23
[41] Cf. Bühler, et al., 2021, p. 14
[42] Bühler, et al., 2021, p. 16
[43] Cf. Bühler, et al., 2022, p. 21

4. Potential innovations related to infrastructural challenges

This chapter examines the two main infrastructure issues for data-driven applications identified from those in chapter 2.2.4, one being access to electricity and the other being a connection to the internet. Potential solutions to both of these challenges are sought and presented below.

4.1 Decentralized electricity supply

A fundamental prerequisite for digital development is access to electricity.[44] Since electricity can be used to supply energy to countless other technologies and consumers, it forms the cornerstone for digital development. As explained in more detail in chapter 2.1.3, access to electricity is particularly difficult in rural areas of Botswana, where many smallholders live and work. The challenge here is to find a robust and affordable solution. Basically, there are two ways to address the energy or electricity deficit. On the one hand, existing infrastructures can be expanded, and on the other, new, decentralized energy plants can be installed, where they are needed.[45] Since the widespread expansion of electrical infrastructure into very remote areas involves an enormous effort, this chapter focuses on the installation of decentralized power supply systems.

Decentralized power plants can be set up where the energy is needed, meaning on the farms of smallholders in rural areas. Plants with a capacity of less than 10 MW are referred to as mini-grids, which offer great potential in rural areas of Africa due to their flexibility and scalability.[46] The challenge of such mini-grids lies in harnessing locally available energy sources, meaning converting existing energy into electricity. In Botswana, such local energy sources are primarily the sun and, especially in agricultural areas, biomass.

4.1.1 Electricity through solar energy

The potential of solar energy is clearly shown in figure 7. As can be seen there, the annual photovoltaic potential averages about 1850 kWh/kWp. In summer, the daylight

[44] Cf. Sunga, 2017
[45] Cf. Bambokela, Belaid, Muzenda, & Nhubu, 2022, p. 1594
[46] Cf. Odarno, 2017, p. 2

duration is almost 10 hours, and in winter still just over 8 hours. In total, about 3200 hours of sunshine per year can be expected in Botswana.[47] This makes Botswana an attractive and highly profitable location for the use of photovoltaics.

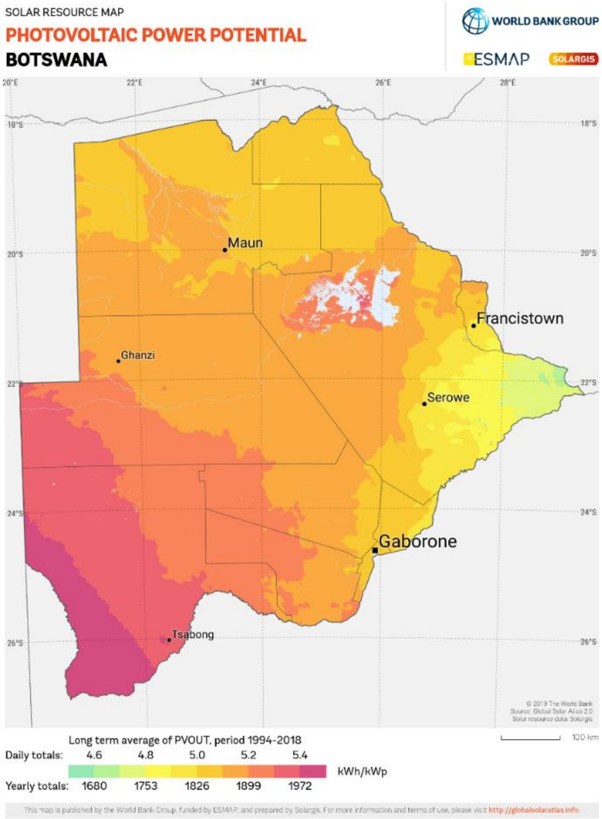

Figure 7: Photovoltaic power potential in Botswana[48]

In order to convert the sun's energy into usable electrical energy, essentially only solar modules and corresponding inverters are required. The solar module is used to generate electrical energy from the incident sunlight. This electrical energy is then available as direct current. However, since electrical consumers usually require alternating current, the current must be converted from direct current to alternating current. This task is performed by the inverter.[49]

Despite the great potential offered by solar energy in theory, there is a lack of practical implementation. The main reasons for this are obstacles such as excessively high investment costs, insufficiently trained specialists, poor technical quality of solar installations, and inadequate political framework conditions.[50] Since smaller systems

47 Cf. Deutsche Energie-Agentur, 2014, p. 41
48 Solargis, 2022
49 Cf. Wesselak & Voswinckel, 2012, pp. 61-64
50 Cf. Deutsche Energie-Agentur, 2014, p. 42

consisting of only a few solar modules are often sufficient in rural areas, the required investment sum is lower there. However, this can hardly be borne by individual households in rural areas alone, which is why community systems with central access represent a possible solution for cost sharing.[51] Smaller solar systems are becoming more common in the country's many safari lodges, usually supported by diesel generators as backup.[52]

4.1.2 Electricity through biomass

Biomass also offers great potential for conversion into usable energy. Biomass is found primarily in agricultural areas, meaning directly at the point of energy demand. This mainly involves animal manure, discarded food, and slaughterhouse waste.[53] To generate electricity from biomass, a bio-digester is required. In such a digester, biogas is produced from the biomass in the absence of oxygen. The gas is then upgraded to biomethane in a purification process. This in turn serves as fuel in the biogas generator and ultimately generates electricity.[54]

Essentially, two processes can be distinguished which can be used in fermenters. One is the continuous process and the other is the batch process. [55] As the name suggests, in the continuous process substrates are continuously fed while the end product is continuously removed. This process enables high productivity but requires a relatively high degree of automation, which in turn requires high investment costs and know-how.[56] In contrast to the continuous process, in the batch process, the fermenter is completely filled before the start of the process and completely emptied after the process is completed. This process can therefore be used more flexibly and requires lower investment costs. If the substrate concentration is too low, substrates or biomass can also be added to the fermenter during the ongoing process in the batch process. This type of batch process is then referred to as a fed-batch process.

There are several ways to build a digester, the fixed dome construction can be erected with manageable technical means, which makes it especially attractive in rural areas.[57]

[51] Cf. Sebusang & Masupe, 2003, p. 47
[52] Cf. Deutsche Energie-Agentur, 2014, p. 42
[53] Cf. Bambokela, Belaid, Muzenda, & Nhubu, 2022, p. 1597
[54] Cf. Tabatabaei & Ghanavati, 2018, pp. 438-440
[55] Cf. Tabatabaei & Ghanavati, 2018, p. 440
[56] Cf. Bürkert, 2022
[57] Cf. Kulkarni, et al., 2021, p. 11

Such a construction, as shown in figure 8, consists essentially of an underground digester or bioreactor with a dome-shaped hood and an expansion tank, which must be located somewhat higher than the septic tank. Suitable materials for this structure include brick, stone, or concrete, while rammed earth construction is also feasible. The septic tank has an entrance through which it can be filled with the appropriate biomass. The resulting gas collects at the top of the dome, while the rising pressure displaces some of the biomass into the expansion chamber. The products from the expansion chamber can be removed and used as fertilizer. Slurry that is not withdrawn flows back into the digester as soon as the gas is withdrawn from the gas outlet, thus lowering the pressure in the vessel.[58]

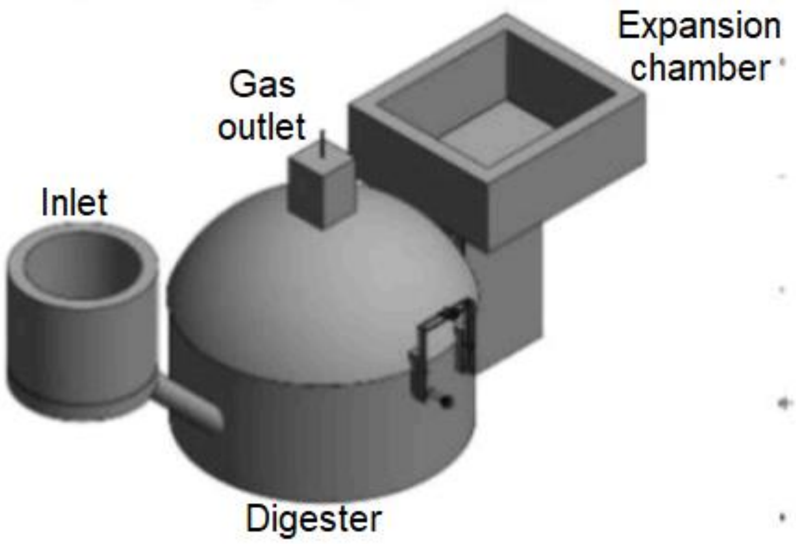

Figure 8: Fixed dome digester design, pilot project in Ibadan, Nigeria[59]

The model just described was implemented by the University of Ibadan, as shown in figure 9, in a pilot project in Nigeria. Cow dung is used as the feedstock for the digester.[60]

[58] Cf. Tabatabaei & Ghanavati, 2018, p. 442
[59] Aralu, Karakitie, & Fadare, 2021, p. 3
[60] Cf. Aralu, Karakitie, & Fadare, 2021, p. 2

Figure 9: Completed digester, pilot project in Ibadan, Nigeria[61]

The gas produced in the 4 m^3 digester is collected in a 2 m^3 bag and then compressed into a gas cylinder so that it can be used flexibly as needed.[62] To generate electricity from this gas, a biogas generator is needed, which uses the gas as fuel to generate electricity.

In addition to the independent construction of a fermenter, there is the possibility of purchasing a portable fermenter of suitable size. These are available on the market in very user-friendly designs, in different sizes. The digester shown in figure 10 is produced by the company HomeBiogas, which has successfully implemented its products through pilot projects, including in rural areas of Africa.[63]

Figure 10: HomeBiogas portable digester[64]

[61] Aralu, Karakitie, & Fadare, 2021, p. 4
[62] Cf. Aralu, Karakitie, & Fadare, 2021, p. 7
[63] Cf. Homebiogas, 2022
[64] Homebiogas, 2022

4.1.3 Mini-grid conception

4.1.3.1 Conceptual design

If a photovoltaic system and a biomass system are connected via an energy management system, a functioning mini-grid is obtained, that is capable of supplying the required access to electricity. A backup system in the form of a diesel generator can compensate for any energy losses.[65] Solar energy losses can occur, for example, due to bad weather or generally at night, while biogas energy losses can occur due to a short-term lack of biomass availability. The energy management system is used to efficiently monitor the different energy sources. It is also useful to compensate for the lack of solar energy at night with one of the other energy sources. For example, the photovoltaic system supplies most of its energy from about 6 a.m. to 6 p.m., which makes it advisable to use the biogas plant from 6 p.m., or to add a battery storage system to the photovoltaic system in order to have electricity available at night as well. However, such battery storage increases the investment costs significantly, which speaks in favor of implementing a hybrid solution of photovoltaics and biogas power generation, to avoid the need for a battery storage.[66]

Figure 11 shows a simplified concept for a mini-grid, suitable for self-sufficient power supply to smallholder farms in rural Botswana.

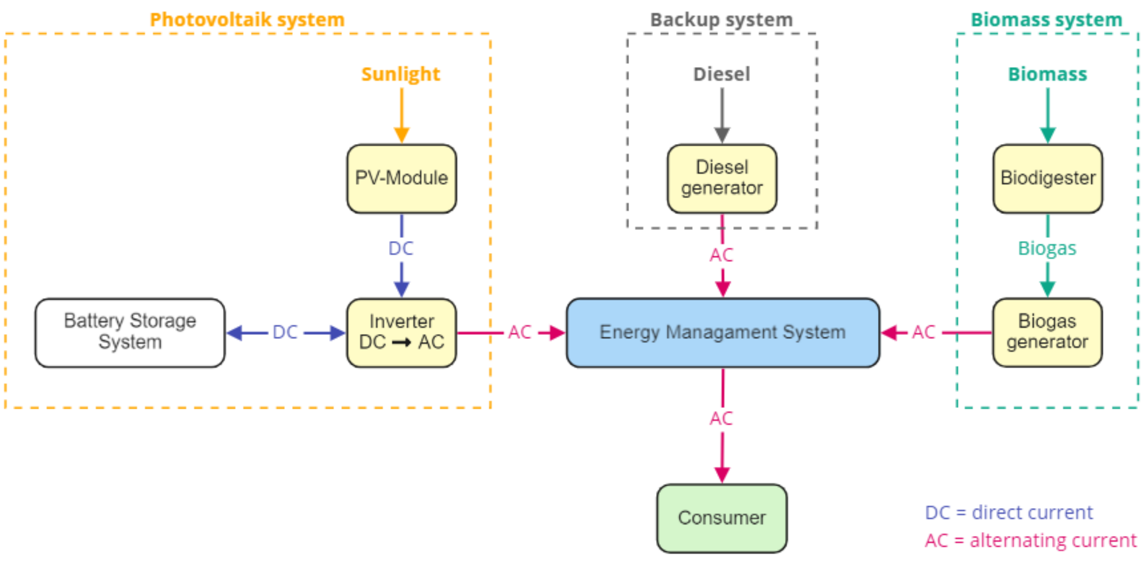

Figure 11: Mini-grid concept[67]

[65] Cf. Bambokela, Belaid, Muzenda, & Nhubu, 2022, p. 1596
[66] Cf. Deutsche Energie-Agentur, 2014, p. 43
[67] Own illustration, 2022

In a pilot project, the University of Johannesburg and the Botswana International University of Science and Technology developed a mini-grid in the form of a biogas-solar system for small farms in Palapye, Botswana. According to the pilot project at the Palapye site, which can be used as a representative example for Botswana, a small solar plant with an output of 4 kW seems appropriate and feasible for such a mini-grid. A 4-kW system generates about 8167 kWh per year at the Palapye site with a south-facing orientation and a tilt angle of 20°. Assuming the average annual consumption of 1500 kWh per capita in Botswana mentioned in chapter 2.1.3, a 4-kW system covers the annual demand of 5 to 6 people. It was also determined that 100 kg of biomass can produce about 2 m^3 of biogas, which can then be converted into electricity.

4.1.3.2 Challenges in implementation

Such a system can unlock untapped potential and help small farmers to move away from subsistence farming, where they produce just enough for the daily needs of themselves and their families and scale up. The biggest challenges in implementing such a system are the financing, the education or readiness to accept of the farmers, as well as space problems.

The financing of such a system requires between 3000 and 4000 USD, possibly even more, depending on the realized size of the system. Small farmers are very price-sensitive and cannot afford this amount of cost, which is why such a system must initially be provided to them free of charge. To cope with this, grants are needed, at least in the beginning. Otherwise, loans must be granted to farmers so that they do not have any expenses in the first few years. This form of loan has to be very substantial and will run over a long period of time. If farmers get a loan to purchase this system and have to pay it back, they will not be able to pay it off in less than five years, making affordability the main challenge in implementing such a system.

The second challenge is to convince smallholders of the usefulness and added value of the system. They have to be shown what solar energy and biogas energy is and how they can benefit from these technologies. Many small farmers are very traditional in their activities and are very skeptical about new ways of doing things. There is a little bit of resistance in trying to educate them and show them new ways that could be beneficial for them.

The third problem is the space needed for the system, as it is relatively spacious. Therefore, it must be considered whether it is appropriate to provide each household with its own system, or whether a system for a cluster of about 5 households is more suitable. One system per household avoids conflicts that can arise if one household claims to have contributed more biomass to the system than others, and thus insists on more output from the system. However, this approach requires more space. Either way, for the realization of such systems in larger groups, it is reasonable to first realize only one system in order to test it and to provide a proof of concept.[68]

4.2 Internet connectivity

In addition to access to electricity, internet connectivity represents another key technological need, or critical infrastructure, for data-driven advancement. A stable internet connection enables access to countless pieces of information that people would otherwise miss out on.[69] Especially in rural areas, people are far away from important sources of news and information. Offices or people who could provide important information are often only to be found in the next town and are not easy to reach.[70] internet connectivity is an important prerequisite for various data-based technologies, such as remote monitoring of farms and animals. In the following, it is explored how a stable, affordable internet connection can be realized in rural areas of Botswana and made accessible with suitable devices.

4.2.1 TV white space

White spaces are existing but unused radio frequencies.[71] These frequency gaps can be used efficiently to send and receive data with the help of cognitive radio systems. This is done by dynamically allocating unused frequency bands to unlicensed users, also known as secondary users. The transmissions of licensed or primary users are not disrupted.[72] White spaces can be used in many different ways. For example, for communication between remote farms and larger cities or, as shown in figure 12, for

[68] Cf. Bambokela J. , 2022
[69] Cf. Lakshmanan, Chockalingam, Murty, & Kalyanasundaram, 2022, pp. 357-364
[70] Cf. Sebusang & Masupe, 2003, pp. 45-46
[71] Cf. Mustapha, Bakura, Mustapha, & Abbagana, 2019, p. 575
[72] Cf. Mustapha, Bakura, Mustapha, & Abbagana, 2019, p. 575

the transmission of generated sensor data, which provide information about animals or plants, to the farmer.

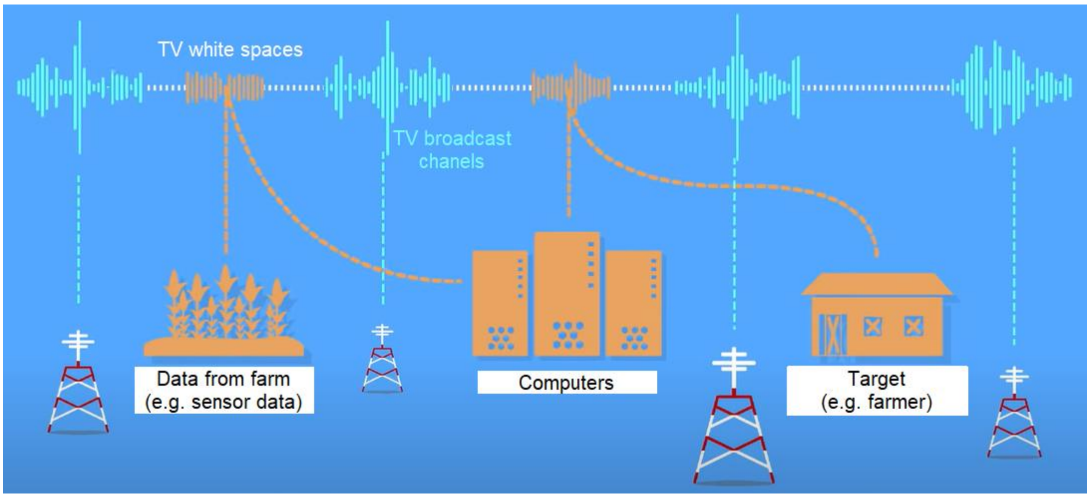

Figure 12: TV white spaces[73]

In rural areas, most TV frequencies are unused, leaving a large amount of white space available.[74] To find and use them, a TV white space device is required. This scans signals to detect channels that are not used by licensed users, such as national television stations. Existing signals that can be scanned are typically analog and digital television systems and wireless microphones. TV white space detection devices must therefore be able to detect these signals.[75]

A number of pilot TVWS testing projects have already been carried out in Africa, including the Kgolagano project.[76] The project was launched in 2015 in collaboration with the Botswana Innovation Hub and Microsoft. The project aims to connect doctors in rural areas of Botswana with better-equipped hospitals in urban areas. For example, advice can be sought by sending high-resolution patient photos from rural areas to cities via TVWS to obtain a more accurate diagnosis.[77]

4.2.2 Low Earth Orbit Satellite

A Low Earth Orbit satellite orbits the earth at an altitude between 200 and 2000 km. Such LEO satellite systems represent a potential solution in the future to provide

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[73] Edited illustration based on Gates, 2018
[74] Cf. Chandra & Collis, 2021, p. 83
[75] Cf. Mustapha, Bakura, Mustapha, & Abbagana, 2019, p. 578
[76] Cf. Mustapha, Bakura, Mustapha, & Abbagana, 2019, p. 582
[77] Cf. Sunday Standard Botswana, 2015

internet connectivity for remote areas.[78] Mainly GEO satellites have been used to provide the internet via space so far. However, due to their long distance from the earth's surface, about 35000 km, these satellites have high latency of about 600 ms. Because of this latency, GEO satellites are of limited use for internet connectivity, as video calls and other delay-sensitive applications are not possible at this latency. Because LEO satellites are much closer to the earth's surface, this results in a much lower latency of only about 50 ms. In addition, LEO satellites offer higher bandwidth and thus greater capacity for users.

To maintain a stable internet connection, a large number of LEO satellites is required. The reason for this is the continuous orbiting of the satellites, with each satellite covering only the part of the earth's surface over which it is located. An area-wide network of satellites is therefore required for a continuous internet connection.[79] Some large companies, such as SpaceX and Amazon, have entered the market with the aim of enabling users to connect directly to satellites. This is to be realized with the help of small phased array antennas, which can be mounted on buildings or even vehicles. Besides the connection between satellites and end users, a connection between satellites and the infrastructure on earth is needed. It is sufficient for individual satellites to communicate with a ground station on earth, while the satellites transmit data to each other. The advantage of this is that no long cable connections, such as those used today on land and at sea, are required.[80]

The solution of establishing an internet connection using LEO satellites cannot be implemented by individuals or single organizations. Rather, it is a challenge that requires high investment and the international cooperation of large corporations. Besides high investment costs, the lower purchasing power in developing countries has to be taken into account, which might not be lucrative enough for companies to provide appropriate access. However, LEO satellite systems offer great potential to provide internet access to remote areas of the world within the next 10 to 15 years.[81]

[78] Cf. Osoro & Oughton, 2021, pp. 1-3
[79] Cf. Voelsen, 2021, p. 12
[80] Cf. Voelsen, 2021, p. 13
[81] Cf. Voelsen, 2021, p. 20

4.2.3 Access devices

An existing internet connection only offers added value for end users if they can access it via an appropriate device. Digitization of the agricultural sector can only be successful if smallholders in Botswana have internet-enabled devices and are able and willing to use them.[82]

At the beginning of 2022, 51.27% of the websites accessed in Botswana were accessed via mobile phones, which is 7.4% more than in the previous year (see figure 13). Looking at users' access to digital platforms such as social media applications, the dominance of mobile phones becomes even clearer. As already mentioned in chapter 2.1.3, there were around 1.2 million active social media users in February 2022, of whom 96.4% accessed these digital platforms using mobile phones.

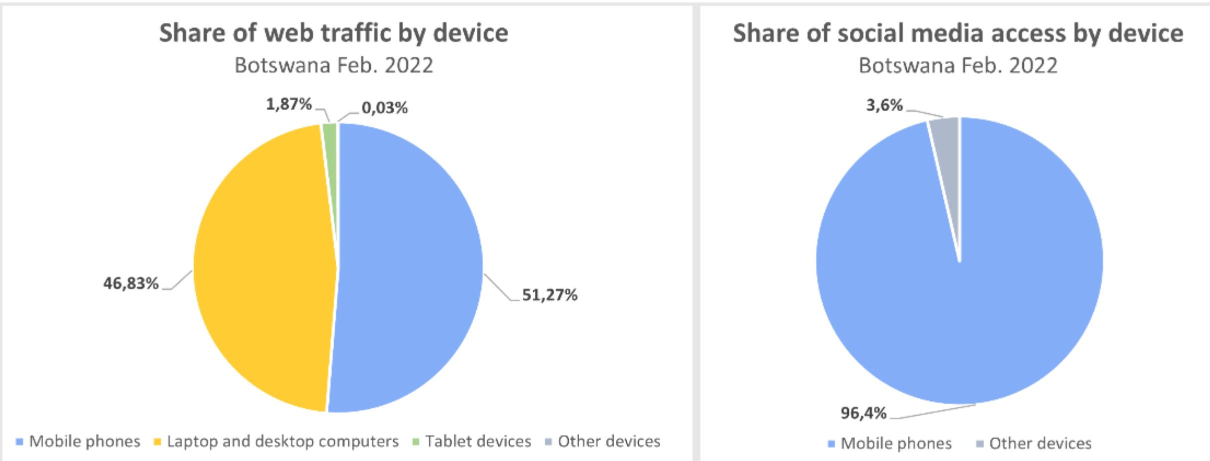

Figure 13: Share of web traffic and social media access by device[83]

As mobile phones are already widely used in Botswana, especially for connecting via social media platforms, the use of such devices also seems to be appropriate for accessing digital platforms in the agricultural sector. Furthermore, mobile phones are more affordable to purchase, compared to laptops or other devices.[84]

The cheapest smartphone available in Botswana costs about 36 USD. To assess the affordability of such a device, this price must be put in relation to the average income in Botswana. This shows that the purchase of such a smartphone represents about 6.8% of the average monthly income in Botswana. To obtain mobile internet access, mobile data is required in addition to an appropriate device. In Botswana, 1 GB of

[82] Cf. Lakshmanan, Chockalingam, Murty, & Kalyanasundaram, 2022, pp. 382-384
[83] Own illustration, 2022
[84] Cf. Kemp, 2022

mobile data costs an average of 3.92 USD, which corresponds to 0.7 % of the average monthly income in Botswana.[85]

Although most farmers do not own laptops, these devices, along with mobile phones, have the potential to allow multiple farmers to access digital applications. It is sufficient if one or a few people per community own a laptop when they make these devices available in some kind of supported internet cafe. Farmers can then visit such internet cafes and access digital services with the help of the farmers who own and operate the laptop. Farmers who can afford a mobile phone can use it from the comfort of their own home or on the way, while farmers without their own device and know-how can visit the farmers with a laptop and use the digital services with their help.[86]

[85] Cf. Kemp, 2022
[86] Cf. Bambokela J. , 2022

5 Potential innovations related to farmers' needs

This chapter addresses potential solutions to the key needs of smallholder farmers presented in chapter 2.2.4. First, it examines how remote monitoring can be realized. This can be used to realize other needs, such as animal monitoring, from which information about the health of the animals or measures against theft can be derived. In addition, digital applications are presented, that enable smallholders to improve connectivity to markets and access to crowdfarming.

5.1 Remote monitoring and management

A key need of farmers in Botswana identified in the ITU report is the ability to monitor and manage farms remotely. Particular emphasis is placed on the need to track livestock, using electronic ear tags so that information on the whereabouts and condition of animals can be accessed remotely.[87]

Remote monitoring technologies require a certain level of technological infrastructure. In addition to access electricity and the internet, the LoRa technology presented below offers the potential to implement remote monitoring in rural areas. Following the theoretical foundations of this technology, a practical solution for livestock tracking using LoRa is presented.

5.1.1 LoRaWAN technology

LoRaWAN stands for Long Range Wide Area Network and enables a cost-effective and energy-efficient communication link over long distances and from remote locations. This radio technology belongs to the Low Power Wide Area Networks, LPWAN for short, which in combination with wireless sensors, are suitable for applications in the field of the Internet of Things.[88] The term LoRa describes the transmission layer that enables communication over long distances, while LoRaWAN describes the basic system architecture of the network.[89]

[87] Cf. Bühler, et al., 2022, p. 18
[88] Cf. Koning, 2017, p. 3
[89] Cf. Linnemann, Sommer, & Leufkes, 2019, p. 25

A functional LoRaWAN network essentially consists of wireless, battery-powered nodes or sensors, one or more gateways, and a LoRa server, providing connectivity to online applications or terminals (see figure 14).

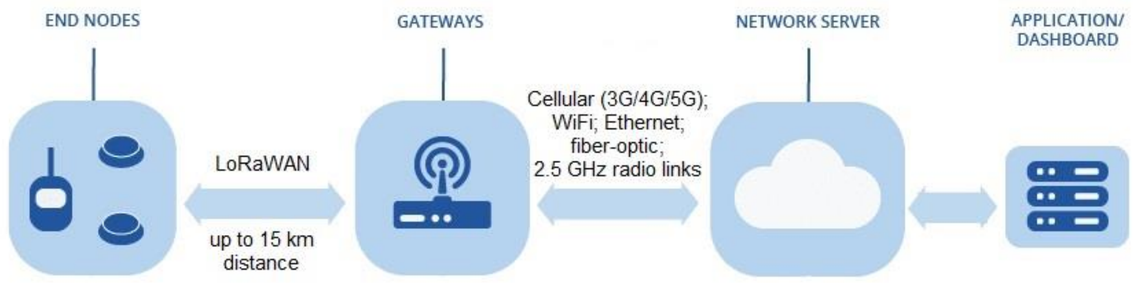

Figure 14: LoRaWAN network[90]

The nodes or sensors are asynchronous and communicate as soon as data is ready to be sent, giving them a lifetime of many years.[91] The sensors send messages or data wirelessly to the nearest gateway or receive data from it. How far away the gateway can actually be from the sensors, depends mainly on the reflection, refraction, and attenuation of objects in the way, such as buildings. In rural areas, a range of about 10 to 15 km can be expected, while in large cities, a range of only about 2 to 4 km can be achieved, which nevertheless surpasses technologies such as WiFi or Bluetooth many times over in terms of range.[92] As tests have shown, the range can still be increased significantly, so distances of 50 km in untouched areas are quite realistic.[93] The world record is currently a range of about 700 km. Such a distance was achieved by the ascent of a LoRa gateway into the stratosphere, which was attached to a weather balloon.

Since wireless technologies are located in a triangle of tension, it must be noted that only two targets of the triangle can be optimized, while the third target is necessarily degraded as a result (see figure 15). While LoRaWAN technology achieves very low energy consumption and a long range, the possible data rate to be transmitted decreases.[94]

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[90] Edited illustration based on M2M Connectivity, 2022
[91] Cf. Koning, 2017, p. 5
[92] Cf. Linnemann, Sommer, & Leufkes, 2019, p. 28
[93] Cf. Weis, 2022
[94] Cf. Linnemann, Sommer, & Leufkes, 2019, p. 28

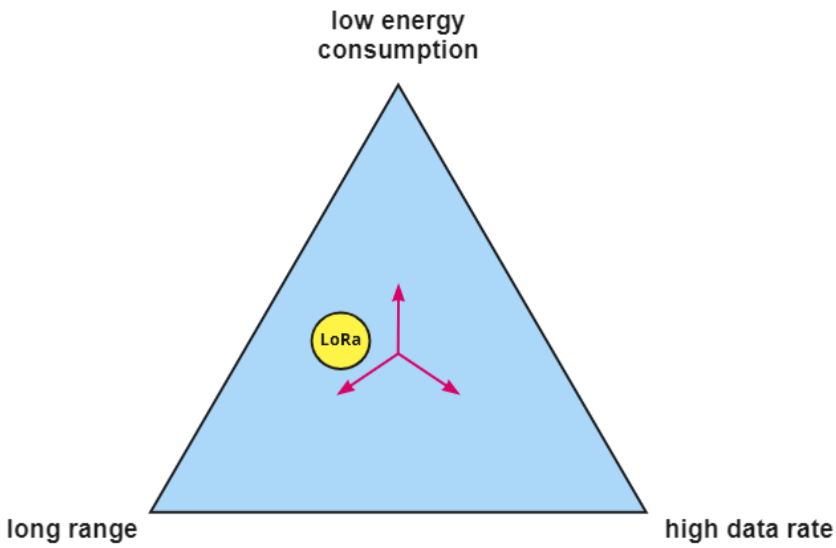


Figure 15: Tension triangle[95]

The gateway itself receives data from the sensors and forwards it to the network server. Communication between the gateway and the server requires a connection via mobile radio (3G/4G/5G), WiFi, Ethernet, fiber optics, or 2.4 GHz radio links.[96] The network server manages the entire LoRaWAN network, allows data to be displayed for analysis as well as process optimization, and interfaces with IoT devices, applications, and other endpoints.[97] A LoRaWAN network uses security at two levels, the network layer, and the application layer, and is therefore considered secure. The network layer ensures the authenticity of the device through a unique ID within the network, while the application layer encrypts the end user's application data throughout the network.[98]

5.1.2 GPS cattle tracking solution with LoRaWAN

This chapter shows how the analyzed LoRaWAN technology can be used for GPS tracking of livestock. For this purpose, the application called mOOvement is presented in the following, which is a complete solution, providing farmers with the necessary equipment to start tracking their livestock, through LoRa networks. The equipment includes a LoRa antenna, GPS ear tags, and appropriate software, for the analysis and monitoring of GPS data (see figure 16).[99]

[95] Own illustration, 2022
[96] Cf. The Things Network, 2022
[97] Cf. Weis, 2022
[98] Cf. Linnemann, Sommer, & Leufkes, 2019, p. 32
[99] Cf. Moovement, 2022

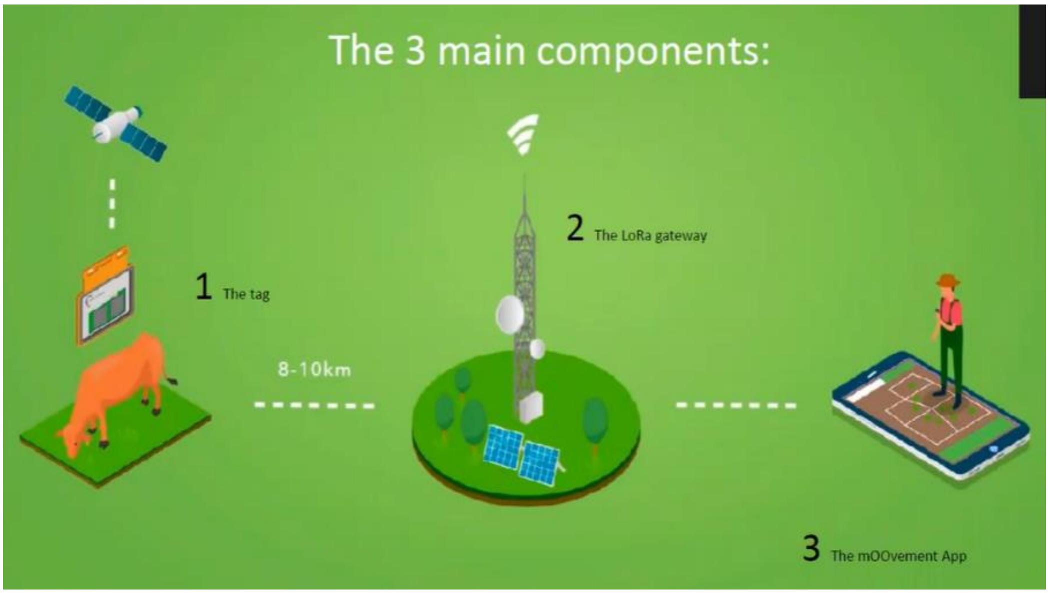


Figure 16: mOOvement main components[100]

The LoRa network enables connectivity to remote areas, as only the LoRa antenna itself needs to be connected to the internet, while the GPS ear tags can be deployed within a radius of about 10 kilometers around the antenna and do not require internet connectivity themselves. In addition to the standard LoRa antenna, which is permanently installed and connected to the power grid, mOOvement offers solar-powered off-grid antennas (see figure 17). These are useful when no power source is available at the ideal location for radio coverage. Another option is a portable, solar-powered antenna, that can be moved with the flock. To make network setup easy, mOOvement offers detailed instructional videos or on-site installation services. In advance, prospective customers can request a wireless mapping analysis of their property to see what wireless coverage will look like.[101]

[100] Vogels, 2020
[101] Cf. Moovement, 2022

Figure 17: LoRa off-grid antennas[102]

The ear tags send information, via the LoRa network, to farmers every hour. In addition to enabling remote animal counting and inventory management, the tags provide information about the location of livestock and send notifications when animals move outside the defined area. Farmers also receive alerts when an animal is not moving, allowing them to quickly intervene in the event of injury or disease. Furthermore, grazing patterns can be displayed. The reusable ear tags weigh 30 grams, have a battery and integrated solar panels, and include Bluetooth, accelerometer, and GPS capability (see figure 18).[103]

Figure 18: mOOvement ear tags[104]

[102] Moovement, 2022
[103] Cf. Moovement, 2022
[104] Moovement, 2022

Further technologies can be integrated into an existing LoRa network. For example, water monitoring technology can be installed that also sends information to the mOOvement platform. Farmers can receive alerts when the water level is below a defined range and can view their water points on a map to check if the animals have access to the water point.[105]

5.2 Connectivity for smallholders

A key challenge for smallholder farmers in remote areas is access to often distant markets and the ability to sell their goods there at a fair price. Digital trading platforms can offer smallholder farmers the opportunity to facilitate the sale of their goods by enabling exchanges between interdependent groups. For example, producers can use a digital platform to communicate with potential buyers, processors, retailers, or end customers without relying on middlemen.[106]

The following digital applications are already being used in various countries in Africa and will be analyzed to explore possible implementations of such digital platforms. In this way, insights can be gained for the development of the pilot project, presented in chapter 2.2.2.

5.2.1 Existing digital applications for market access in Africa

Several digital applications already exist, helping smallholder farmers and pastoralists in remote areas of Africa to access markets. These systems not only give smallholders the opportunity to market their products, but also enable exchange and mutual support between participants, for example by efficiently distributing manure from local animals to local grain farmers. In addition, some service providers of the digital platforms take over logistics along the supply chain or facilitate payment transactions, which offers further added value.[107]

[105] Cf. Moovement, 2022
[106] Cf. Elsäßer, Hänsel, & Feldt, 2021, p. 51
[107] Cf. Elsäßer, Hänsel, & Feldt, 2021, p. 51

5.2.1.1 AgroMarketDay - Uganda

The AgroMarketDay application offers people the opportunity to register on the platform as sellers or buyers for trading in farm inputs, agricultural products, and live animals. In addition, professional online training is offered by industry experts who guide users from the beginning, through harvesting, to market access. Furthermore, different markets can be accessed through the online platform to see the prices of the goods offered there. This allows smallholders to compare prices and to better assess the value of their goods. [108]

The platform is often used by small-scale farmers as an app via smartphones to offer their goods to potential buyers in different locations. Farmers upload their products to the app while prospective buyers scroll through the offers. Once a registered buyer finds an offer, they call the corresponding seller using the phone number registered in the app and proceed to the point of sale to complete the transaction. The advantage for smallholders here is eliminating the need for middlemen, who often set a very low price and thus take away smallholders' control over prices.[109]

Since not all small farmers own a smartphone, groups often form around one farmer who does. This farmer can then upload the products of his colleagues in addition to his own products, hence making the platform accessible to people who do not own a smartphone and are not familiar with the operation of such an app.[110]

5.2.1.2 M-Farm - Kenya

M-Farm is an online agricultural marketplace, providing farmers in Kenya with up-to-date market information and matching farmers with buyers. The goal is to cut out the middlemen in determining prices and give farmers themselves the information they need to set a fair price for their products. Farmers can obtain information on the retail price of their products and find buyers for them, as well as purchase needed inputs directly from producers.

[108] Cf. AgroMarketDay, 2022
[109] Cf. Likamis, 2016
[110] Cf. Likamis, 2016

Price information is currently available on 42 crops in five markets in Kenya and is collected daily by independent data collectors using geocoding. This ensures the prices are being collected from wholesalers who are actually in the relevant market.

There are two ways to use this service. Firstly, there is the option to obtain the information via SMS by dialing the corresponding number. Secondly, small farmers with internet access and smartphone can obtain real-time prices of the last 5 days through a free android app and do business online.[111]

5.2.1.3 Mifugo Trade - Kenya

Mifugo Trade is working with a digital marketplace to cut out middlemen in the livestock supply chain and connect livestock producers directly with buyers. By avoiding the losses that would otherwise be incurred by middlemen, producers can earn significantly higher prices from their livestock.

To digitize the livestock trade, trained livestock valuation agents are deployed to upload pictures and videos of livestock to the online platform, along with data such as weight, age, and gender. Buyers can view the animals for sale on the platform and make purchase offers there. Additional value is added by monitoring transactions and assisting with delivery and money transfer.

For the benefits that cattle farmers receive through the platform, Mifugo Trade charges a commission of 4.5% for cattle sales that are processed through the platform. According to the founder Taylor Fully, producers can obtain prices 20% higher than those on local markets in return. The biggest obstacle, according to the founder, is getting people to see the added value and change their old behavior regarding cattle trade to fundamentally change the industry.[112]

5.2.1.4 UsomiRubi – Kenya, Nigeria, Tanzania

UsomiRubi creates a market system made up of digital elements, physical infrastructure, and on-site staff, connecting smallholder farmers to the market. The

[111] Cf. Technology Exchange Lab, 2022
[112] Cf. Tully, 2015

platform virtually collects the produce of smallholder farmers in East Africa and enables them to earn better prices through economies of scale.

If a smallholder farmer wants to sell their goods, they text USOMI or send a request to sell via the corresponding smartphone app. The system notifies USOMI's commodity expert, who is closest to the requesting smallholder's location. The expert then meets with the smallholder and assesses the quantity and quality of the goods. If the goods meet the predefined parameters, the expert registers the farmer's goods on UsomiRubi and thus offers buyers the chance to view the goods via the app. Once a buyer is found, the seller receives a message and transports the corresponding goods to a collection point managed by UsomiRubi. With this approach, the seller and buyer normally never meet in person.[113]

UsomiRubi can be combined with the digital platform for precision agriculture called UsomiLulu. Here, farmers have the opportunity to register and record production data to get real-time feedback on production status, compared to expected parameters. Weather forecasts and satellite-based soil profiling are used, for example. In the event of excessive deviation or abnormalities, the farmer receives a warning and can intervene in time, before the farm is affected by, for example, incorrect cultivation, diseases, or pests.[114]

5.2.1.5 Selina Wamucii - Africa

Headquartered in Nairobi, Kenya, Selina Wamucii provides a platform for trading food and agricultural products. Farmer groups and cooperatives can offer their goods on the platform, while customers around the world, especially in Africa, can access the offers. Smallholder farmers and ranchers are thus integrated into local and global supply chains. The digital platform facilitates trade, logistics management, inspection, quality control, payments, risk management, and delivery. For buyers, this makes sourcing easier and more secure, while producers are guaranteed a market for their products with the platform as a marketing and buying partner. At the same time, growers reduce the risk of losses due to a lack of sales opportunities or fraud in the

[113] Cf. Elsäßer, Hänsel, & Feldt, 2021, pp. 54-55
[114] Cf. Elsäßer, Hänsel, & Feldt, 2021, p. 55

form of payments not received from customers. Growers can focus on their production while the company takes care of marketing, sales, and payment.[115]

5.2.1.6 Sokoni - Kenya

Sokoni is providing a platform via an app where livestock farmers in Kenya can offer their animals for sale and directly negotiate a price with buyers. If both parties agree, they arrange a meeting point at a market or elsewhere. Sokoni wants to prevent remote livestock farmers from having to travel the often long way to the market, where they may not know what price can be obtained at the market and whether another market would have been a better choice. Often the middlemen know about the risk and the poor level of information of the farmers and take advantage of this by offering low prices.[116]

5.2.2 Existing digital applications for crowdfarming in Africa

In addition to applications that focus mainly on improving market access for small farmers, there are other applications that also involve investors and thereby create platforms for crowdfarming. The idea behind such platforms is to raise funds or services from a large number of people, usually via the internet. The funds raised are intended to enable smallholder farmers to be better occupied and to bridge periods of time, such as raising livestock, until they are sold and the income they generate. In addition to farmers, investors also benefit as they receive a return on the sale of their assets. In the following, digital applications in the field of crowdfarming which are already being used in Africa are presented.

5.2.2.1 BaySeddo - Senegal

BaySeddo is a digital platform connecting Senegalese farmers in possession of land with investors interested in the agricultural sector. The founder, Mamadou Sall, wants to modernize traditional farming practices to gain more opportunities through digital technology. Farmers in Africa who own arable land often lack the means to cultivate it. As a result, large areas of arable land remain unused; in Senegal, this unused land

[115] Selina Wamucii, 2022
[116] Hobbs, 2019

accounts for about 30% of arable land. To cultivate this arable land, farmers need investment. However, 75% of Senegalese farmers have difficulty accessing investment.[117]

On the other hand, there are economic operators or private individuals who are interested in investing in the agricultural sector. They can buy agricultural shares for a limited duration, while BaySeddo ensures the monitoring and management of the farms, for the benefit of all parties involved. At the end of the production or investment cycle, investors receive their invested money plus a return on their investment.[118]

5.2.2.2 Farmcrowdy - Nigeria

Farmcrowdy's developers have observed that smallholder farmers in Africa often have sufficient land, but do not fully utilize it because they have difficulty accessing finance. Producers often lack market access and struggle with transportation challenges, which slows down further development of farms. Farmcrowdy aims to strengthen smallholder farmers and, in turn, domestic food production and food security. Farmcrowdy provides concrete support by connecting investors who want to invest in farms, with farmers in Nigeria who have land and labor but few financial resources. The distance between smallholder farmers and investors does not matter thanks to the Farmcrowdy app.[119]

Suitable farms for a corresponding partnership are selected in a two-step process. In the first step, sites with high land or livestock potential are identified. In the second step, Farmcrowdy then contacts farmer organizations or leading farmers at the identified locations to find suitable, committed farmers and register them in the Farmcrowdy app. Added value for farmers, beyond just investment, consists of services such as training, localized weather information, and early warning information on pests and diseases. It also facilitates negotiations with buyers through aggregation centers. Investors can use the Farmcrowdy app, select a farm and freely decide how many units they would like to sponsor. To ensure a return on investment, Farmcrowdy sends technical specialists to participating farms to provide advice and training to smallholder farmers. On-site development is entered on the website and app so

[117] Cf. CTA, 2018
[118] Cf. Crunchbase, 2022
[119] Cf. Farmcrowdy, 2022

investors can track progress. Once a production cycle ends, the corresponding investor receives his initial investment plus the return.[120]

5.2.2.3 Livestock Wealth – South Africa

Livestock Wealth uses a digital platform to facilitate the connection between farmers in need of working capital and investors who want to invest in growing assets without needing experience in investing, farming, or ranching.

Investors can access and register on the Livestock wealth investor platform through a website or the corresponding app. After successfully logging in, prospective investors can choose the product they want to invest in and freely decide how many units they want to purchase. The choices are macadamia nut trees, free range cows for meat production, and pregnant cows. The selected products are added to the online shopping cart and can be paid by credit card or direct bank transfer. After a successful transaction, the investor will have their asset and corresponding certificate of ownership uploaded to their online profile. The investor is then kept informed about the development of his assets via the online platform.

A farmer takes care of the asset in question, e.g. a cow or a tree, and buys it back for resale once the tree is ready for harvest or the cow is fully grown. The investor then makes a profit on the sale of his asset.[121]

The farmers themselves can benefit from the free Livestock Wealth Farmer app in addition to the investments. This helps them manage, track and eventually sell their livestock on the Livestock Wealth Investor platform. Using a GPS tracking collar, farmers can use the app to track movement within a geo-fence, providing information on whether an animal is being stolen or if the tracking collar has been cut, if it is wandering too far away, or if it has remained motionless for too long and may need assistance. Also, management of the animals can be facilitated by having each animal with information such as gender, age, and collar number, registered in the app.[122]

[120] Cf. Elsäßer, Hänsel, & Feldt, 2021, p. 45
[121] Cf. Livestock Wealth, 2022
[122] Cf. Shezi, 2022

5.2.2.4 Livestock247 – Nigeria

Livestock247 is an online platform for the livestock industry. It focuses on an ecosystem that connects all the key players in the livestock value chain and allows them to coexist to create synergies. Investors, owners, and farmers are connected with buyers across Nigeria.

The platform aims to enable buying and selling of slaughterable and traceable livestock across Nigeria. It also aims to enable buyers to purchase healthy and hygienically processed meat from across Nigeria and have it delivered. Cashless transactions at rural livestock markets, as well as the provision of animal health services, are expected to extend livestock production. Through courses and discussions with veterinarians and animal care experts, knowledge sharing will be created to reduce the spread of zoonotic diseases.[123]

5.3 Crowdfarming App concept

In this chapter, the findings from the research conducted, particularly from the study of existing applications, are practically applied to design a conceptual digital platform. The platform is designed in the form of a smartphone app and represents a suggestion for the realization of a fundamental crowdfarming tool. Farmers are supported in the management of their goods, especially livestock, and are given the opportunity to sell them at fair prices. In addition, users can learn from experts and exchange ideas with colleagues through the platform. Furthermore, farmers have the opportunity to increase their productivity by engaging investors. The conceptual app will be referred to as "ConceptApp" in the following.

[123] Cf. Livestock247, 2022

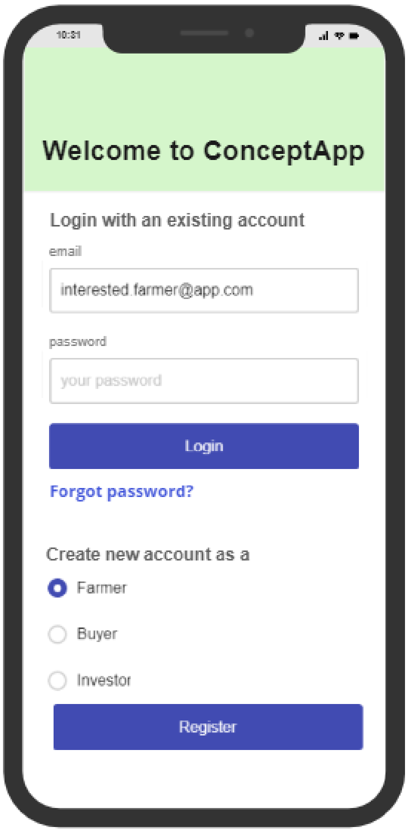


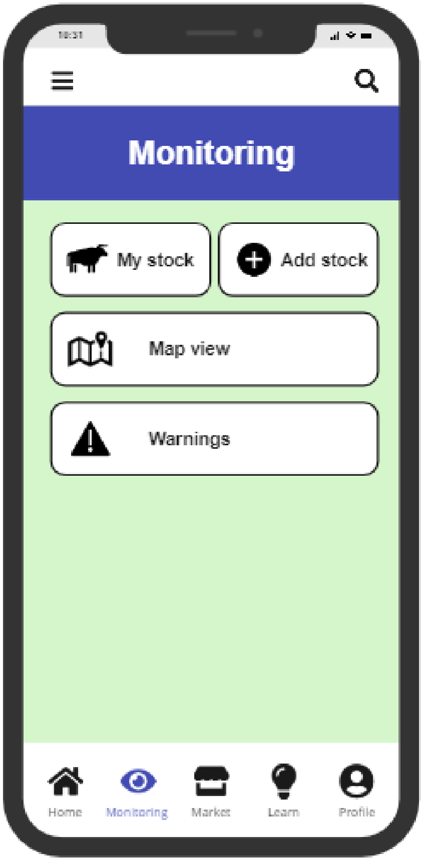
Figure 19: ConceptApp Welcome Screen[124]

After downloading ConceptApp, the user can log in with an existing account, or create a new account by registering as either a farmer, buyer, or investor (see figure 19). A farmer account offers the most features, these include “Monitoring”, “Market”, “Learn” and “Profile”, which are explained below. A buyer, on the other hand, only has access to the marketplace, while an investor only has access to farmers and their offered assets.

5.3.1. ConceptApp - Monitoring

The first feature, “Monitoring”, allows farmers to monitor and manage their goods more easily, whereby the focus of this ConceptApp is on Livestock.

[124] Own illustration, 2022



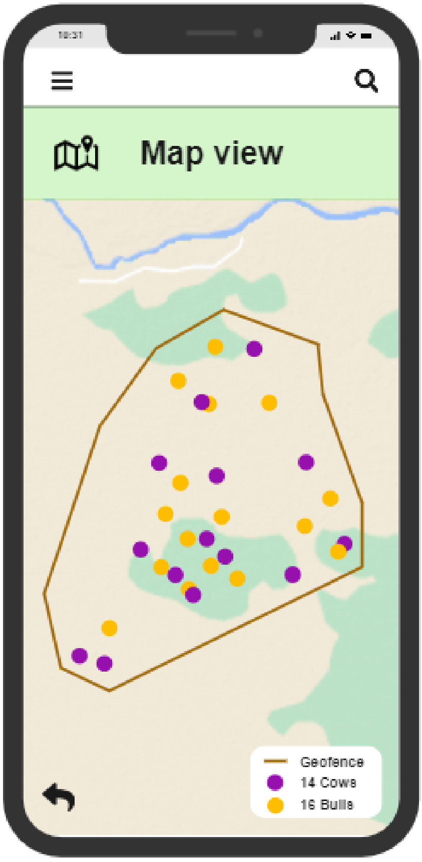


Figure 20: ConceptApp Monitoring[125]

Under the menu item "My Stock" (see figure 20), farmers can view and manage their previously registered animals. For an animal to appear in this list, it must first be registered under "Add stock" (see figure 20). This is where a photo of the animal, along with information about its name, sex, age, weight, and, if applicable, its ear tag, can be added. The greatest added value results when the animal is equipped with an electric ear tag with GPS function and acceleration sensor, which is then assigned to the corresponding animal in the app.

Animals that have been equipped with such an ear tag can be monitored in the "Map view" (see figure 20). This view shows a previously created geofence, as well as the number and position of the registered animals. The geofence is a virtual border that triggers certain actions using GPS data. If an animal equipped with an ear tag comes too close to the geofence or crosses it, a warning is issued, which can be viewed under the menu item "Warnings" (see figure 20). From this information it can be deduced that the animal has to be guided back or even that there is a danger of theft, which enables an early check and intervention of the situation. The previously mentioned acceleration

[125] Own illustration, 2022

sensor, which is integrated in the ear tag, can provide information about the health of the animal and generate corresponding warnings, which can also be viewed under "Warnings". For example, the accelerometer will trigger a warning if an animal has not moved for a pre-defined period of time, which may indicate that the animal has a problem. This allows the farmer to promptly visit the animal and check whether the animal is injured or sick and, if necessary, call a veterinarian. The warnings are displayed chronologically in the corresponding menu and can be checked off manually, once a warning has been taken care of.

5.3.2 ConceptApp - Market

The second feature, “Market”, allows farmers to register their goods and offer them on an online marketplace at fair prices without being influenced by middlemen.

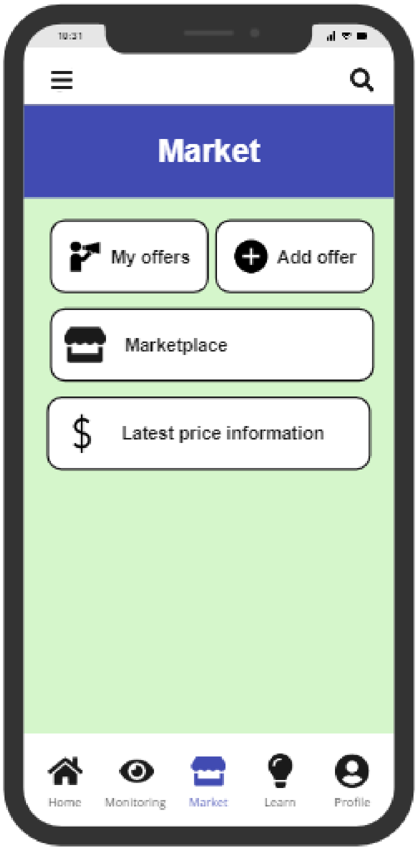


Figure 21: ConceptApp Market[126]

Under the menu item "My offers" (see figure 21), farmers can view their goods that they are currently offering for sale on the digital marketplace. In order for a commodity

[126] Own illustration, 2022

to appear there, it must be added via "Add offer" (see figure 21). Here, for example, cattle that has already been registered and tagged with information under the "Monitoring" menu, can be put up for sale. By clicking on "Marketplace", users can enter the digital marketplace, which can also be accessed by users who have registered as buyers. This is where all goods, which are offered for sale by registered farmers, can be accessed. Buyers can scroll through the offered goods and place bids. If farmer and buyer have reached an agreement, the trade can be concluded and paid for directly via the app. To get a better understanding of the value of their commodity, farmers can click on "Latest price information" (see figure 21). This will list all the goods sold on the market, along with the latest prices obtained.

5.3.3 ConceptApp - Learn

The third feature, “Learn”, is an opportunity for farmers to expand their knowledge, and to discuss and exchange ideas.

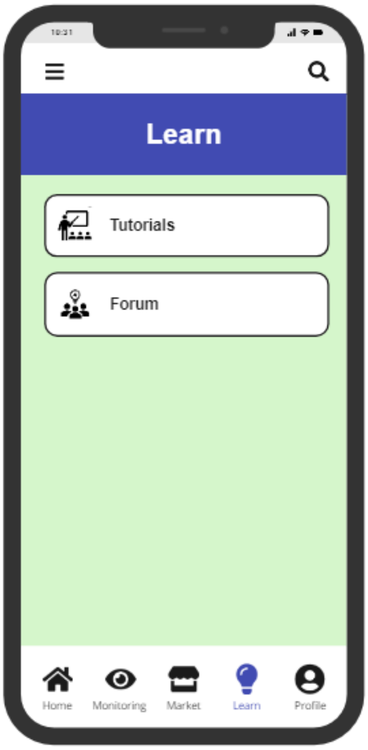


Figure 22: ConceptApp Learn[127]

Clicking on "Tutorials" (see figure 22), takes the user to a series of categorized videos in which agricultural experts share their knowledge on various farming topics, including

[127] Own illustration, 2022

livestock, crop production, marketing, digital technology, and veterinary medicine. The uploaded videos are reviewed by experts to ensure content quality. After a successful review, the videos are marked as verified. Besides tutorials, the menu offers the option to enter a forum, where discussions about current farming topics can be held and contacts can be made.

5.3.4 ConceptApp - Profile

The fourth submenu, “Profiles”, allows users to add information about themselves as well as contact details. In addition, farmers can upload assets to be supported by investors.

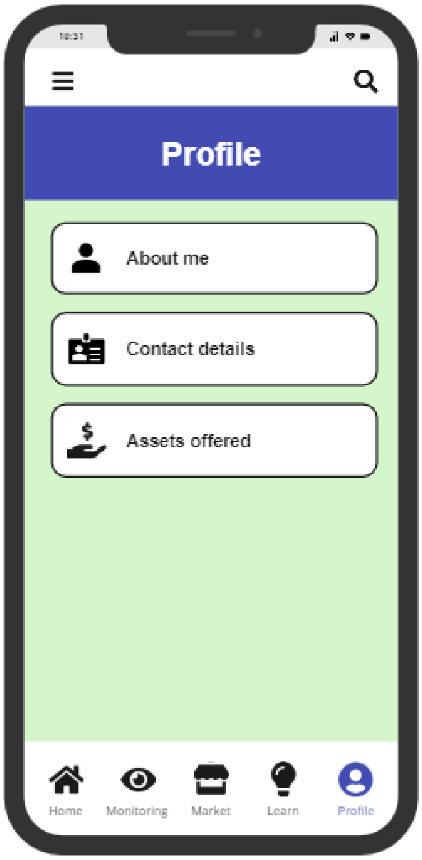


Figure 23: ConceptApp Profile

In the "About me" option (see figure 23), users can enter basic information about themselves, such as name and location. Additional information that might be of interest to other users can also be entered. For example, users can specify the area in which they are active and the topics in which they are interested. Under "Contact details" (see figure 23), users can specify how they wish to be contacted by other users.

Clicking on "Assets Offered" (see figure 23), opens a screen where farmers can enter their assets to show potential investors what assets they can invest in. For example, if a farmer is underutilized but does not have enough money to raise more cattle, the farmer can upload a cow as an asset. In this way, he expresses that he has the capacity to raise another cow but does not have the financial means to do so. An investor can then buy this cow virtually, so that he is the rightful owner of the cow, which is confirmed to him with an online certificate in the app. Since the farmer knows how to raise cattle, the cow remains in his care and is raised by him until it is ready to be sold. When selling the cow, which is now worth more due to the farmer's efforts, the investor participates in the sales profit and gets back his investment plus return. Thanks to the online platform, the investor can be located anywhere in the world, as he is not involved in the raising of the animal, but only provides money for the period of rearing.

5.3.5 Adoption of digital applications

Regarding the adoption of digital applications by smallholder farmers, the planned time frame and the milestones set within that time frame are the primary factors that matter. The time frame must be set realistically, as the adoption of a power supply and internet must first be achieved before digital applications can be adopted. Smallholders need to be educated in this regard to understand the added value of such solutions. Familiarizing smallholder farmers with the technologies, applications, and their benefits and implementing them, takes time. This should be achievable within a period of 3 to 5 years. Shorter periods could also be sufficient however requiring more effort. The first milestone may be the creation of a power supply and education regarding the benefits of such technology. By access to electricity, the access to the internet will be feasible. Based thereof, further opportunities and benefits will emerge through the introduction of digital applications.[128]

[128] Cf. Bambokela J. , 2022

6. Final consideration

6.1 Summary of results and answers to the research questions

This work explored potential solutions for the conception of smart farming solutions in the context of Botswana's digital development. The focus was on smallholder agriculture in Botswana, which forms the backbone of Botswana's economy and is dominated by livestock. Digitization of this sector can contribute a significant part to Botswana's development into a digital economy, by providing smallholder farmers with access to digital services and data. The foundation of an innovative and trustworthy economy can be provided by developing new digital services, based on the concept of digital federation.

The current general conditions, as well as the background of the issue, could be clarified by investigating the current state of affairs in Botswana, regarding the economy, agriculture, and infrastructure. In addition to researching the situation in Botswana, the discussion of the ITU report, which provided some findings prior to this work, allowed the current challenges and needs of smallholder farmers in Botswana to be addressed and categorized. Smallholder farmers' need for reliable access to electricity and the internet, as well as the ability to monitor and manage their holdings remotely, was particularly evident.

To answer the question of how to provide smallholder farmers in Botswana with the necessary infrastructure for data-based applications, a literature review, and technology analysis were used to identify potential innovations. As a possible solution for creating a reliable power supply, based mainly on solar energy and biomass, a conceptual mini-grid for possible installation in rural areas of Botswana was developed and discussed, with the help of an expert interview. In terms of creating internet access in rural areas of Botswana, potential solutions could also be identified. These include both existing technologies that can be deployed in a short period of time, and more visionary solutions that will take years to become operational. In addition, research showed that mobile phones are suitable for accessing the internet because they require comparatively low acquisition costs and are already widely used in Botswana.

By developing a conceptual app, this study answers how smallholder farmers can gain access to data and functionality that solves their needs through a meaningful digital service in the form of a suitable platform. To conceptualize this app, existing digital applications in the field of African agriculture were researched. The focus was on applications in the area of remote monitoring and market access.

6.2 Critical reflection

The purpose of this chapter is to critically reflect and appreciate the methodology and the treatment of the research questions on which this thesis is based.

Through literature review, technology analysis, and the graphic conceptualization of proposed solutions, as well as an expert interview, the research questions regarding the identification and design of potential innovations to support Botswana smallholder farmers and Botswana's digital development, were answered.

Challenges arose primarily in the evaluation of the identified solutions and created concepts by experts, as planned interviews were cancelled. As a result, only the creation of a power supply and thoughts on the introduction of digital applications among smallholders, could be discussed in detail with an expert. Since energy supply is the first prerequisite for the realization of the other identified needs, and the possibility of a partnership was worked out through the interview, this is an important cornerstone.

In other topics, such as the technology analysis of LoRa-WAN solutions, with the combination of a corresponding app, interviews that had already been conducted, as well as recorded conversations between experts, were evaluated. Unfortunately, these did not offer the possibility to include own questions.

Nonetheless, the developed findings and created concepts form the next step towards a crowdfarming prototype and offer the possibility to build on these findings with further research.

6.3 Further need for research

This bachelor's thesis has identified potential innovations and conceptualized possible solutions, suitable for solving the challenges and needs of smallholder farmers, thus supporting Botswana in its transformation to a digital economy.

In subsequent studies, the results and concepts developed, should be additionally validated by further external views, for example, through additional expert interviews with stakeholders.

Furthermore, the contacts made with experts regarding a decentralized power supply in rural Botswana could be built upon in order to jointly implement a real energy supply based on the theoretical concept. After access to electricity, the focus can be on internet access, which in turn opens the doors for digital services such as the conceptual app. This theoretical concept of the proposed app could be further elaborated and practically implemented with the help of computer scientists to realize a working prototype for a crowdfarming marketplace. The first participants should be selected for the app to start a first test phase. Expanding the number of participants and services can then create a digital ecosystem for smallholder agriculture. Further research should also look into financing options and acquiring partners and investors, as well as the price sensitivity of stakeholders.

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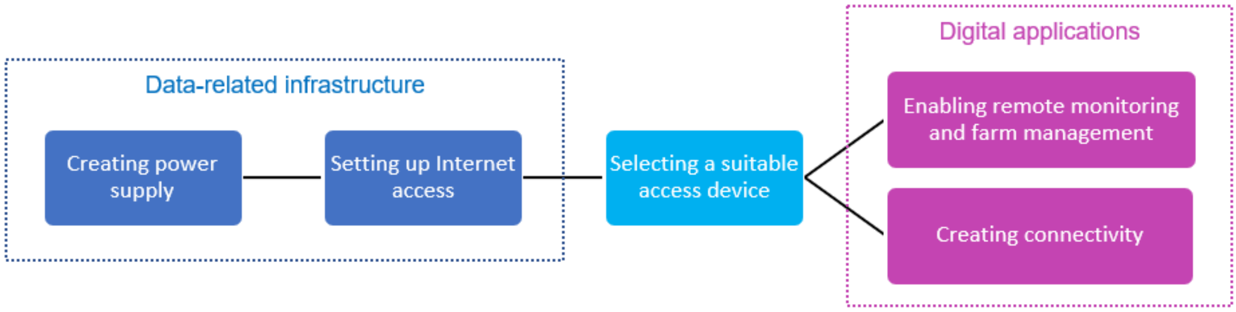
IV. Appendix

Appendix 1: Thesis overview



Own illustration

Appendix 2: Expert interview

Interview partner:	[redacted]
	PhD Student at the University of Johannesburg.
	Expert in the field of decentralized energy supply in rural Botswana.
	[redacted]
Date:	19.08.2022
Location:	Zoom
Duration:	00:00:00 – 00:50:33

Hannes Borgwardt:

Let's start with the first question. What was your motivation for developing a Pilot Biogas-Solar PV System for Farming Communities in Botswana and where do you see the greatest advantages of such a system?

Interview partner:

Okay, thank you for the question. One of the reasons for the project is that we are affiliated with an institution in Palapye, Botswana, which is the Botswana International University of Science and Technology. Palapye is one of the most dynamic cities in Botswana these days. So, Botswana is known for having a considerable number of farmers in some ways, and for having people on board who come from a Botswana university and also have the potential to find communities and also have interest in biogas. We know that biogas depends mainly on feedstock, such as animal manure, food waste, and perhaps other types of waste that can be obtained as organic waste.

Based on all of these ingredients, we decided to explore something that may be innovative, but is specifically dealing with farming communities. First, there is an article from the World Economic Forum that predicts that Africa could be able to generate about $1 trillion in 2030 if the farming industry, or I want to say the agricultural sector, is developed. That showed us that there is an untapped potential in Africa that can be explored. And to develop this further, we first looked at the geographic location that we were in, which was Botswana. And then this was the reason why we decided to look at that. But also the third reason is because we saw a potential, as I said, and we saw challenges that could be dealt with.

And one of the main challenges that was dealt with was energy or power supply. So among maybe others, lack of connection with other farmers, which we have mentioned, and which we have also seen during our research. So power supply, as you know, is the backbone of economic development. It contributes significantly to the welfare of communities. So Africa today is known to have a two major problems, which is food and electricity, you know. So Africa need to be fed and Africa need to also be supplied with electricity.

So we saw that these were two major challenges that farming communities were facing, because as you might have seen, we saw that they were more into subsistence farming. So meaning I am just doing farming for myself and my family to eat today. And then tomorrow we'll think about something else. So it was more about to solve a household problem than to expand and maybe to use it for the gain of a larger group. So we saw that they were just living and focusing on subsistence farming, although they had a potential to upscale the agricultural sector. And as we were assessing, we saw that we could help them upgrade the subsistence farming to a larger, you know, to a bigger scale.

So one of the most important contributions that the state of Botswana had to make to these people was the provision of electricity. Thats why we saw that supply of electricity was highly needed. Apart from supply of electricity, as you said, there was also the need for more infrastructure close to them, because most of them could not migrate to facilities, where they are going to kill the animals. So there was also a transportation problem. So as you say, so there was a need to multiply our facilities and to bring them in proximity to these communities. But as far as we are concerned, we were focusing on the power supply and we try to see what will be the right approach to deal with them.

So this was the motivation for us to develop this topic. And if I have to answer what is the greatest advantage? So, as I said, if we supply electricity, I'm sure that they will be able to have abattoir facilities and that will enable them to use the animals to use whatever resources that they have. And then it will also enable them to upscale their farming. So they will not just do subsistent farming, but they will also do a larger scale of farming. So they will be having their flocks and using them for the benefit of a larger group. So that's the motivation, and this is where the greatest advantages are.

Hannes Borgwardt:

This is in line with my research. You need a reliable energy supply to build upon to enable further services and create further added value, so thanks for your answer. I will move on to the next question. Where do you see the biggest challenges for the implementation of such a system?

Interview partner:

Okay. So the biggest challenges to implement such a system is an economic challenge. So I will say a financial challenge. So you cannot develop this type of system without having financial muscles in the beginning. What I mean is that you need for a beginning to have grants, because you cannot expect the people to pay you for the system. When we were developing this system, we saw that this system alone will cost around 2000, let's say between 3000 to 4000 US Dollars. And even more, depending on the size of the overall system. So it could be very expensive. This means that the affordability is the first challenge. People cannot afford this system. And this means that because people cannot afford the system, it needs to be given for free, at least for the beginning, until the people will be able to do that. If it's not given for free, then we need to identify instruments, maybe to be a form of loan that will be given to them.

But, I can guarantee you that this form of loan will be very extend extensive. You know, it'll be for a longer period and people will not really be able to pay, but this will not be less than five years. So if they have to be given a form of loan for them to acquire this system and they have to pay, I'm sure that they will not be able to repay this in full in less than five years. So affordability is the main challenge that we saw in implementation of the system.

The second thing is an educational challenge, because you need to educate them about the system, what it is, what is solar energy, what is bio gas energy? Why do you need that? How will you benefit from this system? How is it beneficial to the environment, to your plantation, to your farm? You know, so people need to be educated, and in this exercise, they are not always well receptive, because some of them want to stay traditional. They're a bit skeptical. Some of them ask themselves so many questions. They think that you are coming to invade their space. They still want to continue to operate the way they have always operated. So it's not always everyone who embrace change. So this is one thing. So there is a little bit of resistance when you trying to educate them and show them new ways of doing things that could be advantages to them. So, as I said, the first is affordability. The second is about resistance that you have when you're trying to educate the larger group.

And then the third one is, in these places, sometimes you will see multiple households and some of them don't have enough space. So the solution that we are proposing can also require some space. We try to look at two approaches, either having one system to which there will be maybe two or three or even five household connected to this system. So we'll have a cluster. Or let's say, if it's a group of hundred household, you divide them, let's say in a group of 20 and then it means you will have a cluster of five households. And to the five households, you can have a system to connect each of them. So this could be a possibility as well. But this was the first approach.

The second approach was to connect each house with a system. So each house has a system, a bio and solar PV bridge system, maybe at the backyard or at the house. So now we had to use the best approach and we were looking what will be the right way of doing that. So without offending one party or another. So for us, what we were looking at in the beginning was to have one system for each household. In this way, we also wanted to prevent incorrect waste management, because we did not want one household to say, for example, that it injects more waste than others. Therefore they have the right to get more digestate than the other household. And then they have the right to use it to grow the crops compared to the other household. So this was for a better management. But now the problem with this approach is that sometimes you have a household that does not have enough space for you to implement this system. So it's quite a challenge, of course, for solar, because we were thinking about a four kilowatt peak, for solar and five kilowatt for biogas. So it's quite spacious, it requires some space and these house old did not always have the necessary space for us to implement that. And also the two bio digesters requires some space. So the problem that we have seen was the right approach to use and the space for us to put it, if we had to use the second approach, which was each household with each, each system. So this was the three major biggest challenges that we have faced so far.

Hannes Borgwardt:

Okay thank you for this answer, let's move on to the third question, which you have already partially answered. How do you assess smallholders' willingness to adopt and pay for such a system? So you said the adoption is quite a challenge. Cause some smallholders want to keep doing it the traditional way and they're not really willing to explore the new ways of doing things. So I think the key is you have to show them the real added value of such a system so that they can feel and see that they are better with it. And you talked about the payment as well, so you said especially in the beginning it's not possible for the farmers to pay for such an expensive system. So you have to give it for them for free at the beginning and afterwards you have to figure out ways to finance such systems in the long term. Did I understand that, right, or do you want to add to this?

Interview partner:

Yeah exactly, you got it right. So just to pinpoint here that this is a system that works well, if you have grants. With grants you are willing to give it for free in order for you to solve a problem, or in order to improve the welfare of a certain community. Yes. But if it is for commercial purpose, then you have to look for the right instrument, which for me will be to give them a loan. And then a loan that they're going to repay in a space of about five years for those who can afford, and maybe 10 years for those who cannot afford. And you give them a great period where you say for the first three years, they will not pay anything.

And then once they become more economically free or independent, then they can start paying. So there can be instrument that can be put in place in order to improve the implementation of such system. But as I said, everyone will want to have something for free in the beginning. So if there is a grant facility that enable people to get that, we can go ahead. If there is not, then the second option will be to identify a loan that can be given to these people, and then this will be fine.

And also in that system, I think the loan can be paid in part, it can be hybrid so that can be the state or the government that avails something. And then there is just a portion of that loan that is repaid by them at a very, very low cost, or low interest. So just to say that this will really need the cooperation of the states and local communities as well. But it's important to understand here, that people are very sensitive when it comes to money. And especially in that part of the world where people are trying to meet their daily needs.

Hannes Borgwardt:

Thank you very much for your expertise. Let's move on with the next question. You conceptualized your pilot project in Palapye. Can Palapye be taken as a representative location for other places in Botswana, for example Maun?

Interview partner:

Yeah, I think it's possible to take Palapye as a representative location for other places in Botswana. But I will always suggest that you have at least two or three locations, and then you compare them before selecting one representative location. And then based on the criteria that you have, you try to rate them, and then you are going to choose it as the representative location. So I think it's always good to have diversity of choice then to choose just one.

Hannes Borgwardt:

Thank you. The next one is quite a big question. What further steps are necessary to implement such a system?

Interview partner:

The first step is a proof of concept. So I think it'll be good to prove this concept in the context of Palapye. It'll be good to see how it works to have at least one targeted sample of some houses, maybe two or three, five before expanding or implementing this system to larger group. You can maybe choose one house for a start or maybe you can choose two, three, or even five households. And then you experiment and just see the pattern of your system.

And then based on that, you can decide. And if you have also the possibility, you can have a two different location, for example Maun, and then you have this place, you have five households in Palapye where they have this same system. And then you look at the behavior, and then you also look at how it is performing in the other location that you have identified. And then you can make the comparison between the two places, the behavior approach. And then based on that, you can decide where and how to implement such system. As I said, a pilot project still needs to prove its concept before expanding it to a larger group.

Hannes Borgwardt:

Let me jump to the next question. This time, the focus switches a bit from energy provision towards digital applications. In addition to an electricity supply, the aim is to create access to the internet and digital services. How would you rate smallholders' willingness to adopt and pay for digital applications, such as mobile phone apps? What other barriers are faced in the adoption of digital applications?

Interview partner:

Thank you for the question. I think there is nothing impossible. Of course, we have to be realistic about the time frame we are going to set. At some point, as I said before, there is a lot of educational efforts to be done. So we need to educate the people first. They need to be exposed to things that will increase the appetite for certain things. If they've not really been exposed to much of digital applications or if they've not yet been exposed to digital services, internet, these type of things, it'll require some time for them to get familiarized with that. So the first challenge will be time. So it depend on the timeframe that you're considering. Is it something that you like to develop in six months in one year, in two years, in three years?

Based on the time frame, you can now see whether you can really implement it as quickly as planned or not. So, that being said you have to set the time that you targeting. I can tell you that in five years it'll be easy. If it is three years, I will say, yes, it's possible. If you say two years, I'll say, yes, it's still possible, but there will be a lot of effort to be done. If you say one month, I will say it is difficult. It's actually impossible. So it's the timing that you are setting will determine, whether they will be willing to adopt and pay for this or not. And also the reason why I'm mentioning timing is because with time they will learn, they will get to understand the benefit of having such platforms. What is the importance? What is the use of having that? So as I say, to set the timeframe is really important, and of course the key milestones that you are trying to have within the timeframe that you're going to set. So speaking about now, the milestone is also to know what are the milestone that you are looking at? Maybe the first milestone will be to first have electricity in the community that gives them better access. We know with electricity, internet with easily come and with internet digital services will easily come.

There will be many things that will easily come and therefore there will be a great exposure to these type of things. For example, with electricity, they will see that it's not only good for lighting, enabling their children to read better at night, to no longer be sick for the woman to no longer have lung infections like they used to have because they were using charcoal, but they will see also that with electricity, there is also access to internet. They also have better access to things that internet can provide. People can find jobs, for example, from where they are, because they have been contacted, they can connect maybe with other farming communities. So they can also have access to information that they cannot receive. These are educational efforts that need to be rolled out, this is ramp up over a specific period of time and then it'll require some progress, but it all depend on the resources that you're going to avail for them to digest that. Because even if you avail all the necessary resource in one week, two weeks, you also need to give them time to digest and which might take time. So I will just say two things you need to be specific in terms of timeframe. What is the timeframe that you're looking at? And secondly, what are the key milestone that you're looking at. For me, one of the major milestone is electricity. And then second thing, it is an awareness program. You need to make the people aware of the benefit of every digital application in the phone. And also electricity I'm sure will allow the people to have mobile phones. Cause in these places, maybe it's one person who has a mobile phone in the house or maybe two. And with electricity and the internet, they will not just have phones, but they will also have laptops. And then in the long run, they are going to have better access to digitalization. So this is what can be looked at on your end. And then this is what I think you should consider if you're at this topic.

Hannes Borgwardt:

I read about a solution for a digital marketplace in Africa where one farmer had a mobile phone and he uploaded the products of himself and about 10 colleagues there. So not every person needs a mobile phone and not every farmer needs to know how to use it. I think this way offers good opportunities to gradually introduce more and more farmers to new technologies. Do you think mobile phones are the suitable device to support smallholders with digital applications?

Interview partner:

You can have mobile phones and you can have also laptops. Some people will be able to access the digital app from the comfort of their house or wherever they will be. But with a laptop, even if many people don't have laptops, they will have access to internet cafe, they will have access to maybe one guy in the community who assists people to go on internet or to do some activities. Just like the guy that you have mentioned earlier. But the advantage now is that each and everyone will have their own account. I believe that if they have their own account, it means the guy will enable a larger number of people to use the platform. But each one of them will use the respective account. So it'll enable those who have mobile phones to use their mobile phones, to access the app, to access their account, the digital platform that they want to look at to do whatever they want to do. And then it'll also enable those who don't have a phone to maybe go to someone who has a laptop or to those who have laptops and then to help them to access maybe the same platform, but using their respective account. So it can still give access to people, but on a different level. So I think the two should be used mobile phone and laptop.

Hannes Borgwardt:

Thanks for your input and of course for your time. That was my last question, your answers helped me a lot.

Interview partner:

You're welcome, thanks for reaching out. And I also like to mention, that this project is actually in search of funding, so if you, by any means access to people who like to develop these initiative as well with us, i maybe can try to chat to my supervisor as well. I think it's already a connection that we have built thorugh this interview, but if you know facilities or people who will be interested in developing an energy system, not only in Botswana but in other countries of Africa, this will be really good. And then we can try to see how we can try to develop this type of system across the continent. Maybe we can explore a partnership or synergies between our two groups and try to see how they can assist you. And even if you want to research further, they are more than willing to assist.

V. Statutory declaration

Hereby I, Hannes Borgwardt, born on [redacted] in [redacted], declare that I have written my bachelor thesis with the title:

“Conception of smart farming solutions in the context of Botswana's digital development:

Identifying and evaluating potential innovations that enable smallholder farmers in Botswana to access data, connecting them to new resources, knowledge, and markets, based on a federated digital framework to advance Africa's transition to a digital economy.”

in the faculty of Mechanical Engineering (orig. Maschinenbau) under the supervision of Prof. Dr.-Ing. Michael Max Bühler independently and have not used any sources or aids other than those indicated. All text passages taken verbatim and in spirit from external sources have been marked.

[redacted]

Hannes Borgwardt

Konstanz, 31.08.2022