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Sustainable innovations for rural Africa: Case studies from Nigeria and Tanzania

Ayoub Derdabi and Ondřej Dvouletý

Department of Entrepreneurship, Prague University of Economics and Business, The Czech Republic

ABSTRACT

Sustainable entrepreneurship is essential to tackle the negative effects of climate change in communities, especially in the rural areas of Africa. This article presents case studies of two start-ups developing sustainable business models for rural communities in Nigeria and Tanzania. The cases were monitored during an accelerator program, and the analyzed materials come from in-depth interviews, field observations, and secondary data. The obtained data were coded and processed using qualitative thematic analysis. The research activities took place during the years 2022 and 2023. The cases illustrate how the studied entrepreneurs have designed their sustainable business models and engaged with early adopters and opinion leaders within a community. They leveraged existing networks and community associations to provide education and training. This can be highly effective in increasing the adoption rates of innovations. However, navigating the political and cultural dynamics and building trust within communities is crucial to overcoming challenges and successfully diffusing innovations in rural Africa.

KEYWORDS

Community engagement; innovation adoption; rural entrepreneurship; Sustainable Development Goal 11: Sustainable cities and communities

Introduction

Global climate changes have led entrepreneurs, business owners, policy makers, and other stakeholders to significantly reconsider the ways that business activity is pursued, and how products are manufactured and delivered to customers, ensuring continuous economic growth (Terán-Yépez et al., 2020). These challenges include shifting customer preferences toward sustainable businesses, changing the manufacturing and logistic processes reflecting scarcity of resources, and facing physical climate-related risks, including extreme weather threats. This calls for active collaboration of stakeholders across countries and continents, promoting a sustainable global entrepreneurial ecosystem and effective regulations (Chaudhary et al., 2023; Sreenivasan & Suresh, 2023). One of the key challenges for entrepreneurs is to adopt sustainable business models, which is still being done differently across the globe, pushed, for example, differently within the European Union countries compared to the African continent (Ali, 2021). For example,

CONTACT Ondřej Dvouletý ondrej.dvoulety@vse.cz Department of Entrepreneurship, Faculty of Business Administration, Prague University of Economics and Business, W. Churchill Sq. 4, 130 67 Prague 3, The Czech Republic.

Ensign (2023) pointed out that the current state of knowledge is driven by the European-context-related literature, which makes the sustainable entrepreneurship field very Euro-centric, lacking examples of best business and policy practices from the less explored countries and continents.

The key question is whether the approaches and concepts developed within the developing countries' context (for example, frugal innovations, bottom-of-pyramid innovations, entrepreneurial bricolage) addressing the need to come up with innovative sustainable solutions and sustainable business models could be applied within the developing countries context and to what extent they would need to be refined, updated, or adjusted, as noted by Dauda et al. (2021), Hossain (2021), and Omri (2020). Compared to the European continent, African countries are especially subjected to the consequences of global climate changes, including extreme droughts, water stress, soil deterioration, floods, and cyclones (Atwoli et al., 2022; Otache, 2024; Schilling et al., 2020), affecting inhabitants and amplifying the need to search for sustainable solutions and adoption toward sustainable business practices.

Notably, the African continent emits the most minor greenhouse gases, yet its inhabitants suffer predominantly from global changes. African rural communities especially feel climate change impacts on a daily basis (Atwoli et al., 2022; Otache, 2024). Their livelihoods depend highly on natural resources, making them very vulnerable to dramatic events such as droughts or floods, multiplying adverse effects on existing socioeconomic inequalities and vulnerability, agricultural productivity, water availability, the health status of the population (including life expectancy), among many others (Ombaka & Obunga, 2022; Singbo & Lokossou, 2024).

At the same time, the continent has a considerable lack of infrastructure to cover its energy needs. Only 28 percent of the sub-Saharan rural population has access to electricity, and about 600 million people across Africa do not have access to the electrical grid (Kyriakarakos et al., 2020). Lately, there has been a growing interest in the role of sustainable solutions and technologies in helping rural communities build resilience toward climate change. These technologies can help mitigate climate change, but they can also help adapt to its effects and enhance rural communities' economic and social resilience (Islam & Wahab, 2021; Korsgaard et al., 2015; Simba et al., 2023). Yet the current body of knowledge lacks examples of good practices, such as those applying sustainable innovation and business model approaches. The collection of these examples of good practices and cases might inspire the general population to start a sustainable business, scale up the implementation of sustainable innovations, and promote those by policy makers and investors, boosting the entrepreneurial culture of the African sustainable entrepreneurial ecosystem (Tilt et al., 2021).

In response to these multifaceted challenges, this article embarks on an empirical exploration to highlight the role of sustainable entrepreneurship and sustainable business models in supporting rural communities in Africa by providing

specific examples of sustainable start-ups addressing their needs. Through the lenses of sustainable entrepreneurship and sustainable business models, this research aims to scrutinize a selection of case studies to discern effective entrepreneurial strategies that facilitate the introduction and adoption of sustainable business models, serving as good examples to be followed by those considering a sustainable business start-up. Our study is anchored on key objectives, including identifying the strategic approaches that enable the successful development and delivery of sustainable business models within the selected cases by applying mainly the theoretical lenses of entrepreneurial bricolage (Ciambotti et al., 2023) and the sustainable business model canvas application (Bocken, 2021). Furthermore, we aim to dissect how these sustainable business models interact with and influence the unique socioeconomic landscapes of rural African communities.

Through the qualitative case study approach, the authors explore how entrepreneurs design sustainable business models to impact the rural context in Africa. While exploring the cases of successful sustainable businesses in Tanzania and Nigeria, the authors analyzed the strategies of two companies to understand how these entrepreneurs delivered their business models. The study reflects on the following questions:

What were the key barriers and facilitators to deliver their value?

What were the characteristics of their business models that influenced their adoption by the rural communities?

How did these sustainable business models contribute to building the resilience of these rural communities?

Theoretical background

Sustainable entrepreneurship

There is a growing body of literature around the construct of sustainable entrepreneurship. It has been defined as innovations that bring economic, ecological, and social benefits, thus contributing to the triple-bottom-line concept (Shabbir, 2023; Yoon & Tello, 2009). Because social and environmental problems are complex, sustainable entrepreneurs will be able to address these complexities, demonstrate the effectiveness of their solutions, and establish the legitimacy of their approach as a solution. Several problems can be resolved by entrepreneurs worldwide, including waste management, pollution, and mitigating the effects of climate change, to name a few (York & Venkataraman, 2010). It is also important to note that sustainable innovation and entrepreneurship are also defined as the creation of services and products that address the needs of individuals and organizations while respecting natural resources and their capacity to return to life (Yoon & Tello, 2009).

Various definitions of sustainable entrepreneurship can be found in the literature, reflecting the complexity of the concept and its multidimensional nature. In terms of sustainable entrepreneurship, many vital elements should be considered. Achieving the triple bottom line is a crucial component of sustainable entrepreneurship, which entails balancing environmental, social, and economic considerations with each other (Yoon & Tello, 2009). By creating value in the form of financial profitability, it also seeks to create value in terms of a positive social impact and environmental sustainability in addition to financial profitability (Kalyar et al., 2019). It has been stated that sustainable entrepreneurship involves developing and implementing innovative solutions, products, and services that address the sustainability challenges that face the world today. It requires a critical eye, creative thinking, and the ability to identify new market opportunities that align with environmental and social goals that can be met. Sustainable entrepreneurs have also been recognized as power agents that encourage women's empowerment and support the economic development of communities, especially in developing countries (Anand et al., 2021; Egere et al., n.d.).

Sustainable business models

Following the construct of sustainable entrepreneurship, one of the sustainable business models is highly related, as it involves adopting business models that consider environmental and social factors. Embedding sustainability factors in a company implies adopting a new model for the firm; it can be defined by the implementation of a new business model, the transformation of an existing model, diversification, the acquisition of new business models, or even the construction of an entirely new model (Geissdoerfer et al., 2018). To achieve this goal, sustainable practices may be incorporated throughout the value chain, circular economy principles may be adopted (Rattalino, 2018), and socially responsible business practices may be adopted (Yoon & Tello, 2009).

The construct of sustainable business models has gained significant attention in academia to integrate sustainability into the core business strategies of companies. These models aim to create economic value while ensuring environmental stewardship and social equity. Pioneering studies on business models and their design, such as those by Osterwalder et al. (2005) or Zott et al. (2011), laid the ground for understanding how various components of the company and its environment are embedded in the business models. These were also the first steps before the inclusion of sustainability perspectives, emphasizing the need for businesses to adapt to changing environmental and social landscapes.

The adaptation of the traditional business model canvas defined by Osterwalder to incorporate sustainability considerations has been an important development in this field. The Sustainable Business Model Canvas, as outlined by Bocken (2021), extends the conventional canvas to include sustainable value propositions, considering environmental, social, and economic

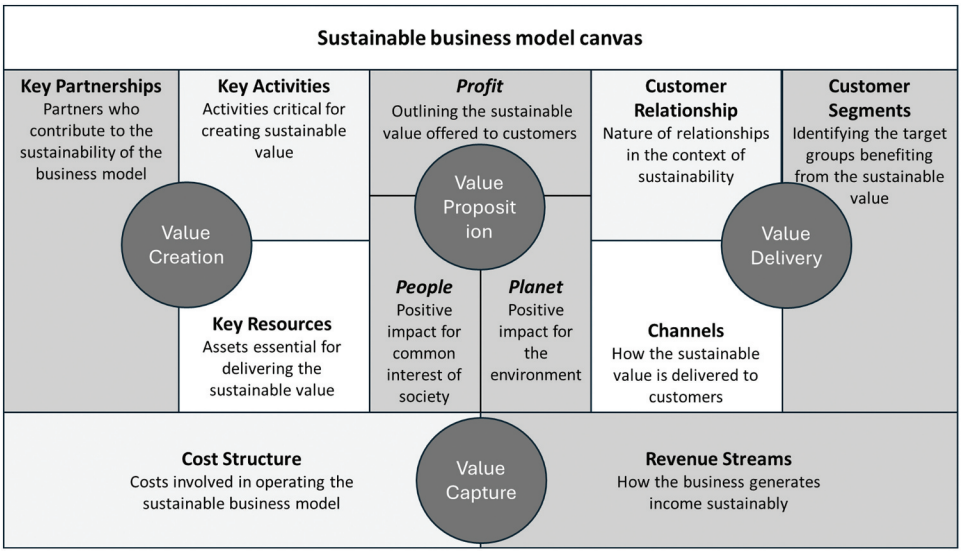

Figure 1. Sustainable business model canvas of Bocken (2021).

impacts (Bocken et al., 2014). The canvas serves as a conceptual template (displayed in Figure 1), facilitating the ideation and development of business models that are not only economically viable but also socially beneficial and environmentally sustainable.

While adapting business model canvases for sustainability presents new opportunities for innovation and value creation, it also introduces challenges. The complexity of balancing economic goals with environmental and social objectives requires businesses to adopt a multifaceted approach. Studies have highlighted, through the angle of the stakeholder theory, the need for businesses to engage with a variety of stakeholders (Freudenreich et al., 2020), incorporate diverse metrics, and navigate complex socioeconomic factors (Matos & Silvestre, 2013) to implement sustainable business models effectively. The current literature on sustainable business models and their canvases provides a robust framework for understanding and implementing sustainability in business practices. These models and tools guide businesses in creating sustainable value and offer a lens to critically assess the impact of business activities on society and the environment (Dobrowolski & Sułkowski, 2021). As the field continues to evolve, it presents a fertile ground for further research, particularly in the application and scalability of these models in different contexts.

Adoption of sustainable business models

Scholars have shown a growing interest in the field of sustainable business models and their adoption by communities. Sustainable innovation has been recognized as a key driver of economic growth, and businesses can achieve

sustainable economic performance by adopting innovative sustainable business models (Boons et al., 2013). The adoption of sustainable business models by rural communities is essential for achieving sustainable development and improving the livelihoods of rural populations. Sustainable business models can help rural communities address environmental, social, and economic challenges like climate change, poverty, and food insecurity. Scholars also agree that the main drivers of sustainable innovation are a combination of internal and external factors, including regulatory policies, consumer demand, technological advancements, and stakeholder collaboration (Hojnik & Ruzzier, 2016). However, various socioeconomic and cultural factors often challenge the adoption of sustainable innovations in rural communities. There needs to be a comprehensive approach to development that considers the complexities of the diffusion of sustainable innovation, hence the importance of involving communities in developing and implementing sustainable innovations to increase their adoption and diffusion (Dearing, 2009).

The diffusion of innovations theory, developed by Everett Rogers in 1962, has been widely used to study the adoption of new technologies, products, and ideas (Boushey, 2012). The theory provides a framework for understanding the process by which an innovation is adopted by members of a social system and identifies five stages of the diffusion process: knowledge, persuasion, decision, implementation, and confirmation (Dearing & Cox, 2018). The diffusion of innovations theory provides a useful framework for understanding the process by which new innovations are adopted by members of a social system. By identifying the factors that influence the rate of adoption of an innovation, it is possible to design effective strategies for promoting the adoption of new technologies, products, and ideas. The main factors are the features of the innovation itself, the communication channels, the social system, and the adopter's "characteristics" (Rogers et al., 2019).

One of the key features of the diffusion of innovations theory is the identification of different categories of adopters. Rogers identified five categories: innovators, early adopters, early majority, late majority, and laggards. Innovators are the first to adopt new innovations, followed by early adopters, who are more influential in promoting the innovation to others. The early and late majority are more cautious in their adoption of new innovations, while laggards are the last to adopt (Stacks & Salwen, 2009).

In the context of innovation adoption in the rural context, several scholars have emphasized the importance of grassroots movements and the involvement of the local communities. Grassroots innovations are solutions prioritizing the values and beliefs of local communities involved over profit, and these community-based solutions aim to address local needs while also potentially influencing broader societal change from the bottom up (Raj et al., 2022). Grassroots innovations can also facilitate the diffusion of sustainable innovations by creating networks and building social capital (Seyfang & Longhurst,

2013). These movements, which involve individuals and communities in developing and implementing innovative solutions, can play a significant role in diffusing sustainable innovations. Understanding the social and political dynamics that influence the success of these movements and the diffusion of their innovations is critical (Smith et al., 2014).

However, scholars have extensively studied the many barriers preventing the spread of sustainable innovations. When discussing the diffusion of sustainable innovations, scholars highlight the importance of understanding the barriers that prevent their widespread adoption. Studies suggest that factors such as lack of knowledge, high costs, and resistance to change can hinder the diffusion of sustainable innovations and that addressing these barriers is critical for achieving widespread adoption and creating a more sustainable future (Schmidt & Druehl, 2008). When diffusing sustainable innovations, it is important to consider the broader societal context in which sustainable innovations are developed and diffused, including political, economic, and cultural factors. Policy makers are encouraged to support the development of sustainable innovations, especially in order to ease the diffusion of technologies such as cleantechs. Sustainable innovation policy should focus on creating a favorable context for innovation and diffusion through policies such as financial incentives, regulations, information and knowledge sharing, and stakeholder engagement (Foxon & Pearson, 2008; Organisation for Economic Co-Operation and Development, 2023; Ritsuko, 2011).

Several studies have applied the diffusion of innovations theory to understand the adoption of sustainable innovations by rural communities. For example, Wossen et al. (2015) applied the theory to understand the adoption of sustainable land management practices in rural Ethiopia. The study found that adopting sustainable land management practices was influenced by various factors, including the farmers' perception of the relative advantage and compatibility of the practices, the availability of resources, and the influence of opinion leaders.

Overall, sustainable innovations can potentially improve rural communities' livelihoods by addressing environmental, social, and economic challenges (Castro-Arce & Vanclay, 2020; Natarajan et al., 2022). However, the diffusion of sustainable innovations in rural areas is often challenging due to various socioeconomic and cultural factors. Several studies have emphasized the strategic role of sustainable innovation and its diffusion in Africa to tackle energy access issues. For example, studies have shown the potential of solar energy and biomass in Nigeria. Due to the remoteness of rural communities, electrification through the grid is very challenging, hence the need to deploy renewable and clean energy for rural development (Ifeanyi-Nze & Okayim, 2022; Osalade et al., 2022).

Several studies have used the diffusion of innovations theory and analyzed the influencing factors. A study analyzing the diffusion of renewable energy technologies in Africa has shown that the adoption remains limited mainly due to the affordability of technologies and the population's lack of awareness (Tigabu,

2018). Smallholder farmers have also faced many challenges in their education in farming practices. In West Africa, knowledge acquisition has improved mainly with the introduction of mobile technology, which has helped to spread education about better agricultural practices (Zossou et al., 2020). Also, the belief that Africa could easily leapfrog in its energy transition has been challenged due to the difficulty of the technologies to spread as rapidly. The main factors shown in the study were that it requires an individual's capacity to adapt to the technologies, to take the economic risks, and to change their behavior (Murphy, 2001).

Some studies have also shown the role of financial incentives in adopting adaptive technology. In Zambia and Zimbabwe, a study has shown how development initiatives can help overcome some adoption barriers by financing these technologies and easing their spread (Twomlow et al., 2008). Finally, one key aspect of adopting innovations is the communities themselves. Rural communities can also be agents of change and bring innovations with a bottom-up approach (Dobson, 2017; Šlapáková Losová & Dvouletý, 2024). In Niger, for example, a case study of the Hausa farmers shows the innovation capabilities of the farmers acting as a community and being in the driver's seat of their own development (Matthews, 2016). This element does not have to be omitted when considering adopting technologies to develop the resilience of rural communities. In Tanzania, a survey of 600 smallholder farmers in four districts of Tanzania found that adopting sustainable agricultural practices was influenced by a range of factors, including access to information and extension services, access to credit, household size and education, land tenure security, and market access. It also found that networks and communities have the potential to lower the labor and financial constraints of farmers and improve their bargaining power to access such innovations (Kassie et al., 2013).

These studies illustrate the context of Africa and its resource constraints and further advocate for the collection of examples of successful sustainable entrepreneurs utilizing the global sustainability trend to explore new combinations of resources with the ambition to find sustainable solutions while pursuing economic activity, as described by the entrepreneurial bricolage approach (Busch & Barkema, 2021). Knowing and promoting these examples of good practices across the African continent (that is, cases of successful sustainable entrepreneurs who managed to scale up their entrepreneurial activities; Onwuegbuzie & Mafimisebi, 2021), further empowers the entrepreneurial culture and fosters the overall quality of the entrepreneurship ecosystem (Kansheba, 2020; Odeyemi et al., 2024), and possibly encourages a new generation of sustainable entrepreneurs (Nayak & Pillai, 2024).

Methodology

This research article adopts a case study approach (Figure 2) focusing on two sustainable companies that have survived the initial critical years since the

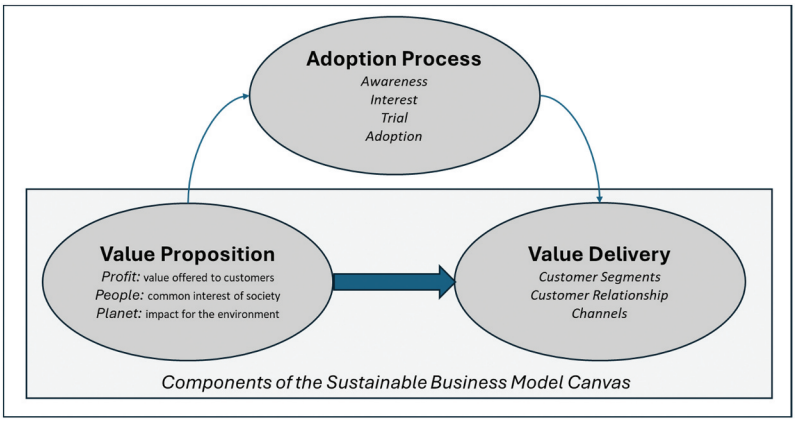

Figure 2. Conceptual framework for case studies analysis.

businesses were set up—NovFeed and D-Olivette Enterprise (company profiles available in Table 1)—that serve as examples of economically active sustainable enterprises that could be studied and serve to inspire others to join a sustainable entrepreneurial career pathway. The main objective of this study is to explore how these companies have designed and implemented sustainable business models targeting rural communities in Africa. The exploratory research applies a multiple case study approach to learn from the experience on the ground. The case study as a research method has been defined as an intensive investigation of a person, a group of people, or a unit (Heale & Twycross, 2018; Gerring, 2004). This method enables an in-depth exploration of the phenomenon under investigation.

The two companies, NovFeed and D-Olivette, were selected as case studies for this research based on their participation in the Africa ClimAccelerator program (https://climaccelerator.climate-kic.org/) in 2022, managed by the European Institute of Innovation and Technology Climate-Knowledge Innovation Community, a leading climate innovation organization based in Europe. The program aimed to support and accelerate innovative solutions to climate change in Africa. The two start-ups were selected because they had relevant, sustainable business models and actively supported rural communities in their respective countries, Tanzania and Nigeria. The choice of the countries was made to show different contexts and regions from the continent with different socioeconomic, cultural, and community structures.

The principal investigator was the lead project manager for the Africa ClimAccelerator program and had the opportunity to observe the two start-ups during the program. In addition, the authors conducted in-depth, semi-structured interviews with the management of each company, as well as customers, to gather more detailed information on their business models, challenges, and successes. The interviews were also conducted throughout 2023 via videoconferences and were followed by phone calls with customers.

Table 1. Profiles of the studied companies.

Name of company: Novfeed
Foundation year: 2017
Headquarters: Dar Essalam, Tanzania
Founders: Diana Orembe, Otaigo Elisha, Innocent Lymo
Website: https://novfeed.com/
Short Description:
Novfeed is a start-up company founded by Diana, a microbiologist with a passion for sustainability and animal welfare. The company focuses on producing a sustainable and environmentally friendly alternative to traditional animal feed. Novfeed's mission is to reduce the environmental impact of animal agriculture while ensuring that animals receive proper nutrition.
The company's primary product is a novel protein source made from bacteria that can be used as a feed supplement for livestock. The protein is produced using a fermentation process that uses food waste as a substrate, reducing the amount of waste that would otherwise end up in landfills.
Novfeed's approach to animal feed production is unique and environmentally conscious, and the company has gained attention from investors and customers who are interested in sustainable agriculture. Diana's background in microbiology and her passion for sustainability have enabled her to create a product that addresses both environmental and animal welfare concerns.

Name of company: D-Olivette
Foundation year: 2018
Headquarters: Lagos, Nigeria
Founders: Tunde Adeyemi, Damilola Aminat Adeyemi
Website: https://www.doe.com.ng/
Short Description:
D-Olivette is a Nigerian company that manufactures domestic systems known as the Kitchen Box, which convert waste into biogas for cooking and lighting, with the byproduct used as fertilizer. The company's innovation has several key characteristics, including portability, affordability, variety, scalability, user-friendliness, and technological upgrades. Their products are designed to meet different demands and are available in various sizes, ranging from kitchen-scale to community-scale devices that can be used in both rural and urban communities. Their smallest biodigester costs $49, which is much lower than conventional biodigesters in Nigeria, which cost over $20,000. Additionally, their Kitchen Box comes with an app that helps users track how much biogas to expect and calculate its cooking or electricity capacity, as well as the expected output of fertilizer.

A field trip in August 2023 was also organized in Tanzania, where the principal investigator visited the production site of Novfeed, observed the production process, and discussed it with the team on the ground. The principal investigator also collected and analyzed documentation on the companies, including their websites, qualitative surveys captured during the program, videos produced by the companies, pitch decks, and reports. This variety of data sources helped to triangulate and verify the findings.

The data collected for this research article were analyzed using a qualitative approach. The data were first coded using a coding scheme developed based on the conceptual framework for the case analysis. The coding scheme was designed to capture key themes and concepts related to the companies' sustainable business model and their strategies for delivering value and getting adoption from rural communities (Table 2). Thematic analysis was used to analyze the data collected from the in-depth interviews with the two start-ups and the documents collected. The coding scheme was designed to capture essential factors related to the sustainable business model and the adoption of the innovations. The conceptual framework was based on the canvas of the sustainable business model. The focus was put on the value proposition (profit, people, and planet) and the value delivery

Table 2. Sustainable value proposition of NovFeed and D-Olivette.

	Novfeed	D-Olivette
Profit: value offered to customers	NovFeed offers an economically viable alternative to traditional animal feed. This reduces the cost burden on farmers, leading to more affordable fish products for local communities. Economically, NovFeed offers an affordable and high-quality alternative to traditional animal feeds, reducing costs for smallholder farmers and improving their profitability.	D-Olivette's innovation provides affordable and efficient energy solutions to rural communities, also potentially creating job opportunities, especially for women, in managing biodigesters.
People: common interest of society	NovFeed addresses food security and supports climate resilience by providing sustainable and affordable fish feed to farmers. This indirectly assists the community by ensuring a steady supply of sustainably produced fish, contributing to better nutrition and food security. NovFeed's approach supports food security and nutrition by providing affordable fish feed, leading to more accessible fish protein for local consumption.	D-Olivette, by providing clean cooking and lighting solutions, improves health outcomes by reducing smoke inhalation problems and increasing access to clean energy, thereby enhancing the overall well-being of the community members. It aims to tackle the persisting issue of energy poverty in rural Nigeria.
Planet: impact for the environment	NovFeed's conversion of organic waste into sustainable fish feed significantly reduces environmental damage. It prevents the depletion of small fishes like sardines and anchovies, essential for the ocean's ecological balance. Additionally, by diverting organic waste from landfills, NovFeed mitigates the negative impact on microorganism biodiversity. NovFeed's process of converting organic waste into sustainable fish feed helps reduce landfill waste and carbon dioxide emissions. It also helps in preserving marine biodiversity by reducing the need to harvest small fish for feed.	D-Olivette's biodigesters transform organic waste into biogas and biofertilizer, reducing reliance on harmful energy sources like firewood and charcoal, thereby mitigating deforestation and reducing greenhouse gas emissions. By replacing the usage of wood and bringing a clean cooking solution, D-Olivette helps to prevent rapidly growing deforestation in Nigeria.

(customer segments, customer relationship, and channels), two fundamental components of the sustainable business model canvas (Bocken, 2021). The conceptual framework combines the value proposition and value delivery from the sustainable business model canvas. A third element is the diffusion of innovations theory, which is the adoption process (Al-Suqri & Al-Aufi, 2015). This framework helped to analyze the cases and draw insights to answer the research questions. The analysis involved coding the data, identifying patterns and themes, and developing a narrative that explains how the business models from Novfeed and D-Olivette create value and are being adopted in rural communities. Examples from the interview data were also used to provide in-depth findings. The analysis was also compared to existing literature on sustainable business models and adopting innovations in rural communities to provide a broader context. Furthermore, we note that the research was conducted in line with the ethical standards of doing qualitative research; the participating companies agreed to participate in the research and were informed about the usage of their materials.

Results and findings

Creating economic, environmental, and social value for rural communities

Novfeed produces sustainable and affordable fish feed from organic waste. The company uses a fermentation process in which microorganisms produce a nutritious, high-protein feed that is free of toxins, highly scalable, and has better nutrition. The feed has been tested extensively and has shown higher growth rates and a 97 percent survival rate, with NovFeed's product yielding $3 in fish for every $1 spent. The innovation is characterized by using waste as an input source, eliminating harmful gases and reducing carbon emissions. It is also 30 percent cheaper than traditional sources, highly scalable, and has high protein content. Novfeed's innovation solves the challenge of protein in fish feed, which covers more than 70 percent of the total cost of the total fish feed. The company aims to help smallholder farmers access affordable, high-quality fish feed that will take six to seven months to harvest fish.

> Due to the high cost of protein-rich animal feed, these farmers are forced to spend 70 per cent of their production costs on pricey feeds like soy and fishmeal. This is a global problem, but it will hit Africa harder than the developed world. (Diana Orembe, chief executive officer [CEO] of Novfeed)

Novfeed's approach is more sustainable than traditional methods, as it uses less water, energy, and time to produce bacteria-based protein and releases 80 percent less carbon dioxide in the production process than traditional routes. The company plans to continue investing in research and development to discover other ingredients to reduce the cost of feed to farmers significantly. Novfeed targets farmers left behind by the industry and who currently cannot afford to buy pricey feeds like soy and fishmeal. The company also hopes to observe positive impacts resulting from increased farmed fish consumption and Tanzanians' household nutrition status. By doing so, they reduce the environmental impact by reducing deforestation and the removal of small fish like anchovies, sardines, and herring from the marine ecosystem.

> Every week, NovFeed recycles eight to 10 tonnes of food waste, reducing more than seven tonnes of carbon dioxide emission per week. But more than that, the company is proud to educate the community about the importance of recycling, climate change, and empowering them with the right attitude and knowledge to make informed decisions. (Diana Orembe, CEO, Novfeed)

This helps to address the challenge of meeting the protein demand of a growing global population while transforming the entire feed and food production chain to one that is both environmentally and socioeconomically sustainable in the long term.

> Our oceans have reached their biological limit; we are no longer able to produce enough fish to feed animals as a source of protein as well as feed human beings. It doesn't make

> any sense economically and environmentally to use freshwater fish to feed farmed fish. (Innocent Lyimo, aquaculture expert at Novfeed)

NovFeed's innovation benefits the community by reducing the price of fish for human consumption, making it more affordable, educating them about the importance of recycling and climate change, and empowering them with the right knowledge.

D-Olivette's innovation has several key characteristics, including portability, affordability, variety, scalability, user-friendliness, and technological upgrades. Their products are designed to meet different demands and are available in various sizes, ranging from kitchen-scale to community-scale devices that can be used in both rural and urban communities. The company's innovation also aims to tackle energy poverty in rural Nigeria by providing pocket-friendly and scalable solutions. D-Olivette provides training for women on how to refuel biogas and sell it to their neighbors. They have upgraded their products to include town regulators, making it easier for customers to regulate the gas flow. D-Olivette's innovation is designed to improve lifestyles while mitigating environmental pollution and climate change by reducing energy expenses, producing free fertilizer, and providing affordable and efficient energy solutions.

> I found the installation of solar quite expensive, and I had to quickly think of another means to help my community. After doing research, I thought of coming up with biodigesters to provide clean cooking to the community. (Tunde Adeyemi, CEO, D-Olivette)

D-Olivette provides solutions to the issue of energy poverty in rural Nigeria by transforming organic waste into renewable energy and biofertilizer through biodigesters. This innovation comes as an alternative to using firewood and charcoal, which are harmful to the environment and human health.

> Long periods of exposure to smoke can cause serious health complications, and I watched my grandmother and mother struggle with illness due to smoke exposure. Her mother struggled with her health for quite some time without knowing the cause of the illness until it was informed to us by a doctor that the cause was due to smoke exposure. Over 50,000 rural Nigerian women and girls lose their eyesight yearly from decades of exposure to smoke inhalation from the "Adogan" or open firewood stoves. (Damilola Aminat Adeyemi, cofounder, D-Olivette)

It is common in these rural areas due to the scarcity of affordable alternatives. The production of organic waste is abundant, and this waste is often left to rot in the streets, attracting flies and causing diseases. D-Olivette's innovation will help reduce greenhouse gas emissions, providing electrification to homes, farms, and businesses in rural and off-grid communities through biodigesters. They also provide technical skills and training to girls and women to manage the biodigesters, create job opportunities, and reduce energy poverty in the project communities. The innovation also provides a digital feature to help users keep track of

organic waste input and expected biogas and biofertilizer output. Overall, D-Olivette's innovation has significant environmental and social impacts, including reducing emissions, improving waste management systems, and reducing health risks associated with using firewood and charcoal while also creating economic opportunities and reducing energy poverty for rural communities.

> The trees have been cut down for firewood because kerosene is no longer affordable [for] the people. Before, people used 50% kerosene and 50% firewood. But now there is no kerosene, and firewood [is] very expensive. So they get plastic, cut [it] into little pieces and use [it] for cooking. (Tunde Adeyemi, CEO, D-Olivette)

Challenges to deliver value and adoption from rural communities

To convince rural communities to adopt their sustainable fish feed solutions, NovFeed emphasizes the advantages of their feed, such as stronger fish immunity and faster growth in market size. They also stress the importance of sustainability and affordability in their products and the fact that they use ingredients that do not contribute to the destruction of the environment or oceans. NovFeed also aims to communicate with rural communities in a respectful and nonpatronizing way, using their language and avoiding making them feel ignorant or uneducated.

> When you tell someone that this waste is producing greenhouse gases, they don't see how it's affecting them directly. It's hard to understand because they are not aware and don't have knowledge about climate change, what causes it, why weather patterns have changed, and why it doesn't rain like it used to. So, we looked for the simplest way to explain all this. (Diana Orembe, CEO, Novfeed)

One of the main barriers to adoption is the fact that NovFeed's sustainable fish feed is a new product to the community. Farmers may be hesitant to try it immediately, preferring to wait until they have more information or sell their current fish stock. NovFeed acquires customers by building trust and providing education about the benefits of their products. Once the farmers try the solution, they are rapidly convinced and become ambassadors for Novfeed.

> The customers are coming back to buy our product and they're not only coming back, but they're also spreading the word about the product in their community. When we are onboarding new customers, they often mention that they have been referred by previous customers they trust. (Otaigo Elisha, cofounder, Novfeed)

Additionally, the cost of the product could be a barrier to adoption, especially if it is significantly more expensive than the current feed options available to farmers. Hence, Novfeed ensured their product was more competitive than market prices. Another barrier to adoption may be taboos or cultural beliefs

within rural communities. NovFeed takes these into account and adjusts its messaging and approach accordingly.

> In rural areas, the farmers' communities may have a lot of taboos. You're going to introduce this technology, and they're going to say, for example, it's not allowed to use that or in our community women are not allowed to go outside. (Otaigo Elisha, cofounder, Novfeed)

NovFeed in Tanzania built trust, provided education, and successfully overcame barriers to adoption to introduce sustainable fish feed solutions to rural communities. To interact with rural communities, D-Olivette employs several strategies, such as collaborating with local associations, market leaders, and institutions such as the Nigerian Institute of Climate Change to present their innovation as a national renewable energy solution.

> In Nigeria, just like in most of Africa, we have a lot of community associations. And the reason we have associations is simply because you'll have to be part of an association to express your concerns to be heard by the authorities and to have access to benefits. People express, for example, their security challenges and development needs, and the community can assist them. (Tunde Adeyemi, CEO, D-Olivette)

Additionally, they provide environmental education, climate awareness, and the benefits the communities can get from their alternative solution through product flyers in the weekly rural markets, which helps create deep-rooted circular and environmental awareness in the minds of their customers. One of the challenges is the lack of awareness and understanding of the benefits of using biodigesters, which D-Olivette addresses through their education and community engagement strategies.

> We bring a sample in the associations gathering. So, we think they are going to be receptive to the product. We do a demonstration by putting organic waste into the digestor. We came back one month later to show how to use the gas produced for cooking and electricity production. In most cases, the first time we go through the association, maybe like 2% or sometimes 1% of the members adopt the technology and buy the biodigester. Many people are sceptical; they don't really believe in it; they think it's a gimmick. It is only when they see the first adopters using it that they get interested. (Tunde Adeyemi, CEO, D-Olivette)

One of the main barriers to adopting D-Olivette's solutions is affordability. They recognize that their pricing must be something rural communities can afford, and they work with associations and communities to provide payment-plan options.

> We often see that anybody that makes an inquiry about a product that is more than $100, solar panels for example, maybe biodigesters whatever it is, if it's over $100, most of the customers in rural communities in Nigeria won't consider and they won't come back. (Tunde Adeyemi, CEO, D-Olivette)

D-Olivette is taking a holistic approach to promoting renewable energy and clean cooking in rural Nigeria. By collaborating with local associations and market leaders, providing financing options, and educating their customers on

the benefits of using biodigesters, they are working toward creating a paradigm shift in the minds of rural women, families, and farmers toward a more climate-friendly, sustainable way of life.

Strategies to facilitate adoption of sustainable business models

Novfeed's approach to scaling its model includes several strategies. First, they have a business-to-business model where they sell protein ingredients to feed millers. They have secured agreements with six companies and signed a contract with a feed manufacturer to supply 5 tons per month, which is expected to increase to 30 tons per month once they scale. They plan to sell directly to fish farmers and launch distribution by 2025 in almost all of Tanzania's 25 regions to reach another 4,000 small-scale fish farmers that large distributors are currently not serving.

In order to scale and reach the large addressable market, NovFeed must first increase production capacity to meet current unmet demand. They plan to do this by procuring and installing new single-cell bacteria processing equipment that can achieve a higher capacity of at least 8 tons per day, allowing them to service their existing unmet demand of 100 tons per month from waitlisted clients. Novfeed's challenges to scaling include accessing capital, as getting the necessary funding to scale has been a challenge.

> We are ready to scale, but getting access to the capital has been the biggest challenge for us. We have tried our best to approach different investors. We are in an ongoing conversation with some of these [venture capital] ventures, and we constantly apply for grants. (Diana Orembe, CEO, Novfeed)

Second, Novfeed plans to expand outside of Tanzania, as fish farming is prevalent in many countries and fish farmers face the same challenges of high-cost and low-quality feeds. They have already received interest in their product from prospective clients in Uganda and Kenya. However, to scale outside of Tanzania, they need to find the right intermediaries in regions and/or countries with high market potential.

Novfeed is also struggling to produce the desired volume of bacteria-based protein. To mitigate this, they plan to try other types of food waste, as maximum production of bacteria-based protein depends on the optimization of growth conditions. Additionally, Novfeed must overcome the challenge of reaching a larger customer base by selling directly to fish farmers, especially in rural areas where there are no animal feed suppliers with whom to partner. Finally, the lack of an active association for fish farmers in Tanzania presents a challenge to Novfeed in terms of reaching potential customers and introducing them to their products.

> There is an association for aquaculture for fish farmers, but it is not active, unfortunately. It was a means to bring the farmers together so that they could learn the new practices. Sometimes they work actively when they get funding to bring the farmers together;

> otherwise, the farmers don't usually meet, which makes our engagement with the communities more difficult. (Diana Orembe, CEO, Novfeed)

D-Olivette, a Nigerian-based company, has implemented several strategies to scale its business. The company has raised over $100,000 from the Development Bank of Nigeria and other organizations to fund its operations. It also aims to maintain an active community and customer group network through various communication channels to offer updated information about the organization and products. Additionally, the company plans to grow its customer base through referrals.

> After trying some of our biodigestors, the Youth Farmers Association of Nigeria is interested in biotech and wants to purchase about 300 units. So, we are going to do what we call a batch installation. So they are going to start 20% on a monthly basis till we finish the entire installation. So when there are plenty, it is easier for us. Our current customers, at the end of the day, are going to do a lot of marketing for us. In 2022, about 91% of our customers were referred. (Tunde Adeyemi, CEO, D-Olivette)

D-Olivette has also expanded its reach by targeting remote communities, including those in Ogun, Ondo, and Taraba, Nigeria. D-Olivette's challenges in scaling its business are the cultural language barrier and currency differences when entering new markets, such as Benin and Ghana.

> Benin is 30 minutes away from our factory. You can take a motorbike. But they have a different culture, a different language, French, and they have a different currency that is not stable, which makes our distribution and pricing strategies more difficult. (Tunde Adeyemi, CEO, D-Olivette)

Additionally, the company has encountered payment issues with customers who choose to pay in installments, resulting in defaults. This was a key success factor for the adoption of the innovation as, for most households, a down payment is impossible. Unfortunately, in order to reach scale, this strategy is not viable if the company does not have access to proper funding.

> In 2021, we had a lot of problems with payment; with people doing instalments, many of them defaulted. So, in 2022, we changed the approach. In order to pay for installments, they have to come to us through what we call a service group or club. So the service club will say if they are solvent by writing a letter on their behalf. (Tunde Adeyemi, CEO, D-Olivette)

Discussion

Two introduced cases offered an exciting snapshot of the contextual environment of their companies and how they create social and environmental impact within the rural communities with whom they engage. Both cases show the successful development of solutions that target communities' heavy pain, like access to energy, the dependency on animal feed

importation, price fluctuations, and the high cost of sustainable solutions. The companies also engaged with the communities to showcase their innovations and make the communities adopt them. However, these cases showed that it is not easy to reach the communities and successfully get adopted in rural Africa, and entrepreneurs have to develop the right strategies to overcome the barriers to adoption. They also showed that even though entrepreneurs manage to introduce themselves in a rural community, the challenges to scale the model remain hard to overcome.

These cases contribute to a broader understanding of how sustainable business models can create environmental, social, and economic value in rural communities. They demonstrate how innovations can address critical issues like climate change, energy poverty, and food security (Egere et al., n.d.), as seen in the literature. These case studies contribute to the sustainable business model literature by demonstrating the practical application of sustainability principles in creating multidimensional value in specific African contexts, addressing the needs of rural communities, and benefiting from the solutions provided by the two companies. They exemplify how businesses can be designed to address specific local needs while being economically viable and environmentally and socially responsible. Both companies address critical needs in rural communities, offering affordable and innovative solutions. NovFeed's cost-effective, sustainable fish feed and D-Olivette's affordable biogas systems provide rural communities with accessible alternatives to more expensive or environmentally harmful options, potentially boosting local economies. This aligns with the studies that raised the importance of tackling the barriers to adoption based on the high cost (Schmidt & Druehl, 2008). NovFeed's innovation reduces the environmental impact of animal feed production, while D-Olivette's biodigesters offer a sustainable alternative to traditional energy sources, reducing greenhouse gas emissions and environmental pollution. Both companies enhance the quality of life and the resilience of rural communities. This builds on the studies that have analyzed the communities' resilience and highlighted the importance of local organizations, social networks, and community leadership, among other factors (Kulig et al., 2008). In the two cases, the companies work with the communities to support their resilience building. NovFeed's approach helps improve nutrition and food security, while D-Olivette's biodigesters address health issues related to traditional cooking methods and create job opportunities, particularly for women.

The cases helped to gather valuable insights into the main factors that contribute to the diffusion of innovations in start-ups operating in Tanzania and Nigeria. From both cases, we can learn that it is important to engage with early adopters and opinion leaders within the community to increase awareness and adoption rates (Dearing & Cox, 2018). Providing education and training on the benefits of the innovation and offering financing options can make it more accessible to rural communities (Korsgaard et al., 2015).

Leveraging existing networks and community associations can also be effective in reaching a wider audience. However, it is crucial to navigate the political and cultural dynamics within a community to avoid blockages to innovation diffusion (Boushey, 2012).

The cases offer insights into the specific barriers to adoption in rural African communities, such as affordability, cultural beliefs, and lack of awareness. They stress the need for strategies that overcome these barriers, such as education and training, and emphasize the need for innovations that are economically viable for rural populations. Effective communication and community engagement are crucial. Both companies emphasized education about their products' benefits, addressing specific community needs and concerns. Addressing the economic constraints of rural communities was a key success factor, with strategies such as affordable pricing and financing options, which is well described by the entrepreneurial bricolage approach (Ciambotti et al., 2023). Understanding and navigating local cultural dynamics and potential barriers to adoption were essential.

The diffusion of innovations theory describes how new ideas or technologies spread throughout a society or organization. It is useful to analyze the cases of Novfeed and D-Olivette and understand how they engaged rural communities to diffuse innovation and scale their approach. From the Novfeed case, we can see that they used a bottom-up approach to engage with rural communities, as seen in studies on grassroots innovations (Raj et al., 2022; Rahayu et al., 2024). They scouted for and identified early adopters within the community and leveraged their influence to spread awareness about their product. They also provided education and training to farmers on the benefits of their products. By doing so, they were able to create a sense of ownership within the community, which helped to increase adoption rates. On the other hand, D-Olivette used a top-down approach by collaborating with established farmer associations. They recognized the importance of community associations in rural areas and leveraged their networks to reach a wider audience. However, they also faced challenges in dealing with multiple associations within a community and political and cultural issues that can hinder innovation diffusion.

Both the Novfeed and D-Olivette cases demonstrate some key aspects of the diffusion of innovations theory, such as the importance of social networks, the role of opinion leaders, and the need for effective communication channels. However, there are also some limitations and deviations from the theory in these cases that should be noted.

Finally, in terms of scaling the approach, it is important to consider the unique characteristics of each community and tailor the approach accordingly. Creating partnerships with established organizations and government agencies can also help to reach a wider audience and scale the approach. Additionally, leveraging digital technologies can help to increase access to

education and training and streamline communication and distribution channels (Onwuegbuzie et al., 2022).

Conclusion

The case studies of NovFeed and D-Olivette helped to demonstrate that the adoption of sustainable innovations in the rural context in Africa can be complex and multifaceted. Through the analysis of the sustainable business models of the companies operating in Tanzania and Nigeria, the empirical research highlighted how important it is for companies to understand the social and cultural contexts of the communities and the need to work with the local leaders and associations in order to understand the needs and facilitate the adoption of the innovations.

The findings from both companies indicate unique insights into how crucial it is to build a strong value proposition by creating economic value for the company and the communities as well as social and environmental value, especially in the rural context in Africa that faces numerous challenges from energy poverty, low income, and high vulnerability to climate change effects. For example, NovFeed addressed the cost and availability of farmers' feed, while D-Olivette tackled the health and environmental issues caused by traditional cooking methods. In both cases, intermediaries played a crucial role in facilitating the adoption of innovation. The cases also demonstrate the potential for scaling innovation to a wider audience through collaboration and partnerships with various stakeholders, including government agencies, nongovernmental organizations, and private corporations. This has been described within the entrepreneurial ecosystem approach (Tilt et al., 2021), encouraging collaboration within the African context and mobilizing individuals to start sustainable entrepreneurship through success stories as an essential part of the entrepreneurial culture pillar (Adu-Gyamfi et al., 2023).

This research article participates in the growing literature on sustainable entrepreneurship, sustainable business models, and sustainable innovation adoption (Agu et al., 2021; Ciambotti et al., 2023; Terán-Yépez et al., 2020). It sheds light on grassroots innovations that are locally developed and locally sourced within the resource constraints and that solve problems faced by African rural communities. Using the sustainable business model canvas (Bocken, 2021) helped to understand how value is created. The authors combined the canvas with the diffusion of innovations theory and entrepreneurial bricolage approach to understand the adoption process. The provided sustainable business model canvas (Bocken, 2021) cannot be fully transferred as a one-to-one case to the developing African context, yet it helps us to understand the successful cases of sustainable entrepreneurs, and it can be used as a navigating tool by those considering starting a sustainable business.

We recommend further development of the canvas within the community of African investors and successful entrepreneurs, thus reflecting better the local context, and further helping scholars and practitioners to design the value added/created and define strategies to launch and grow sustainable innovations in African countries (Akinboade et al., 2023).

Because this was empirical qualitative research based on multiple case studies, several limitations need to be acknowledged. The research primarily focuses on rural communities around the capital cities of Lagos in Nigeria and Dar Es Salaam in Tanzania. Therefore, the findings may not be universally applicable to all rural contexts in Africa, which are diverse and complex in terms of culture, economy, and environment. The case studies involve only two companies in their growth stage (NovFeed and D-Olivette), which might not capture the full spectrum of challenges faced and strategies developed by sustainable entrepreneurs in rural African communities. While the study employs in-depth interviews and thematic analysis, the scope of data might be limited to the perspectives of the companies' management and the observational data collected during the Africa ClimAccelerator program and the field trip to Tanzania. The article focused on specific types of sustainable business models (alternative protein for animal feed and biodigesters for energy and fertilizer), which may not cover other relevant, sustainable innovations applicable in rural African settings, such as sustainable agriculture or water technologies.

Finally, we point out that it is crucial to shed light on grassroots innovation in the rural context, especially in Africa. Indeed, the continent is vast and diverse, so more research is needed to cover and understand the differences between countries. Further research is also needed to understand the role of partnerships and collaborations in scaling these sustainable innovations, the impact of the political and cultural factors on adoption, and the potential of digital technologies in facilitating the diffusion of innovation to rural communities in Africa. In this manner, we suggest enhancing future research on the entrepreneurial ecosystem in Africa and its pillars, determining the overall role of entrepreneurial culture (including success stories) in shaping sustainable entrepreneurship development.

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ORCID

Ondřej Dvouletý http://orcid.org/0000-0001-9151-2033

Author contributions

All authors have accepted responsibility for the entire contents of this article and approved its submission.

Consent

Representatives of both studied start-ups (NovFeed and D-Olivette), have been informed about the usage of all the materials in the research article and agreed to participate in the research.

Data availability statements

All data sources and used materials are cited properly and linked with the studied organizations.

Ethical approval

The study was written in line with the ethical standards of conducting research at the author´s institutions and international research ethics standards.

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