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Review article

Scaling climate information services and climate smart agriculture through bundled business models

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ABSTRACT

There is a general agreement among scholars that bundling Climate Information Services (CIS), Climate Smart Agriculture (CSA), and other agricultural products and services can positively impact agriculture. However, many questions still need to be answered regarding how the bundling can be achieved through scalable and farmer-centric CIS-CSA bundled business models. This study narrowed the knowledge gap by revealing 1) how CIS, CSA, and other agricultural products and services may be bundled to support sustainable agriculture, 2) what types of CIS-CSA bundled business models are successfully reaching and benefiting farmers and entrepreneurs, and 3) proposing an evaluation framework for assessing CIS-CSA bundled business models ready for scaling. Drawing on the synthesis analysis of available relevant publications, we devised a 1–5 scale evaluation framework based on nine scaling readiness indicators—*technology*, *impact*, *bundling*, *infrastructure*, *relevance*, *evidence*, *barriers*, *sustainability*, and *value addition*—to assign scalability scores to 29 business cases with bundled CIS-CSA products and services across Africa and Asia. Eleven CIS-CSA bundled business models with publicly available quantitative scaling readiness data (financial capacity, the number of customers, customer categories, and the number of beneficiaries) were used to quantitatively model how different CIS-CSA products and services bundling strategies, the revenue stream structure of a CIS-CSA business, and the structure of a CIS-CSA business's stakeholder network (the diversity of its stakeholders) affect its scaling readiness. Based on the scaling readiness evaluation framework, of the 29 identified CIS-CSA bundled business cases, 12 were ready for scaling. The quantitative analysis revealed that the type of a CIS-CSA model significantly determines its scalability— for example, a government-to-donor-to-business-to-consumer (G2D2B2C) CIS-CSA bundled business model would have 10 million USD more invested capital than a government-to-business-to-consumer (G2B2C) bundled business model type. Additionally, the G2D2B2C bundled business model type would serve 5 million farmers and three customer categories and gain ten partners more than the G2B2C. The finding also suggests that multi-stakeholder CIS-CSA business models, which provide a more diverse package of CIS-CSA products and services and have many revenue sources, have the potential to benefit all categories of farmers and entrepreneurs. This study reveals a reason for optimism about the future of agriculture; it suggests that scalable bundled CIS-CSA products and services can contribute significantly to attaining climate resilience and food security.

1. Introduction

1.1. Rationale

Climate change and variability have emerged as an existential threat to the livelihoods of the global agricultural community. It is widely agreed that bundling CIS, CSA, and other agricultural products and services through business models could be an effective and efficient solution to the climate change and variability problems. However, how the bundling can be achieved in a way that benefits innovators and farmers has yet to be understood.

Climate change and variability have a detrimental effect on

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agricultural output and, consequently, the global food system) (Zhao et al., 2017). Globally, there are around a billion people who are food insecure (Carthy et al., 2018), and this number could continue to grow if nothing is done. There is evidence that climate change is one of the primary obstacles to achieving sustainable food systems (Shirsath et al., 2017; Zimmermann et al., 2017). It is highlighted that 70 % of people live poorly in rural areas and depend on rain-fed agriculture, which is vulnerable to climate change and variability (FAO, 2021). The climate change and variability problems could worsen; predictions show an alarmingly high crop yield loss of up to 70 percent by 2030 (Campbell et al., 2018; Jalloh et al., 2013). The global community now faces the daunting task of adapting to and reducing the long-term effects of climate change (Belay et al., 2022).

Bundling CIS, CSA, and other agricultural products and services through scalable business models is one of the most promising courses of action towards climate adaptation and resilience (Casey et al., 2021; Pietosi, 2021; Zougmoré et al., 2021). It is observed that complementarity and dependence relationships exist between specific products and services; therefore, CIS-CSA business models that bundle a wide range of products and services would benefit entrepreneurs and a broad category of farmers. CIS supports adaptation to climate variability and change in agriculture by, for example, generating location-specific climate and weather information (Zougmoré et al., 2021); CIS is used as an entry point to select climate-smart practices and technologies (Bayala et al., 2021). For a CIS-CSA bundled business model to attain its expected financial success and meet its customers' spatially and temporarily evolving needs, it must be scalable.

A large body of knowledge on the drivers of scaling readiness of innovations is mostly qualitative. For example, Minh et al. (2022) provides a guideline on how to qualitatively assess the scalability of an innovation bundle to design the best-fit scaling strategies and highlights that the network structure of a business (the diversity of its stakeholders) determines its scaling readiness; in other words, a business with a denser network of users and stakeholders would be more scaling-ready. Additionally, Coviello et al. (2015) and Chesoli et al. (2024) note that a diverse customer base is another determinant of the scaling readiness of an innovation.

This study, using 29 CIS-CSA bundled business models operating mainly across Africa and Asia, quantitatively and qualitatively explored how the network of a CIS-CSA bundled business model's stakeholders, its products and services bundling strategies, and its revenue generation stream structure affect its scalability. The study sought to find out how CIS and CSA can be bundled together with other agricultural services/products to support sustainable development, which business models can support the implementation of CIS and CSA in a manner that maximally benefits farmers and business innovators, and what evaluation framework can be used to evaluate scalable business models. The research contributes to the existing body of literature by revealing the features of potentially scalable CIS-CSA bundled business models that can make climate resilience and food security interventions more effective and efficient.

1.2. Bundling CIS and CSA

CSA is gaining much attention from researchers and business innovators. This is because the social and physical environment highly impacts the smooth implementation of CSA (Ulvenblad et al., 2019). The concept of CSA is based on global development priorities and aims to sustainably improve food security and climate change resilience and reduce greenhouse gas emissions (Abegunde et al., 2020; Egeru et al., 2022; FAO, 2021; Tesfaye et al., 2021).

CIS generates and delivers climate and weather information to meet users' context-specific needs (Findlater et al., 2021). It involves creating, diffusing, and interpreting climate and weather information to back its users (specifically farmers) in coping with climate change and variability shocks in the agriculture sector (Vaughan et al., 2018); CIS is used as an entry point to select climate-smart practices and technologies (Bayala et al., 2021). CIS supports adaptation to climate variability and change in agriculture by availing practically helpful weather and climate information to farmers (Zougmoré et al., 2021), shielding farmers' livelihoods, farms, and value chains from the adverse effects of weather and climate shocks. CIS also harmonizes policies and financing to mobilize and create innovative delivery channels and financial mechanisms (Zougmoré et al., 2021) and facilitates climate-sustainable financing and institutional coordination to ensure conditions for food systems that meet human needs in both short and long-term (Dinesh et al., 2017; Neufeldt et al., 2013).

Despite the immense potential of CIS, its provision still needs to be developed, especially in Africa (Ouedraogo et al., 2022). There is still an unmet demand for CIS. In Western Africa, for example, 68 % of local farmers need CIS (Ouedraogo et al., 2022). CIS owes its high demand to the accuracy and reliability of the weather forecast information it provides to farmers; for instance, CIS empowers the farming community to make climate-smart crop options (Ouedraogo et al., 2022). On the supply side, however, research is underfunded in most National Meteorological and Hydrological Services and other regional WCIS (Weather Climate Information Services) research institutions to inform the supply of context-specific WCIS (Findlater et al., 2021). This may result in the farmers' continuous dependence on indigenous climate knowledge due to their inability to translate climate and weather data into practically sound farming decisions (Findlater et al., 2021; Rammer et al., 2021). Larosa and Mysiak (2020) claim that demand-driven quality-assured WCIS provision is essential for formulating context-specific policies and decisions to ensure sustainable food systems. Zougmoré et al. (2021) note that a significant shift in managing food systems is necessary to achieve sustainable agriculture and food security. This critical transformation can be achieved by leveraging the synergistic relationships between CIS, CSA, and other agricultural products and services (Tesfaye et al., 2021) through scalable business models.

Bundling CIS, CSA, and other agricultural products and services empowers farmers to improve climate risk management, make wise decisions regarding climate variability, improve soil fertility, increase production, generate income, achieve food security, and, as a result, build climate resilience (Chang, 2017; Long et al., 2017; Tesfaye et al., 2021). Bundled CIS and CSA with effective communication technologies and other services such as financial and insurance leads to a sustainable farming system (O'Grady & O'Hare, 2017) and lowers costs incurred by farmers (Devare et al., 2021). The sustainability of the bundling would be enhanced by business models that bundle CSA, CIS, and other agricultural products and services associated in a financially strategic manner (Prager et al., 2021).

1.3. Business models

A business model is a complex, multifaceted system (Margretta, 2002; Lüdeke-Freund, 2014) that encapsulates a company's customer structure, market offer, revenue generation, and value creation processes. It illustrates how private-led institutions enter markets, create value, innovate, and identify clients (Benijts, 2013; Long et al., 2017). In the agriculture sector, business models are primarily private initiatives aimed at providing farmers with essential goods and services, enhancing productivity, reducing climate-related risks, and promoting value chain participation (Chang, 2017; Pels & Sheth, 2017).

Effective business models are defined by a clear understanding of the customer, including strategies for engagement, customer access, and awareness-building. They also encompass business operations, resource needs, and key partnerships required for value creation, along with cost and revenue projections (Long et al., 2017; Lüdeke-Freund, 2014). As Margretta (2002) states, "A good business model begins with an insight into human motivations and ends in a rich stream of profits." Ideally, a well-designed business model leverages opportunities by addressing customer pain points effectively while generating profits for

stakeholders (Lüdeke-Freund, 2014).

For sustainability, a business model must be compatible with the socioeconomic conditions of its environment and include stakeholders—such as customers, suppliers, and shareholders—in critical decision-making processes (Lüdeke-Freund, 2014; Rosenstock et al., 2020).

CIS-CSA business models include financial models, insurance models, value/supply chain models, knowledge models (advisory and capacity building), digital innovation models, and mechanization models (Chang, 2017; Long et al., 2017; Vedeld et al., 2019). These models, for example, agri-tech companies provide digital platforms that connect farmers with farm input providers, extension agents, research institutes, weather forecasters, mobile operators, and financial institutions. These business models offer farmers reliable weather and climate forecasts, empowering them to adopt improved farming practices, increase productivity, and build resilience to climate shocks (FAO, 2021; Pietosi, 2021). Financial support allows farmers to access services at subsidized rates or minimal cost, while service providers generate revenue through small charges, subscriptions, commissions, and loan recoveries (Casey et al., 2021; Hansen et al., 2019; Pietosi, 2021).

1.4. Scaling and scalability

Scaling is a multifaceted process that allows firms to respond to the favorable and economically "unhospitable" spatial–temporal dynamics of their environments. Businesses with high levels of scalability would navigate the spacetime evolutions of their markets without compromising on their core value proposition and the expectations of their stakeholders (Mathaisel, 2012).

Scaling involves various processes: horizontal, vertical, and diagonal processes (Neufeldt et al., 2013). Horizontal scaling is about emulating successful methods, devices, or prototypes in new places by demonstrating the efficiency and effectiveness of practices, technologies, and models. Vertical scaling involves institutional and policy change and makes it easier to remove barriers to uptake by various stakeholders (Linn, 2012). Diagonal scaling entails adding project mechanisms and altering the structure and strategy to keep up with the changing environment (Neufeldt et al., 2013). Direct and indirect strategies are used in both vertical and horizontal scaling approaches. Direct strategies denote a circumstance where the concerned institution has direct responsibility for enacting changes (Neufeldt et al., 2013). Indirect tactics refer to a situation where a company or organization encourages individuals to transform and embrace new practices or procedures (Neufeldt et al., 2013).

Scaling requires the comprehension of the dynamics, contexts, and factors driving innovation in a more realistic setting (Wigboldus & Leeuwis, 2013). Effective scaling of a business model with bundled CIS-CSA services must integrate landscape analyses and approaches, context-specific drivers and spaces, partnerships and knowledge management, institutionalization, multi-dimensional monitoring and evaluation, capacity development through co-learning, and gender inclusivity (Neufeldt et al., 2013; Prain et al., 2020; Rosenstock et al., 2014; Wigboldus et al., 2016), perceived value of the service or product, the support infrastructure, and the clientele to justify expenditure (Groot et al., 2019; Long et al., 2017). This implies that scaling is a multi-stakeholder-driven process with participatory and partnership platforms that are simple to mobilize members, flexible to integrate new members, and foster shared learning across numerous stakeholders with a variety of abilities (Andrieu et al., 2019; Wigboldus et al., 2016). Scaling is an evidence-based market-oriented process (Cooley & Howard, 2018; Kilelu et al., 2017; Masud et al., 2017) involving developing and testing innovations, approaches, concepts, and tools (Prain et al., 2020). Acknowledging the complexity and dynamic nature of the scaling process is essential; the process takes an average project lifespan of three to five years (Rosenstock et al., 2014; Woltering et al., 2014).

According to Mathaisel (2012), "Scalability refers to the ability of the enterprise to grow without losing [its] customers, diminishing quality, or changing [its] core value proposition…" The scalability of an innovation reflects its acceptance, impact, and sustainability (Masud et al., 2017; Rosenstock et al., 2014; Schut et al., 2020; Wigboldus & Leeuwis, 2013). The growth of a business may not always reflect its scalability (Mathaisel, 2012; Mussapirov et al., 2019). A high-scalability business innovation would consistently perform under a wide range of spatial and temporal conditions of its market.

Several factors influence the scalability of a business innovation. The more a business's operations rely on physical resources, the less is likely to cost-effectively and efficiently respond to the spatial and temporal evolutions of its environment (market), and, consequently, the less is scalable. Additionally, businesses with "rigid" decision-making structures regarding resource mobilization would have low scalability (Mussapirov et al., 2019). Furthermore, small businesses and start-ups, due, for example, to their "infant" operational systems and low profiles, would be less scalable (Mathaisel, 2012). A business can increase its scalability by, for instance, creating new distribution channels, overcoming bottlenecks, and diversifying customers and partners (Mussapirov et al., 2019; Sartas et al.,2020).

From the CIS-CSA perspective, scaling is about efficiency and coverage in delivering the impact of CIS-CSA bundled products and services to last-mile users. The proposed framework (Table 2) identified two primary conditions for the scaling readiness (scalability) of a business: the ability to generate revenue and develop partnerships with intermediaries to reach the end-users with the bundled products and services. This suggests that private-sector-led, network-centric business models are critical for scaling bundled CIS—CSA by creating market incentives for innovation and participation and accelerating link formation between information, service providers, and users.

1.5. Types of business models and their delivery modalities

In the CIS-CSA sphere, the delivery modality of a direct-provision or indirect-provision business model encapsulates how it diffuses its innovations to its customers using a network of trusted agents that are indirectly or directly involved in the production and marketing of its wide range of trusted services or products.

The trusted agents/networked agents are the stakeholders in the business model, which include, among others, agricultural extension agents, government institutions, NGOs, research institutions from both the private and public, telecommunication organizations, financial institutions, agriculture officers, consumers, suppliers, farmers, and insurance institutions (Pietosi, 2021).

According to Tinsley & Agapitova (2018), trusted services as a bundling modality include weather information services, agro-advisory services, financial services, telecommunication/mobile networks services, internet services, insurance services, credits and loans services, capacity building/training/knowledge services, market accessibility services, farm input services such as mechanization, fertilizers, selected seeds, and pesticides. These services and products are bundled to meet context-specific farmers' needs. Products and services can reach last-mile users with direct-provision business models or with indirect-provision business models.

Usher et al. (2018) provide nine categories of business models, including B2D, B2D2C, B2D2G2C, B2G2C, B2B, B2B2C, B2C and G2C, where B = business; D = donor; G = government; and C = consumer. These are business models that create value for clients. The categorization is based on a business's network structure, the nature of its stakeholders, and their relationships. For example, a B2B2C model can transact with other businesses and directly supply its products and services to its customers.

2. Methods

2.1. Research scope

The content scope of this study covered ways in which CIS and CSA can be bundled with other agricultural services/products to support sustainable agricultural development, the business models that can enhance the adoption of CIS and CSA in a manner that benefits farmers and business innovators, and the evaluation framework that can be used to evaluate the scalability of such business models. The main focal regions of the data collection were Africa and Asia.

2.2. Research strategy

Review design: We used a descriptive literature review to analyze and synthesize various publications. This design helps to systematically collect and synthesize research findings, reveal evidence, and uncover areas where more studies are required for theoretical framework development (Snyder, 2019). For the scaling readiness evaluation framework, through the literature review, we aimed to synthesize selected works that would identify business models with bundled CIS-CSA services ready for scaling.

Data selection criteria: Data were retrieved from gray and peer-reviewed literature, primarily accessed through publication databases such as Scopus, Google Scholar, and Web of Science. A selective approach was employed to specifically obtain the required data, utilizing the following keywords in the database search engines: climate information services, climate-smart agriculture, climate-smart agriculture practices, bundling CIS with CSA, partnerships, agents, business models in CSA and CIS, scaling CSA and CIS, scaling strategies, business products, agents and services, business cases, gender inclusion in CSA business models, and sustainability. Experts across Asia and Africa were consulted through various means and asked to recommend viable, ready-to-scale models. Using a predefined set of criteria, only 29 of the hundreds of recommended business models qualified for this study.

2.3. Conceptual framework

This conceptual framework explains the CIS-CSA bundled business models and prerequisites for their scaling readiness. In bundled CIS-CSA approaches, the value proposition (and hence the business model) arises from the network of services provided rather than a single pipeline of information. This "networked business model" is common in the emerging technology sector and hinges on the idea that no single entity can govern all the resources, information, and products required to satisfy customer needs (Palo & Tähtinen, 2011). The first step in developing the networked business model conceptual framework is pre-competitive research collaborations, as shown in Fig. 1. The primary goal of pre-competitive collaboration is to develop and implement innovations (Johnson-Woods, 2022). We clearly show how several partners in the business of CIS-CSA innovations find it more attractive to engage in pre-competitive collaboration to attract support from partners such as governments and development partners. Pre-coopetition is a revolutionary paradigm that combines competition and cooperation (Chin et al., 2008). At this level, the framework indicates that businesses generating innovations around the CIS-CSA collaborate or compete with specific stakeholders. However, they often do both simultaneously, giving rise to a competitive system of value creation (Osarenkhoe, 2010).

Following coopetition, there is a need to repurpose the value already created to create more value by combining multiple individual services into one bundle. It is hypothesized that the more offers contained in a bundle, the higher the *Perceived Value* of the bundle will be. Osarenkhoe (2010) attests that bundling has the potential to build momentum around innovative new approaches by lowering the cost, increasing use, and leveraging existing/popular services/products to introduce new/unpopular products. The proposed framework presents in Table 1 what gets bundled.

2.4. Evaluation framework

2.4.1. Qualitative evaluation of CIS-CSA bundled business models that are ready for scaling

The qualitative evaluation framework merges the works of Prager et al. (2021), Jacobs et al. (2018), and Sartas et al. (2020) to assess the "scaling readiness" of CIS-CSA bundled business models. Jacobs et al. (2018) reveal the determinants of a business's scaling readiness: the value, user-friendliness, and availability of its technology, how it allows users to access markets, its gender inclusivity, and its context-specific applications. For Sartas et al. (2020), "scaling readiness" is affected by spatial and temporal contexts, innovations scale as part of packages, presence of bottlenecks, and multi-stakeholder agreement and coalitions. Prager et al. (2021) noted that sustainability is critical to scaling readiness. Thus, we designed an integrated evaluation framework that

Table 1
Bundled CIS-CSA spectrum showing examples of services or products that are typically bundled.

CIS-CSA services/products that are typically bundled	Types of services or products
Knowledge services (KS)	CIS, CSA recommendations, early warning, etc.
Consumables (C)	Certified seed, fertilizer, chemical inputs, etc.
Financial services (FS)	Microloans, insurance products, banking, etc.
Physical services (PS)	Mechanization, milling, solar, etc.

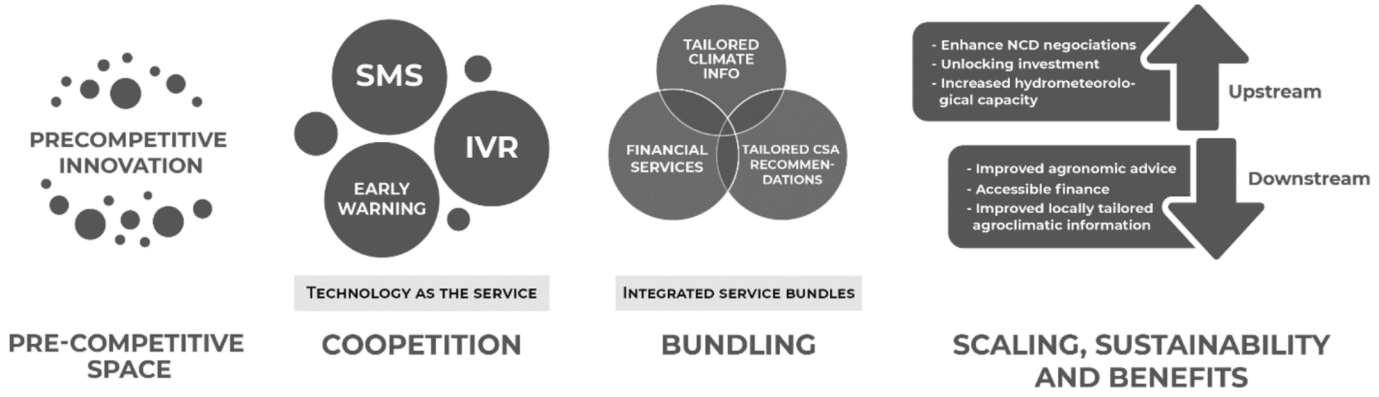

Fig. 1. Conceptual framework emphasizing the systems-level sustainability.

Table 2
Integrated evaluation framework descriptors for measuring business innovation scaling readiness.

Parameter	Description	Source
Technology	Technology is assessed based on its availability, accessibility, and effectiveness in facilitating the production, translation, and transmission of effective climate services.	Authors of this paper
Impact	Impact indicators may include changes in yields, improved food security, climate-resilient livelihoods, avoided losses, and increased income.	Authors of this paper
Barriers	Barriers may exist in different forms: economic, institutional/regulatory, behavioral or psychological, organizational, consumer/ market, and social.	Authors of this paper
Bundling	Business cases are assessed based on how well the business model bundles different services to tailor products and services to the targeted users.	Authors of this paper
Infrastructure	This rating criteria explores how the lack of/ existing infrastructure inhibits or stimulates the climate services market. Infrastructure should be assessed across various factors, including effectiveness, usability, affordability, and capacity to support further technological innovation.	Authors of this s paper
Relevance	Products must be tailored to meet users' requirements and expectations. It has been recognized that effective CIS is aimed at specific users of the service and their particular needs.	Authors of this paper
Evidence	We use evidence of access, use, and impacts of bundled CIS-CSA cases as a criterion to illustrate the success of the business models.	Authors of this paper
Value addition	Additional value creation by combining features and benefits or through any other method that results in increased understanding, use, and adoption of CIS/CSA.	Jacobs et al (2018)
Sustainability	Bundling itself does not make a business model scalable. Sustainability requires business models that are private-sector-led and have intermediary organizations (e.g., SME agribusinesses, input providers, and producer associations) to run profitable businesses with financially sustainable approaches that create value for consumers while creating one or more revenue-generating streams (service fees, commissions, direct sales, etc.) for their investors.	Jacobs et al (2018)

includes the sustainability factor.

We further adjusted the scale by Prager et al. (2021) by adapting the scalability scale of Sartas et al. (2020) to improve the objectivity of the ratings. Though they were assessing pure technology innovations and using a scale ranging from zero to 8, we identified similarities that helped determine the scores to evaluate the identified bundled CIS-CSA business models using our rating scale of 1–5: (1) substantially underdeveloped—meaning it is not scalable; (2) space to improve—meaning it needs improving in order to be scalable; (3) promising approach; (4) demonstrated viability—meaning it has the potential for scalability; and (5) scaling ready— meaning it is ready to be scalable. In Table 3, we present this scale and its descriptions.

After detailing the parameters for the evaluation criteria described in Table 2 and the readiness assessment scale in Table 3, we demonstrate how the business cases can be evaluated for scalability and sustainability. Thus, each identified business case was subjected to the evaluation framework, which assessed each of the nine parameters to ascertain its level of scalability. The final score of each business model is given by the average of the individual parameter scores, as described in Fig. 2.

Business models identified using the approach described in Section 2.2 were quantified manually using Excel to ascertain their regional distribution and characteristics in terms of their type and services/ products they provide.

Table 3
Business scores, levels, and their basic descriptions.

Scale 1–5 (Prager et al. 2021)	Description of the scale adapted from Sartas et al (2020)
1 = Substantially underdeveloped	The innovation team is still developing the technology, which is not being used to achieve the intervention's objective in the specific spatial–temporal context where the innovation is to contribute to achieving impact.
2 = Opportunity to improve	The technology innovation team has developed effective partners. At this level, the innovation has stakeholders and partners that may or may not be involved in its development.
3 = Promising approach	Technology development partners form an innovation network: Innovation is commonly used by effective partners who contribute to its development by providing data and information.
4 = Demonstrated viability	Innovation networks form an innovation system in which business innovations are commonly used by stakeholders, including those developing similar, complementary, or competing innovations.
5 = Scaling ready	An innovation system graduates into a livelihood system when the business innovation is commonly used by stakeholders who are not in any way involved in or linked to its development to contribute to achieving impact.

Further categorization was done to quantify the different bundling modalities, business associations, and networks. The evaluation framework further helped distinguish scalable business models by considering their ability to generate revenues and the existence of intermediaries and partners to scale the innovations to last-mile users.

2.4.1.1. Measurement scale for scaling readiness of CIS-CSA bundled business models. During the assessment, different variables were assigned varying weights. For instance, impact and sustainability were weighted more heavily at 1.5, while other variables were assigned a weight of 1. The weighting scale was set as 0–10. This weighting scale was based on the fact that a synthesis of multiple surveys indicate that 0–10 scales with 5 set as the mid-point consistently revealed smallest numbers of missing data than scales of 1–10 (Hopper, 2024). Leveraging expert knowledge, the authors established a rigorous threshold score of 7 out of 10 (at least 70 %). This high standard minimizes the likelihood of overestimating the scaling readiness of innovations.

The review was mainly descriptive and critically fills the gaps in the work by Prager et al. (2021). The findings are presented in tables and discussed in Sections 3 and 4.

2.4.2. Quantitative evaluation of the drivers of scaling readiness of CIS-CSA bundled business models

To identify the features of potentially scalable CIS-CSA bundled business models, we used the multivariate regression analysis technique to quantitatively investigate how the number of bundled products and services, the type of a CIS-CSA business model (the diversity of its stakeholders), and its number of revenue streams affect its scaling readiness.

In our quantitative exploration of the determinants of the scaling readiness of CIS-CSA bundled business models—based on the definition that scaling readiness reflects a CIS-CSA bundled business's ability to cater to the needs of a broad customer base and meet the financial expectations of its investors—we chose the number of customers and customer categories (smallholder farmers, large farmers, and cooperatives) served by a CIS-CSA bundled business, its capital investment, and the number of its partners to be the quantitative dependent variables of our regression models.

Data on the dependent and independent variables were obtained

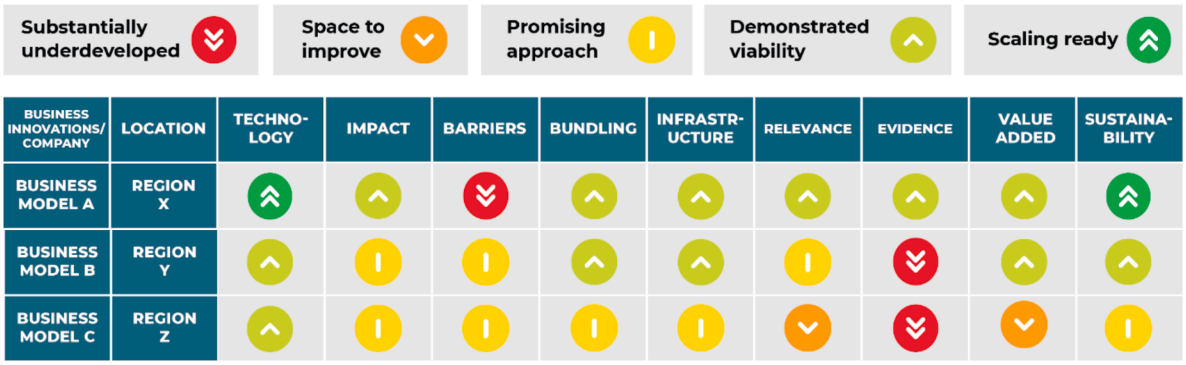

Fig. 2. Evaluation framework of bundled CIS-CSA business cases for Scaling Readiness.

from various online sources by visiting the businesses' official websites. For the CIS-CSA initiatives without online web pages, we relied on the websites of their affiliates, partners, and stakeholders to gather the data. Of the 29 identified CIS-CSA bundled business models across the sampled regions of Asia and Africa, 11 had publicly accessible data about our model's dependent and independent variables. Thus, we selected them for our quantitative analysis.

Raw data on the explanatory variables—the type of a CIS-CSA bundled business model, the categories of customers, the number of revenue streams, and the number of beneficiaries—were summarized and arranged using Excel. The categorical variables had the following levels: revenue streams; goods transactions, services transactions, commissions, direct sales, subscription fees, licensing, brokerage fees, advertising, lending or leasing, transactional/project service/recurring, goods and services tax/income tax/corporate tax/non-tax revenues, side gigs, self-employment, royalties, interest, and capital gain; the structure of a CIS-CSA bundled business model; government, donor, business, and consumer; the categories of customers; smallholder farmers, large farmers, cooperatives, agro-dealers, and extension agents.

We then subjected the collected data to multivariate regression analysis to analyze the statistical significance of the combinations of the levels of the explanatory variables. We used the regression model $Yj = B1Xj + B2Zj + B4Wj + B4(XjZj) + B5(XjZjWj)$, where B1, B2, B3, B4, and B5 are the regression coefficients. Xj represents the model type of a CIS-CSA (the diversity of its stakeholders); Xj ranges from 2 to 4 (B2C = 2,… G2D2B2B2C = 4; B = business, D = Donor, G = government, C = customer); Zj represents the number of CIS-CSA bundled products and services; Zj ranges from 1 to 4 depending on what a CIS-CSA business bundle (FS only = 1, FS and C = 2, FS, C, and KS = 3, KS only = 1, C only = 1, PS only = 1, KS, FS, C, and PS = 4…), where FS: Financial services, KS: knowledge services, and C: Consumables, PS: physical services; and Wj represents the number of revenue streams of a CIS-CSA bundled business model(the number of ways through which a CIS-CSA business generate income). Wj starts from one. For example, for a CIS-CSA bundled business model that earns money through goods transactions, services transactions, commissions, direct sales, subscriptions, licensing, brokerage fees, advertising, lending, dividends, capital gains, and interest, Wj is the sum of the individual revenue sources which is 12 in the above example. We assume that the model has a trial solution, that, in other words, it passes through the origin.

3. Results

3.1. Characteristics of CIS-CSA bundled business models

Table 4 shows 29 identified business models selected for inclusion in the analysis. It indicates the name of a business case, the bundled CIS-CSA services and products it offers (KS, C, FS, and PS), the source/author, and the target groups. Four business models were identified in Southern Africa, four in Asia, one in the Horn of Africa (Ethiopia), five in West Africa, four across Africa, eight from East Africa, and two that operate globally. Table 4 also highlights the dominance of knowledge and financial services in the bundled CIS-CSA market. The results reveal significant variations in the spatial distribution of bundled services. For instance, knowledge services are more prevalent in East Africa (27 %) than in the other regions, while consumables (29 %) and financial services (25 %) also show a similar trend. This underscores the regional diversity in providing bundled services, with knowledge and financial services emerging as the key services across all the sampled regions. In contrast, bundled physical services are more prevalent in Asia (60 %) than in the other regions.

Table 5 illustrates the categories of CIS-CSA bundles: knowledge, consumables, financial, and physical services. In the area of knowledge services, tips on farming management are predominant in Asia (27 %). On the other hand, capacity-building services are more predominant in East Africa (36 %) and across Africa (21 %) than in the other regions. Other services predominantly offered include climate and weather data (25 %) in East Africa, advisory services in East Africa (21 %) and West Africa (21 %), market prices in Asia (25 %), and access to markets where they stand at 20 % in Southern Africa, Asia and globally, respectively. The finding underscores the need for more attention to bundling market prices and access to markets with other products in most regions. These services are crucial for farmers as they provide assurance and guidance for the growth and sale of produce. Fertilizers and seeds are the most offered consumable services, especially in East Africa (21 %) and across Africa (21 %). Southern Africa significantly dominates the other regions in providing consumables; pesticides/agrochemicals are provided at 100 %. Seeds are provided at the same level (20 %) in East Africa, West Africa, and across Africa compared to the other regions where they are less bundled. On the offered financial services, subsidies are the most predominantly provided in Asia (43 %) and Southern Africa (29 %) compared to the other regions. Indexed-based insurance services bundling is provided chiefly in Southern Africa (22 %) and West Africa (22 %) compared to the other regions. There are no significant variations in how loans and credits are offered (20 %) in Southern Africa, West Africa, and East Africa compared to 15 % offered in Asia and across Africa. Regarding the physical services offered in terms of machinery provision, Asia has the most providers (29 %), followed by the other regions (14 %) except East Africa (0 %), indicating that business models in East Africa do not include machinery services in their CIS-CSA bundles, despite over 50 % of all the sampled business cases identified in this paper being from this region.

3.2. Type and delivery modalities of CIS-CSA bundled business models

Table 6 illustrates business model types identified in 29 business cases across all the sampled regions. They include G2C, B2C, B2B2C, B2G2C, B2D2G2C, B2B, and B2D2C. They exist in the form of bipolar, tripolar, and quadrupolar. There is a significant variation of these models across all the sampled regions in benefiting users. For example,

Table 4
List of business cases, their geographical locations, bundled CIS −CSA services, and targeted customer base.

CIS -CSA bundled business case	Location	KS	C	FS	PS	Source	Target group
1. ZFU Eco Farmer Combo	Zimbabwe	✔		✔		(CTA, 2020; Kakooza, 2014)	Farmers union and extension agents, and agro-dealers
2. FARMIS	Uganda	✔		✔		(Kakooza, 2014)	Small farmers, extension agents, and agro-dealers
3. MUIIS	Uganda	✔		✔		(Chang, 2017)	Small farmers and agro-dealers
4. 8 villages	Indonesia	✔		✔	✔	(FAO, 2021)	Farmers cooperatives, individuals, extension agents, and agro-dealers
5. IFFCO-Kissan	India	✔	✔	✔	✔	(Vedeld et al., 2019)	Large, and small farmers, cooperatives, and extension agents
6. Lima Links, Rupaya and Vitality	Zambia	✔	✔	✔	✔	(Vitalite and Links, 2021)	Small farmers, cooperatives, and agro-dealers
7. Services for CSA and CIS consulting and capacity building	East Africa	✔	✔			(Ngingi and Muange, 2022)	Cooperatives, small farmers, and agro-dealers
8. Participatory integrated climate services for agriculture (PICSA)	Global	✔				(Dorward et al., 2015)	Small farmers, cooperatives, extension agents, and agro-dealers
9. ESOKO	Ghana	✔	✔	✔		(Nii-Koi, 2021)	Individual, small farmers, extension agents, and agro-dealers
10. Farmer links	Philippines	✔		✔		(Chang, 2017)	Cooperatives, extension agents, and agro-dealers
11. One Acre fund	East Africa	✔	✔	✔		(Tinsley and Agapitova, 2018)	Small farmers
12. Digital Agro-Climate Advisory (DACA)	Africa	✔				(Kagabo et al., 2020)	Individuals, small and large farmers, cooperatives, and extension agents
13. Solutions for cereals and livestock farmers in Southern Africa	Southern Africa	✔	✔	✔		(CTA, 2020)	Cooperatives, individuals, agro-dealers, and extension agents
14. CIMMYT/BISA	India	✔	✔		✔	(Vernet, 2017)	Large and small farmers, cooperatives, extension agents, and agro-dealers
15. Climate-Smart Villages approach	Global	✔	✔	✔		(Aggarwal et al., 2018)	agro-dealers, small farmers, and cooperatives
16. aMaizing	Kenya	✔	✔	✔		(Pietosi, 2021; Prager et al., 2021)	Individuals, small and large farmers, cooperatives, and extension agents
17. Rwanda Climate Services for Agriculture	Rwanda	✔				(Prager et al., 2021)	Farmers, agro-dealers, cooperatives, and extension workers
18. Manobi Africa	Africa	✔		✔		(Manobi Africa, 2022)	Farmers, financial institutions, and value chain actors
19. Bundled Advisory Services Kits for Enabling Transformation in Agriculture (BASKET-A)	Senegal	✔		✔		(Prager et al., 2021)	Farmers, agro-dealers, extension workers, and value chain actors
20. PPP business models for CIS delivery in Climate Smart Villages in Northern Ghana	Ghana	✔				(Partey et al., 2019)	Small and large farmers, agro-dealers, value chain actors, private sector, and extension workers
21. Shamba Shape Up and i-Shamba	East Africa	✔				(iShamba, 2022; Pietosi, 2021)	Farmers (small and large) agro-dealers, financial institutions, and cooperatives,
22. Bundling CIS with agricultural inputs, in Senegal	Senegal	✔	✔	✔		(Prager et al., 2021)	Small farmers, extension workers, and value chain actors,
23. Integrated soil nutrient and climate risk management (ISN-CRM) in Mali.	Mali	✔	✔			(Prager et al., 2021)	Small and large farmers, extension workers, and agro-dealers,
24. Lersha	Ethiopia	✔	✔	✔	✔	(Prager et al., 2021)	Farmers, the private sector, financial institutions, and value chain actors
25. Climate risk insurance and information in Zambia (CRIIZ)	Zambia	✔		✔		(Prager et al., 2021)	Farmers and financial institutions
26. Viamo platform	Global	✔				(Usher et al., 2018)	The private sector, farmers, and financial institutions
27. Acre Africa	Africa	✔				(CTA, 2020)	Financial institutions, farmers,
28. aWhere	Africa	✔		✔		(Pietosi, 2021; Usher et al., 2018)	Farmers, financial institutions, private sector, and agro-dealers
29. MasterCard Farmer Network- MFN	Africa	✔	✔	✔		(MasterCard Foundation, 2015)	Farmers, financial institutions, the private sector, and agro-dealers.

across all the regions, B2C (n = 18), B2D2C (n = 16), and B2B2C (n = 10) were the dominant, followed by B2B (n = 9), B2D2G2C (n = 9), B2G2C (n = 4), and G2C (n = 4). The predominant business models in East Africa were B2D2C (n = 5) followed by B2C (n = 3). In Southern Africa, B2C (n = 3) and B2G2C (n = 2) are the most dominant. In West Africa, B2D2C (n = 4), B2C (n = 3), G2C (n = 2), and B2G2C (n = 2) are the common existing models. In the Horn of Africa, B2D2G2C (N = 2) dominates. Across Africa, B2C dominates.

The business models in Table 7 generate revenues/profits from various bundled services through goods transactions, services transactions, commissions, direct sales, subscription fees, licensing, brokerage fees, advertising, lending/leasing/renting, government goods and services tax, income tax, corporate tax, non-tax revenues, union tax duties, earned jobs and side gigs, interests, loyalties, etc. The regional distribution of these revenue-generation services is depicted in Table 7, showing significant variations across all the sampled regions. Subscription fees, for example, are the most common revenue-generation means in Asia and Southern Africa (33 %), respectively. The same applies to service transactions in both regions (30 % in Southern Africa and 20 % in Asia) compared to the other regions.

Table 8 presents the categories of business models based on the services they offer (trusted services, trusted agents, trusted products, and direct provisions). Table 8 shows that 100 % of all the evaluated business cases across all the sampled regions offered trusted services regarding KS, C, FS, and PS. This implies that the provided services are trusted because the end users value the value or benefits they bring to their livelihoods.

In the trusted services, intermediaries and private sector-led

Table 5
Regional distribution and descriptions of types of bundled CIS-CSA services/products categorized as KS, C, FS and PS. The out-of-the-bracket represents the occurrence of a service per region while the numbers in brackets are their corresponding percentages.

Knowledge (KS)	Global	Across Africa	East Africa	West Africa	Southern Africa	Horn of Africa	Asia	Total
Tips on farming management	2(18)	0(0)	2(17)	1(9)	2(18)	1(9)	3(27)	11
Climate and weather data forecasting	2(10)	2(10)	5(24)	4(20)	4(20)	1(5)	2(10)	20
Market prices	1(13)	1(13)	1(13)	1(13)	1(13)	1(13)	2(25)	8
Access to market (agricultural produce/implements…)	2(20)	1(10)	1(10)	1(10)	2(20)	1(10)	2(20)	10
Advisory services	2(14)	2(14)	3(21)	3(21)	1(7)	1(7)	2(14)	14
Capacity building	2(14)	3(21)	5(36)	1(7)	1(7)	0(0)	2(14)	14
Consumables (C)								
Fertilizers	1(7)	3(21)	3(21)	2(14)	2(14)	1(7)	2(14)	14
Seeds	1(7)	3(20)	3(20)	3(20)	2(13)	1(7)	2(13)	15
Pesticides/Agro-chemicals	0(0)	0(0)	0(0)	0(0)	2(100)	0(0)	0(0)	2
Financial services (FS)								
Loans	1(5)	3(15)	4(20)	4(20)	4(20)	1(5)	3(15)	20
Credits	1(5)	3(15)	4(20)	4(20)	4(20)	1(5)	3(15)	20
Subsidies	0(0)	0(0)	1(14)	0(0)	2(29)	1(14)	3(43)	7
Index-based insurance	1(6)	3(17)	3(17)	4(22)	4(22)	1(6)	2(11)	18
Physical services (PS)								
Machinery (farming tractors)	1(14)	1(14)	0(0)	1(14)	1(14)	1(14)	2(29)	7

Table 6
Regional distribution and description of bundled CIS − CSA business model types Numbers represent the occurrence of a service per region.

Type of business model	Number of bundles per type service (all the sampled regions)	Across Africa	East Africa	West Africa	Southern Africa	Asia	Horn of Africa	Global
G2C	4	0	1	2	0	0	0	1
B2D2C	16	4	5	4	0	1	1	1
B2G2C	4	0	0	2	2	0	0	0
B2D2G2C	9	1	1	1	1	2	1	2
B2B	9	2	1	1	0	0	0	1
B2B2C	10	4	2	1	1	1	1	0
B2C	18	4	3	3	3	3	1	1

Table 7
Regional distribution and description of revenue generation streams of business models with bundled CIS-CSA services ready for scaling. The out-of-bracket numbers represent the occurrence of a service per region, while the numbers in brackets are their corresponding percentages.

Intermediary organizations	Number of bundles per service type (all regions)	Across Africa	East Africa	West Africa	Southern Africa	Asia	Horn of Africa	Global
Goods transactions	11	2(18)	0(0)	1(9)	2(18)	3(27)	1(9)	2(18)
Services transactions	10	1(10)	1(10)	0(0)	3(30)	2(20)	1(10)	2(20)
Commissions	6	1(17)	0(0)	1(17)	1(17)	2(33)	1(17)	0(0)
Direct sales	7	1(14)	1(14)	1(14)	2(29)	1(14)	0(0)	1(14)
Subscription fees	9	0(0)	1(11)	0(0)	3(33)	3(33)	1(11)	1(11)
Licensing	11	2 (18)	1 (9)	1 (9)	3 (27)	2 (18)	0 (0)	2 (18)
Brokerage fees	8	1 (13)	2 (25)	1 (13)	3 (38)	1 (13)	0 (0)	0 (0)
Advertising	14	3 (21)	2 (14)	1 (7)	3 (21)	3 (21)	1 (7)	1 (7)
Lending/leasing/renting	13	3 (23)	2 (15)	1 (8)	2 (15)	3 (23)	1 (8)	1 (8)
Transactional, project, service and recurring	8	1 (13)	2 (25)	0 (0)	2 (25)	2 (25)	1 (13)	0 (0)
Government are Goods and Services Tax (GST), Income tax, corporation tax, non-tax revenues, union excise duties	2	0 (0)	0 (0)	0 (0)	0(0)	2 (100)	0 (0)	0 (0)
Earned jobs and side gigs	11	3 (27)	2 (18)	0 (0)	2 (18)	3 (27)	0 (0)	1 (9)
Dividends	10	2 (20)	2 (20)	0 (0)	2 (20)	2 (20)	1 (10)	1 (10)
Running your own business	11	2 (18)	2 (18)	0 (0)	2 (18)	3 (27)	1 (9)	1 (9)
Royalties	2	1 (50)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	1 (50)
Interest	5	0 (0)	1 (20)	0 (0)	2 (40)	1 (20)	0 (0)	1 (20)
Capital gains	1	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	1 (100)

network-centric models are provided in Table 9. As results indicate, SME agribusinesses, input providers, producer associations, creating market incentives for innovation, participation of service providers, and accelerating link formation between information and service providers and users are the ways intermediaries and private sector-led network-centric business models operate in varying manners to deliver bundled series across all the regions.

3.3. CIS-CSA bundled business models that are ready for scaling

Twenty-nine CIS-CSA bundled business models (Table 4) were subjected to the developed evaluation 1–5 scaling readiness framework

Table 8
Type of networks of business models built around bundled CIS- CSA services/products per region. The out-of-bracket numbers represent the occurrence of a service per region, while the numbers in brackets are their corresponding percentages.

Intermediary organizations	Number of bundles per type service (all regions)	Across Africa	East Africa	West Africa	Southern Africa	Asia	Horn of Africa	Global
Trusted Services	16	1 (6)	3 (19)	5 (31)	2 (13)	3 (19)	0 (0)	2 (13)
Trusted Products	7	1 (14)	4 (57)	0 (0)	1 (14)	0 (0)	1 (14)	0 (0)
Trusted Agents	7	1 (14)	1 (14)	0 (0)	1 (14)	2 (29)	0 (0)	2 (29)
Direct Provision	0	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)

Table 9
Regional distribution of CIS-CSA service/products intermediaries and private-sector- led-and network-centric business models. The out-of-bracket numbers represent the occurrence of a service per region, while the numbers in brackets are their corresponding percentages.

Services	Across Africa	East Africa	West Africa	Southern Africa	Asia	Horn of Africa	Global
SME agribusinesses	3(13)	7(29)	5(21)	2(8)	4 (17)	1(4)	2(8)
Input providers	3(15)	6(30)	5(25)	2(10)	3 (15)	0(0)	1(5)
Producer associations	1(8)	3(23)	3(23)	2(15)	3 (23)	0(0)	1(8)
Creating market incentives for innovation	4(17)	6(26)	3(13)	3(13)	4 (17)	1(4)	2(9)
Participation of services providers	5(19)	8(30)	4(15)	3(11)	4 (15)	1(4)	2(7)
Accelerating link formation between information and service providers and users	6(21)	8(29)	4(14)	3(11)	3 (11)	1(4)	3(11)

presented in Fig. 2, and the results are presented in Table 10. These cases were evaluated using the framework outlined in Section 2.4.1 to assess their readiness for scaling.

While all the innovations may benefit farmers and entrepreneurs, our analysis found that only 12 cases were ready for scaling, while the others required further development. The bundled business models that we deemed ready for scaling (those which scored 7–10) were Lersha, Rwanda Climate Services for Agriculture, Climate-Smart Villages approach, Services for CSA and CIS consulting and capacity building, MasterCard Farmer Network, ZFU Eco Farmer Combo, One Acre Fund, Solutions for cereals and livestock farmers in Southern Africa, CIMMYT/ BISA, PICSA (Reading University), IFFCO-Kissan, and ESOKO. They scored exceptionally higher in technological aspects than the other innovations in the study, implying that their technologies are affordable, accessible, simple, and easy to use (Zamboni et al., 2019).

For sustainability, the leading innovations are Rwanda Climate Services for Agriculture, One Acre Fund, Climate-Smart Villages approach, and ZFU Eco Farmer Combo, which all show exceptional performances on other ratings. In this study, impact and sustainability were weighed heavily. The innovations notable for the highest impact observed were the Climate-Smart Villages approach, PICSA (Reading University), and One Acre Fund. As the results show, it has proven difficult for many of these innovations to break through barriers to achieve their development objectives; most of the innovations scored low on the barrier parameter; only two innovations, the Climate-Smart Villages approach and One Acre Fund, were able to score as high as 0.75.

3.4. Drivers of CIS- CSA

bundled business models for scaling readiness Bundled CIS-CSA business models from Table 10 were subjected to quantitative analysis to explore how the network of a CIS-CSA bundled business model's stakeholders, its products and services bundling strategies, and revenue generation stream structure individually or jointly affect its scalability. Table 11 shows the results from the multivariate regression analysis of the effects of the type of a CIS-CSA bundled business model, the number of revenue streams, and the number of bundled products and services on the size of its customer base.

Table 11a reveals a statistically significant effect of the type of business model on its customer base (the diversity of its customers) ($p = 0.012$). However, Table 11a reveals a statistically negative significant interactive effect between the CIS-CSA bundled business model type and its revenue stream ($p = -0.029$). Table 11b reveals that the type of a CIS-CSA business model has a statistically significant effect on its number of partners ($p = 0.015$). Table 11c shows that the type of CIS-CSA business model significantly affects the total number of people it serves ($p = 0.04$). Table 11d reveals that the CIS-CSA bundled business model type has a statistically significant effect ($p = 0.012$) on its financial capacity.

4. Discussion of results

4.1. Components of bundled CIS-CSA business models for sustainable agriculture

The results reveal gaps in the provision of the bundled CIS-CSA services, as presented in Tables 4 and 5. KS, C, FS, and PS are provided in varying ways across the regions investigated. KS, C, and FS bundled services predominate in East Africa. On the other hand, PS is predominantly provided in Asia, rarely in the other regions, and not in East Africa. The results show that most business models in Africa do not include PS in their bundles; in Africa, most CIS-CSA bundled businesses provide KS, C, and FS. This might be attributed to the fact that PS, such as mechanization, solar energy, etc., are expensive and remain in commercial farming. One reason could be that the subsistence farmers of Africa would not afford PS bundles. CIS-CSA bundled businesses in Africa must be heavily subsidized to offer PS bundles at reasonably affordable prices. Another reason may be related to the lack of funding to promote the creation of the innovation and a lack of knowledge of the value of the innovation that bundling CIS-CSA services will generate (Findlater et al., 2021; Rosenstock et al., 2020). This finding reflects the shortcomings of CIS-CSA systems in Africa. Ineffective CIS-CSA service delivery systems may slash farmers' adaptability and resilience to climate-change risks. According to Casey et al. (2021), the private and public financing of bundled CIS-CSA services is necessary to attain scalable and sustainable agriculture.

Table 10
Evaluated CIS-CSA business models for their scaling readiness.

Substantially Underdeveloped (0%)	Opportunity to Improve (25%)	Promising Approach (50%)	Demonstrated Viability (75%)	Scaling Ready (100%)
				

Bundled CIS-CSA Business Models	Technology (1)	Impact (1.5)	Barriers (1)	Bundling (1)	Infrastructure (1)	Relevance (1)	Evidence (1)	Value added (1)	Sustainability (1.5)	Score in %
ZFU Eco Farmer Combo										71
IFFCO-Kissan										70
Services for CSA and CIS consulting and capacity building										78
PICSA (Reading University)										79
ESOKO										75
One Acre fund										98
Solutions for cereals and livestock farmers in Southern Africa										70
CIMMYT/BISA										70
Climate-Smart Villages approach										98
Rwanda Climate Services for Agriculture										75
Lersha										73
MasterCard Farmer Network- MFN										70

The study's scaling-readiness assessment reveals 12 potentially scaling-ready business models (Table 10). The business cases deemed ready for scaling scored exceptionally higher in technological aspects than the other innovations evaluated by the study. Their success is attributed to the accessibility, affordability, and user-friendliness of their technologies (Zamboni et al., 2019). Additionally, these business cases are primarily led by the private sector and have intermediary agents (Jacobs et al., 2018). For example, the One Acre Fund is a private-sector-led business case that provides agro-weather advisories bundled with inputs from fertilizers and agrochemical suppliers. Furthermore, the businesses offer diverse product and service packages, serving many categories of customers (smallholders and large farmers and co-operatives (Table 4) to ensure many revenue-generation streams. The success of the initiative can be explained by the impact and sustainability of the products and services it bundles and its close collaborations with governments, NGOs, and other entrepreneurs (Casey et al., 2021; Vitalite and Links, 2021; Pietosi, 2021; Chang, 2017; FAO, 2021; Kakooza, 2014).

Table 11
Quantitative evaluation of drivers of CIS- CSA bundled business models for scaling readiness.

Variables and their interactions	B-coefficients	Standard error	T-statistic	P-value
11a. *The effects of the type of CIS-CSA bundled business model, the number of revenue streams, and the number of bundled products and services on the number of customer categories (smallholder farmers, large farmers, and farmers' cooperatives)*				
Type of a CIS-CSA business model	2.586	0.799	3.235	0.012*
Number of revenue streams of a CIS-CSA bundled business model	−0.165	0.167	−0.99	0.351
Type of a CIS-CSA business model X number of bundled products and services	−0.165	0.167	−0.99	0.351
Type of a CIS-CSA business model X number of revenue streams of a CIS-CSA bundled business	−0.188	0.071	2.66	0.029*
11b. *The effects of the type of business model and the number of bundled products and services on the number of partners of a CIS-CSA bundled business model*				
Type of a CIS-CSA bundled business model	10.308	3.357	3.07	0.015*
The number of bundled products and services	3.545	19.387	0.183	0.859
Type of a CIS-CSA bundled business model X number of bundled products and services	−2.43	5.262	−0.462	0.657
11c. *The effects of a CIS-CSA bundled business model and the bundle size on the total number of its potential customers*				
Type of a CIS-CSA business model	4,925,500	2,621,500	1.88	0.04*
Number of bundled products and services	−6,039,800	4,340,000	−1.39	0.197
11d. *The effects of the type of CIS-CSA bundled business model and the number of bundled products and services on a CIS-CSA bundled business's financial capacity*				
Type of a CIS-CSA business model	10,119,000	2,851,100	3.549	0.012*
Number of bundled products/services	11,577,000	15,597,000	0.742	0.486
Number of revenue streams of a CIS-CSA bundled business model	−3,577,000	4,169,200	0.858	0.424
Type of a CIS-CSA bundled business model X Number of bundled products and services	−4,493,600	4,049,200	−1.11	0.31
Type of a CIS-CSA business model X number of revenue streams of a CIS-CSA bundled business model	514,140	1,116,000	0.461	0.661

*A p-Value below 0.05 indicates that the variables or their interactions have statistically significant effects. The capital X indicates the interactions.

4.3. Drivers of CIS- CSA bundled business models for scaling readiness

Results show that the type of a CIS-CSA bundled business model consistently positively affects all the investigated scaling readiness indicators: the diversity of its customers, its financial capacity, the number of partners, and the size of the reached population (Table 11a, b, c, and d). In other words, other things being equal, a D2G2B2C business model would be more scalable than a G2B2C type. The joint effects of the scaling readiness explanatory variables are not statistically significant. Nevertheless, in most cases, our analysis shows that the interaction effects are positive (results not presented).

Table 11 reveals that adding one more active stakeholder to a CIS-CSA bundled business network would enable it to reach a broader customer base; a G2B2B2C CIS-CSA business could serve three more customer categories than a B2B2C. The finding may imply that multi-stakeholder CIS-CSA business models could reach and satisfactorily serve all categories of farmers—small and large farmers and co-operatives. While Chen et al. (2023) state that the multi-stakeholder approach would not always be beneficial due to the complexity of the business environment, Dembek et al. (2018) remark that multi-stakeholder business models can benefit clients with a broad range of economic statuses.

The study shows that the interaction between the type of a CIS-CSA bundled business model and the number of its revenue streams statistically significantly negatively affects the number of its customer categories (Table 11a, $p = 0.028$). In low-income countries where smallholder farmers comprise a significant fraction of the farming community, most farmers would prefer the for-free to the for-fee option. Thus, the stakeholders of CIS-CSA bundled business models have to monetize their products and services in a way suitable for financially unfortunate smallholder farmers. Zhang et al. (2015) state that engaging paying and non-paying customers would be necessary for a business model to reach a broad customer base in low-income countries.

Table 11b, which presents the effects of the type a CIS-CSA bundled business model, its number of bundled products and services, and its number of revenue streams on its partnership, shows that adding one more active stakeholder (government, private agent, or donor) to a CIS-CSA business network would attract ten new business partners; in other words, other things being equal, a G2B2C CIS-CSA bundled business would have ten more business partners than a B2C CIS-CSA type. The finding may imply that the highly networked CIS-CSA business models, thanks to their collective intellectual and material resourcefulness, would be able to meet the expectations of their stakeholders and, as a result, retain or grow the number of their partnerships. Shankar et al. (2012) state that a network is imperative for the success of a business. MacDonald et al. (2022) also emphasize the importance of multi-stakeholder partnerships for sustainability. According to Usher et al. (2018), multi-stakeholder CIS-CSA bundled business models, such as B2D2G2C and B2D2C, would benefit farmers and entrepreneurs.

Based on the results in Table 11c, for example, a D2B2C CIS-CSA bundled business model would serve five million more farmers than a B2C type. The finding suggests that CIS-CSA bundled business models with diverse stakeholders, owing to their extensive network of agents and sizeable geographical coverage, would reach as many last-mile users as possible and significantly impact the farming community. Soundararajan et al. (2019) state that the multi-stakeholder approach can enhance the supply chain.

Table 11d shows that, for instance, a G2D2B2C CIS-CSA bundled business model would be more financially resourceful than a D2B2C type. The former's financial capacity would be 10 million USD more than the latter's. Thus, in developing worlds where a private or public entity would not single-handedly handle the operations of a CIS-CSA business financially, business models with many stakeholders would be financially wise options; the more diverse the network, the more resources.

The diversity of stakeholders (private and public) that operate a CIS-CSA bundled business would significantly determine its scalability. While the joint effects of the three studied explanatory variables for the scalability of CIS-CSA bundled business models are not statistically significant, perhaps because our sample was small ($n = 11$), the effects are positive, suggesting that multi-stakeholder CIS-CSA bundled businesses that bundle a variety of products and services (for example, knowledge, financial, value-chain, insurance, and digital services) (Chang, 2017; Long et al.,2017; Vedeld et al.,2019), and generate income from many sources such as service subscriptions, commissions, concessions and loan recovery, and indemnities (Casey et al., 2021; Hansen et al., 2019; Pietosi, 2021) would resiliently navigate the unfavorable spatial–temporal evolutions of their markets and meet the

spatially and temporarily varying needs and expectations of their customers and investors.. Bundling CIS-CSA with effective communication technologies and financial and insurance services leads to sustainable agriculture (O'Grady & O'Hare, 2017). It is worth remarking that while the study shows that CIS-CSA bundled business models that can benefit entrepreneurs and farmers are those that have diverse stakeholders, Prager et al (2021) demonstrate that some of the potentially scalable business models can be public, not necessarily public–private, and in these instances the model is "G2X" (i.e., government to consumers) rather than "B2X" (i.e., business to consumers). Successful G2X examples include the Rwanda Climate Services for Agriculture (RCSA) (Birachi et al., 2020). RCSA, while initially viewed as perhaps not having a business model, the successful government-run initiative demonstrates how public CIS-CSA business models can serve as part of the available public services to lower risk and improve climate outcomes for both farmers and the government alike.

5. Conclusions and recommendations

The study exposes the spatial distribution of CIS-CSA bundled business models, services, and products they bundle across the sampled regions of Africa and Asia. It also introduces a 1–5 scale framework, a potentially valuable tool for assessing the scaling readiness of CIS-CSA bundled business models. The research also quantitatively explores how the type of a CIS-CSA business model (the diversity of its stakeholders), the number of products and services it offers, and its number of revenue streams affect its scaling readiness.

The study reveals that knowledge services are the most common CIS-CSA services across Africa, while mechanization services are rare in the region. Asia dominates the physical services (mechanization) sphere. The CIS-CSA businesses in Africa have yet to work with their partners to make mechanization services available and financially affordable.

The 1–5 scaling readiness evaluation framework shows that of the 29 evaluated CIS-CSA bundled business models across Africa and Asia, less than 50 % (12) are ready for scaling, suggesting that there is still a long way to go to attain effective and efficient CIS-CSA services delivery systems.

The quantitative analysis of the study suggests that the type of a CIS-CSA business model (the diversity of its stakeholders) significantly determines its financial capacity, the number of customers it can reach, the customer categories it can serve, and the number of its partners, and, therefore, its scaling readiness. Therefore, all else being equal, multi-stakeholder CIS-CSA bundled business models, for example, D2G2B2C, G2B2C, G2D2B2B2C, and D2B2C CIS-CSA business models that offer diverse packages of CIS-CSA products and services (knowledge services, consumables, financial services, and physical services) at reasonably affordable prices could significantly benefit entrepreneurs, smallholder and larger farmers, and cooperatives.

The statistically negatively significant interaction between the CIS-CSA bundled business model type and its number of revenue streams underscores the need for smallholder-farmer-centric revenue-generation strategies in low-income countries. If the goal is to leave no farmer behind, CIS-CSA bundled businesses must engage non-paying and paying customers to reach all categories of farmers.

We recommend investing in CIS-CSA value-oriented business models, having a network of agents from public and private domains, bundling a wide range of products and services, serving a diverse customer base, and having multiple revenue streams.

CRediT authorship contribution statement

Desire M. Kagabo: Writing – review & editing, Writing – original draft, Supervision, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Livingstone Byandaga:** Writing – review & editing, Writing – original draft, Methodology, Formal analysis, Conceptualization. **Patrick Gatsinzi:** Writing – review & editing, Writing – original draft, Methodology, Formal analysis, Data curation, Conceptualization. **Patrick Mvuyibwami:** Writing – review & editing, Writing – original draft, Methodology, Formal analysis, Data curation, Conceptualization. **Yvonne U. Munyangeri:** Writing – original draft, Formal analysis. **Nasson Ntwari:** Writing – review & editing, Writing – original draft, Methodology. **Mathieu Ouedraogo:** Writing – review & editing, Supervision, Methodology, Conceptualization.

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Declaration of competing interest

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Data availability

Data will be made available on request.

References

Abegunde, V.O., Sibanda, M., Obi, A., 2020. Determinants of the adoption of climate-smart agricultural practices by small-scale farming households in King Cetshwayo District municipality, South Africa. Sustainability 12, 195. https://doi.org/10.3390/su12010195.

Aggarwal, P., Jarvis, A., Campbell, B.M., Zougmoré, R.B., Chhetri, Vermeulen, S., Loboguerrero, A.M., Sebastian, L., Kinyangi, Findji, Maren, 2018. The climate-smart village approach: Framework of an integrative strate" by Pramod K. Aggarwal, Andy Jarvis et al. [WWW Document]. URL https://scholarworks.uvm.edu/rsfac/85/ (accessed 4.20.23).

Andrieu, N., Howland, F., Acosta-Alba, I., Le Coq, J.-F., Osario-Garcia, A.M., Martinez-Baron, D., Gamba-Trimino, C., Loboguerrero, A.M., Chia, E., 2019. Co-designing Climate-Smart Farming Systems With Local Stakeholders: A Methodological Framework for Achieving Large-Scale Change [WWW Document]. URL https://www.frontiersin.org/articles/10.3389/fsufs.2019.00037/full (accessed 1.25.23).

Bayala, J., Ky-Dembele, C., Dayamba, S.D., Somda, J., Ouédraogo, M., Diakite, A., Chabi, A., Alhassane, A., Bationo, A.B., Buah, S.S.J., Sanogo, D., Tougiani, A., Traore, K., Zougmoré, R.B., Rosenstock, T.S., 2021. Multi-actors' co-implementation of climate-smart village approach in West Africa: achievements and lessons learnt. Front. Sustain. Food Syst. 5.

Belay, A., Oludhe, C., Mirzabaev, A., Recha, J.W., Berhane, Z., Osano, P.M., Demissie, T., Olaka, L.A., Solomon, D., 2022. Knowledge of climate change and adaptation by smallholder farmers: evidence from southern Ethiopia. Heliyon 8, e12089. https://doi.org/10.1016/j.heliyon.2022.e12089.

Benijts, T. 2013. A Business Sustainability Model for Government Corporations. A Belgian Case Study [WWW Document]. URL https://onlinelibrary.wiley.com/doi/abs/10.1002/bse.1784 (accessed 1.25.23).

Birachi, E., Radeny, M., Tesfaye, A., Hansen, J., Kagabo, D. 2020. Rwanda Climate Services for Agriculture: Farmers willingness to pay for improved climate services.

Campbell, B.M., Hansen, J., Rioux, J., Stirling, C.M., Twomlow, S., (Lini) Wollenberg, E., 2018. Urgent action to combat climate change and its impacts (SDG 13): transforming agriculture and food systems. Curr. Opin. Environ. Sustain. 34, 13–20. https://doi.org/10.1016/j.cosust.2018.06.005.

Carthy, et al., 2018. Global food security— Issues, challenges, and technological innovations. Trend Food Sci. Technol. 77, 11–20. https://doi.org/10.1016/j.tifs.2018.05.002.

Casey, J., Bisaro, A., Valverde, A., Martinez, M., Rokitzki, M., 2021. Private finance investment opportunities in climate-smart agriculture technologies.
Chang, E., 2017. ICT4Ag Trends: To Bundle Or Not To Bundle? [WWW Document]. TaroWorks. URL https://taroworks.org/ict4ag/ (accessed 1.13.23).
Chen, V.Z., Zhong, M., Duran, P., Sauerwald, S., 2023. Multistakeholder benefits: a meta-analysis of different theories. Bus. Soc. 62 (3), 612–645. https://doi.org/10.1177/00076503221110181.
Chesoli, N.R., Sartas, M., Muzhingi, T., Emanuel, O., 2024. Application of the scaling readiness approach for scaling of nutrition-sensitive initiatives in Kenya, Uganda, and Malawi: a case of orange fleshed sweet potato value chain. Crop Sci. https://doi.org/10.1002/csc2.21053.
Chin, W.W., Peterson, R.A., Brown, S.P., 2008. Structural equation modeling in marketing: some practical reminders. J. Mark. Theory Pract. 16, 287–298. https://doi.org/10.2753/MTP1069-6679160402.
Cooley, L., Howard, J. 2018. Scale Up Sourcebook.
Coviello, N., Autio, E., Nambisan, S., Patzelt, H., Llewellyn, D.W., Thomas, 2015. Organizational scaling, scalability, and scale-up: definitional harmonization and a research agenda. J. Bus. Ventur. 39 (5). https://doi.org/10.1016/j.jbusvent.2024.106419.
CTA, 2020. CTA Project Completion Report: Scaling up Climate-smart Agricultural Solutions for Cereal and Livestock Farmers in Southern Africa (Report). Technical Centre for Agricultural and Rural Cooperation.
Dembek et al.(2018). Creating value for multiple stakeholders: Sustainable business models at the Base of the Pyramid. Journal of Cleaner Production, (192). Pages 1600-1612. Creating value for multiple stakeholders: Sustainable business models at the Base of the Pyramid - ScienceDirect.
Devare, M., Aubert, C., Benites Alfaro, O.E., Perez Masias, I.O., Laporte, M.-A., 2021. AgroFIMS: a tool to enable digital collection of standards-compliant FAIR data. Front. Sustain. Food Syst. 5.
Dinesh, D., Aggarwal, P., Khatri-Chhetri, A., Rodríguez, A.M.L., Mungai, C., Sebastian, L., Zougmoré, R. 2017. The rise in Climate-Smart Agriculture strategies, policies, partnerships and investments across the globe.
Dorward, P., Clarkson, G., Stern, R. 2015. Participatory Integrated Climate Services for Agriculture (PICSA): Field Manual [WWW Document]. CGIAR Gend. Platf. URL https://gender.cgiar.org/publications/participatory-integrated-climate-services-agriculture-picsa-field-manual (accessed 1.25.23).
Egeru, A., Bbosa, M.M., Siya, A., Asiimwe, R., Mugume, I., 2022. Micro-level analysis of climate-smart agriculture adoption and effect on household food security in semi-arid Nakasongola District in Uganda. Environ. Res. Clim. 1, 025003. https://doi.org/10.1088/2752-5295/ac875d.
FAO, 2021. Climate-smart agriculture case studies 2021. FAO. doi: 10.4060/cb5359en.
Findlater, K., Webber, S., Kandlikar, M., Donner, S., 2021. Climate services promise better decisions but mainly focus on better data. Nat. Clim. Change 11, 731–737. https://doi.org/10.1038/s41558-021-01125-3.
Groot, A.E., Bolt, J.S., Jat, H.S., Jat, M.L., Kumar, M., Agarwal, T., Blok, V., 2019. Business models of SMEs as a mechanism for scaling climate smart technologies: the case of Punjab. India. J. Clean. Prod. 210, 1109–1119. https://doi.org/10.1016/j.jclepro.2018.11.054.
Hansen, J.W., Vaughan, C., Kagabo, D.M., Dinku, T., Carr, E.R., Körner, J., Zougmoré, R. B., 2019. Climate services can support african farmers' context-specific adaptation needs at scale. Front. Sustain. Food Syst. 3, 21. https://doi.org/10.3389/fsufs.2019.00021.
iShamba, 2022. iShamba: Shamba Shape Up's farmer information service. [WWW Document]. URL http://ishamba.com (accessed 12.30.22).
Jacobs, F., Ubels, J., Woltering, L., 2018. The Scaling Scan- A practical tool to determine the strengths and weaknesses of your scaling ambition.
Jalloh, A., Nelson, G.C., Thomas, T.S., Zougmoré, R., Roy-Macauley, H. 2013. WEST AFRICAN AGRICULTURE AND CLIMATE CHANGE.
Johnson-Woods, C., 2022. Will Results-Based Climate Finance (RBCF) Yield Greater Outcomes and Impact? [WWW Document]. URL https://www.resonanceglobal.com/blog/will-results-based-climate-finance-rbcf-yield-greater-outcomes-and-impact (accessed 4.21.23).
Kagabo, D.M., Munyangeri, Y., Mvuyibwami, P., Byandaga, L., Waswa, B., Butare, Mamo, T., Chirwa, R., Rubyogo, J.C., Onyango, P., 2020. Putting digital agro-climatic services in the hands of bean value chain actors | PABRA [WWW Document]. URL https://www.pabra-africa.org/putting-digital-agro-climatic-services-in-the-hands-of-bean-value-chain-actors/ (accessed 2.4.23).
Kakooza, C. 2014. Mobile-based "bundled" services: Example of Agri-Fin Mobile.
Kilelu, C., Klerkx, L., Omore, A., Baltenweck, I., Leeuwis, C., Githinji, J., 2017. Value chain upgrading and the inclusion of smallholders in markets: reflections on contributions of multi-stakeholder processes in dairy development in Tanzania. Eur. J. Dev. Res. 29, 1102–1121. https://doi.org/10.1057/s41287-016-0074-z.
Larosa, F., Mysiak, J. 2020. Business models for climate services: An analysis. Clim. Serv., Special issue on European Climate Services Markets – Conditions, Challenges, Prospects, and Examples 17, 100111. doi: 10.1016/j.cliser.2019.100111.
Linn, J., 2012. In: Scaling Up in Agriculture, Rural Development, and Nutrition. International Food Policy Research Institute, Washington, DC. https://doi.org/10.2499/9780896296756.
Long, T.B., Blok, V., Poldner, K., 2017. Business models for maximising the diffusion of technological innovations for climate-smart agriculture. Int. Food Agribus. Manag. Rev. 20, 5–23. https://doi.org/10.22434/IFAMR2016.0081.
Lüdeke-Freund, F., 2014. BP's solar business model: a case study on BP's solar business case and its drivers. Int. J. Bus. Environ. 6, 300–328. https://doi.org/10.1504/IJBE.2014.063775.
MacDonald, A., Clarke, A., Huang, L., 2022. In: Multi-Stakeholder Partnerships for Sustainability: Designing Decision-Making Processes for Partnership Capacity. Business and the Ethical Implications of Technology. Springer, Cham. https://doi.org/10.1007/978-3-031-18794-0_7.
Manobi Africa, 2022. Our businesses. URL https://www.manobi.com/our-businesses/#agriculture.
Margretta, J., 2002. Why do business models matter? Harv. Bus. Rev. http://designblog.uniandes.edu.co/blogs/dise2102pc/files/2013/08/Why_Business_Models_Matter2.pdf.
MasterCard Foundation, 2015. The MasterCard Foundation: Rural and Agricultural Finance Strategy.
Masud, M., Azam, M., Mohiuddin, M., Banna, H., Akhtar, R., Alam, A.S.A.F., Begum, H., 2017. Adaptation barriers and strategies towards climate change: challenges in the agricultural sector. J. Clean. Prod. 156, 698–706. https://doi.org/10.1016/j.jclepro.2017.04.060.
Mathaisel, D., 2012. Is scalability necessary for economic sustainability? Eur. J. Sustain. Dev. 4 (2). https://doi.org/10.14207/ejsd.2015.v4n2p275.
Minh, T.T., Michalscheck, M., Singh, R., Schmitter, P. 2022. A guideline for the profiling of innovation bundles.
Mussapirov, K., Djalkibaev, J., Kurenkeyeva, G., Kadirbergenova, A., Petrova, M., Zhakypbek, L., 2019. Business scaling through outsourcing and networking. Entrepreneurship Sustain. Issues 7 (2), 1480–1495. https://doi.org/10.9770/jesi.2019.7.2(48).
Neufeldt, H., Jahn, M., Campbell, B.M., Beddington, J.R., DeClerck, F., De Pinto, A., Gulledge, J., Hellin, J., Herrero, M., Jarvis, A., LeZaks, D., Meinke, H., Rosenstock, T., Scholes, M., Scholes, R., Vermeulen, S., Wollenberg, E., Zougmoré, R., 2013. Beyond climate-smart agriculture: toward safe operating spaces for global food systems. Agric. Food Secur. 2, 12. https://doi.org/10.1186/2048-7010-2-12.
Ngingi, M.W., Muange, E.N. 2022. Access to climate information services and climate-smart agriculture in Kenya: a gender-based analysis [WWW Document]. URL https://link.springer.com/article/10.1007/s10584-022-03445-5 (accessed 1.25.23).
Nii-Koi, G. 2021. ESOKO Integration with digital financial products as a bundled service to AICCRA Farmers [WWW Document]. URL https://cgspace.cgiar.org/handle/10568/117717 (accessed 1.25.23).
O'Grady, M.J., O'Hare, G.M.P., 2017. Modelling the smart farm. Inf. Process. Agric. 4, 179–187. https://doi.org/10.1016/j.inpa.2017.05.001.
Osarenkhoe, A. 2010. A coopetition strategy - a study of inter-firm dynamics between competition and cooperation [WWW Document]. URL https://www.proquest.com/docview/763665374 (accessed 1.25.23).
Ouedraogo, A., Egyir, I.S., Ouedraogo, M., Jatoe, J.B.D., 2022. Farmers' demand for climate information services: a systematic review. Sustainability 14, 9025. https://doi.org/10.3390/su14159025.
Palo, T., Tähtinen, J., 2011. A network perspective on business models for emerging technology-based services. J. Bus. Ind. Mark. 26, 377–388. https://doi.org/10.1108/08858621111144433.
Partey, S.T., Nikoi, G.K., Ouédraogo, M., Zougmoré, R.B. 2019. Scaling up climate information services through public-private partnership business models.
Pels, J., Sheth, J.N., 2017. Business models to serve low-income consumers in emerging markets. Mark. Theory 17, 373–391. https://doi.org/10.1177/1470593117704262.
Pietosi, S. 2021. GSMA Mobile for Development.
Prager, S.D., Byandaga, L., Kagabo, D.M. 2021. Scaling and Sustaining CIS and CSA through Bundled Business Models 13.
Prain, G., Wheatley, C., Odsey, C., Verzola, L., Bertuso, A., Roa, J., Naziri, D., 2020. Research-development partnerships for scaling complex innovation: Lessons from the Farmer Business School in IFAD-supported loan-grant collaborations in Asia. Agric. Syst. 182, 102834. https://doi.org/10.1016/j.agsy.2020.102834.
Rammer, W., Braziunas, K.H., Hansen, W.D., Ratajczak, Z., Westerling, A.L., Turner, M. G., Seidl, R., 2021. Widespread regeneration failure in forests of Greater Yellowstone under scenarios of future climate and fire. Glob. Change Biol. 27, 4339–4351. https://doi.org/10.1111/gcb.15726.
Rosenstock, T.S., Lubberink, R., Gondwe, S., Manyise, T., Dentoni, D., 2020. Inclusive and adaptive business models for climate-smart value creation. Curr. Opin. Environ. Sustain. 42, 76–81. https://doi.org/10.1016/j.cosust.2019.12.005.
Rosenstock, T., Tully, K., Arias-Navarro, C., Neufeldt, H., Butterbach-Bahl, K., Verchot, L., 2014. Agroforestry with N2-fixing trees: sustainable development's friend or foe? Curr. Opin. Environ. Sustain., Sustainability Challenges 6, 15–21. https://doi.org/10.1016/j.cosust.2013.09.001.
Sartas, M., Schut, M., Proietti, C., Thiele, G., Leeuwis, C., 2020. Scaling Readiness: science and practice of an approach to enhance impact of research for development. Agric. Syst. 183, 102874. https://doi.org/10.1016/j.agsy.2020.102874.
Schut, M., Leeuwis, C., Thiele, G., 2020. Science of scaling: understanding and guiding the scaling of innovation for societal outcomes. Agric. Syst. 184, 102908. https://doi.org/10.1016/j.agsy.2020.102908.
Shankar, V., Berry, L.L., Dotzel, T.(2012). A Practical Guide to Combining Products and Services. https://strategicdesignthinking.wordpress.com/wp-content/uploads/2012/11/hbr-pgervices1.pdf.
Shirsath, P.B., Aggarwal, P.K., Thornton, P.K., Dunnett, A., 2017. Prioritizing climate-smart agricultural land use options at a regional scale. Agric. Syst. 151, 174–183. https://doi.org/10.1016/j.agsy.2016.09.018.
Snyder, H., 2019. Literature review as a research methodology: an overview and guidelines. J. Bus. Res. 104, 333–339. https://doi.org/10.1016/j.jbusres.2019.07.039.
Soundararajan, V., Brown, A.J., Wicks, A., 2019. Can Multi-Stakeholder initiatives improve global supply chains? Improving deliberative capacity with a stakeholder orientation. business. Ethics 29 (3). https://doi.org/10.1017/beq.2018.38.

Tesfaye, K., Desta, L.T., Demissie, T., Seid, J., Haile, A., Mekonnen, K., Solomon, D. 2021. A Framework for Bundling Climate-Smart Agriculture (CSA) and Climate Information Services (CIS) in Ethiopia 12.

Tinsley, E., Agapitova, N. 2018. Private Sector Solutions to Helping Smallholders Succeed, Other Agricultural Study. World Bank. doi: 10.1596/29543.

Ulvenblad, P.-O., Ulvenblad, P., Tell, J., 2019. An overview of sustainable business models for innovation in Swedish agri-food production. J. Integr. Environ. Sci. 16, 1–22. https://doi.org/10.1080/1943815X.2018.1554590.

Usher, J., Phiri, C., Linacre, N., O'Sullivan, R., Qadir, U., 2018. Climate Information Services Market Assessment and Business Model Review, USAID-supported Assessing Sustainability and Effectiveness of Climate Information Services in Africa project.

Vaughan, C., Dessai, S., Hewitt, C., 2018. Surveying climate services: what can we learn from a bird's-eye view? Weather Clim. Soc. 10, 373–395. https://doi.org/10.1175/WCAS-D-17-0030.1.

Vedeld, T., Mathur, M., Bharti, N., 2019. How can co-creation improve the engagement of farmers in weather and climate services (WCS) in India. Clim. Serv. 15, 100103. https://doi.org/10.1016/j.cliser.2019.100103.

Vernet, P.A. 2017. Business models for scaling Climate Smart Agriculture in Bihar, India (Report).

Vitalite, L., Links, l., 2021. CSA/CIS Bundle 1: Sustainable financing for off-grid solar irrigation: Using big data to provide user-centric financial solutions to scale end-to-end irrigation technologies and services for small-scale farmers in Zambia [WWW Document]. URL https://cgspace.cgiar.org/handle/10568/117962 (accessed 1.25.23).

Wigboldus, S., Leeuwis, C. 2013. Towards responsible scaling up and out in agricultural development.

Wigboldus, S., Klerkx, L., Leeuwis, C., Schut, M., Muilerman, S., Jochemsen, H., 2016. Systemic perspectives on scaling agricultural innovations. A review. Agron. Sustain. Dev. 36, 46. https://doi.org/10.1007/s13593-016-0380-z.

Woltering, M., Atahan, P., Grice, K., Heijnis, H., Taffs, K., Dodson, J., 2014. Glacial and Holocene terrestrial temperature variability in subtropical east Australia as inferred from branched GDGT distributions in a sediment core from Lake McKenzie. Quat. Res. 82, 132–145. https://doi.org/10.1016/j.yqres.2014.02.005.

Zamboni, K., Schellenberg, J., Hanson, C., Betran, A.P., Dumont, A. 2019. Assessing scalability of an intervention: why, how and who? | Health Policy and Planning | Oxford Academic [WWW Document]. URL https://academic.oup.com/heapol/article/34/7/544/5542084 (accessed 8.5.24).

Zhang, J.J, Lichtenstein, Y., Gander, J.(2015). Business Models and Modelling. https://www.emerald.com/insight/content/doi/10.1108/S0742-332220150000033006/full/html.

Zhao, et al., 2017. Temperature increase reduces global yields of major crops in four independent estimates. Agric. Sci. 114 (35), 9326–9331. https://doi.org/10.1073/pnas.1701762114.

Zimmermann, A., Webber, H., Zhao, G., Ewert, F., Kros, J., Wolf, J., Britz, W., de Vries, W., 2017. Climate change impacts on crop yields, land use and environment in response to crop sowing dates and thermal time requirements. Agric. Syst. 157, 81–92. https://doi.org/10.1016/j.agsy.2017.07.007.

Zougmoré, R.B., Läderach, P., Campbell, B.M., 2021. Transforming food systems in Africa under climate change pressure: role of climate-smart agriculture. Sustainability 13, 4305. https://doi.org/10.3390/su13084305.