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What really impedes the scaling out of digital services for agriculture? A Kenyan users' perspective

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ABSTRACT

Impediments to the scale-out of digital services for agriculture (DSAs) exist in sub-Saharan Africa (SSA). This is despite the promise of these information systems (IS) artifacts to unlock agricultural productivity and outcomes. Existing literature identifies these impediments fortuitously, failing to explain the dimensionality and patterns of association among them. To inform suitable focused effort in the digitalization of agriculture in SSA, the study set out to examine the underlying structure of impediments to DSA scaleout from a likely users' perspective. Employing a parallel convergent mixed-methods design, the study obtained quantitative and qualitative evidence from likely DSA users in Kenya. Using exploratory factor analysis (EFA) on a half-split sample (n=276) the researchers obtained a three-factor structure underlying the impediments to scale-out of DSAs. Using a second split-half sample (n=276), the researchers undertook confirmatory factor analysis (CFA) on the three-factor structure, yielding a good fit. The dimensions in the latent structure, christened "*the three-factor structure of impediments to DSA scale-out*", were technology accessibility, service discoverability, and service value proposition. The researchers undertook thematic analysis of the qualitative evidence (n=241) and proceeded to integrate the resulting six themes with the three-factor structure. The themes were *digital skills, technology infrastructure, service discoverability, service usability, service affordability,* and the *public policy environment*. The researchers integrated five of the themes into the three-factor structure. The researchers argued that the sixth theme on the public policy environment is implicit within the three-factor structure. The study also discussed the implications of the strong covariance between discoverability and value propositions of DSAs for practitioners. This is one of the first research efforts to examine the structure underlying impediments to the scaling out of DSAs from a users' perspective. It also proposes a measurement scale for such impediments. Attention to the three dimensions in the three-factor structure can yield focussed efforts in eliminating these impediments for the increased digital transformation of agriculture in SSA settings.

1. Introduction

Agriculture is arguably the most promising sector for addressing the remaining poverty in Africa [1]. Studies confirm that growth in agriculture is more poverty reducing than an equivalent amount of growth outside agriculture [2,3], more so for the poorest people in the poorest countries [4]. Despite this potential, the sector has continued to exhibit low productivity levels in sub-Saharan Africa (SSA) [5]. Value-added per worker[1] for Agriculture, forestry, and fishing in SSA has steadily[2] almost doubled from 869 US$ in the year 2000 to 1,526 US$ in the year 2019, yet the absolute numbers compare dismally with other sectors. The sector's highest value-added per worker attained in 2019 is tiny in comparison to the services sector values[3] which remained above 6,000 US$ since the year 2,000. The values in the industry sector[4] at over 10,000 US$ per year in the two decades period dwarf the productivity of agriculture even further.

In spite of the dismal performance of agriculture, a promise exists for digitalization to further unlock agricultural productivity and out-

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[1] Value adjusted for purchasing power relative to the US Dollar in 2015.
[2] https://data.worldbank.org/indicator/NV.AGR.EMPL.KD?locations=ZG - Value-added per worker in agriculture, forestry and fishing - sub-Saharan Africa.
[3] https://data.worldbank.org/indicator/NV.SRV.EMPL.KD?locations=ZG - Value-added Per worker in the service sector - sub-Saharan Africa.
[4] https://data.worldbank.org/indicator/NV.IND.EMPL.KD?locations=ZG - Value-added per worker in the industry sector - sub-Saharan Africa.

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comes in SSA countries [6,7]. According to Deichmann et al. [8], the mechanisms by which this promise can be actualized include overcoming the information asymmetry challenges responsible for market inefficiencies in the sector. The mechanisms also include improving on-farm productivity through information-based knowledge and extension services, as well as through the infusion of innovation in supply chain management according to the authors. The application of digital agriculture has also been argued to impact methods of farming and to demand different knowledge, skills, and labor arrangements, ultimately redefining what it means to be a farmer [9,10]. Such digitalization has been argued to promise hyper-transparency in the sector, shifting the roles of stakeholders and broadening the boundaries of global value chains in ways that enhance inclusivity for smallholder farmers [11]. Despite these promises, and many digital agriculture solutions being launched, these IS artifacts have often failed to scale out and achieve widespread usage in SSA [6,8].

Kieti et al. [12] defined a Digital Service for Agriculture (DSA) as *"a solution that uses digital equipment and devices such as mobile phones, computers, satellites, and sensors to solve challenges in agriculture"*. The study adopts this definition while concurring with Han et al. [13] who caution against conflated use of the term *digital platform*. The researchers thus acknowledge a distinction between DSAs, and digital platforms for agriculture (DPAs) as defined in Kieti et al. [[12] and expected to exhibit intermediary logic ([14,15]]. The focus of this study is not DPAs *per se*, but the DSAs which may be constituent components of a DPA [71] or may thrive as stand-alone digital artifacts. Understanding the latent structure of impediments to the scale-out of DSAs has the potential to inform the focusing of interventions to unlock agriculture's digital transformation in SSA. This includes identifying low-hanging fruits for accelerating deployment and the impacts of DSAs.

As discussed in section 2, the researchers found a paucity of literature examining impediments to DSA scale-out comprehensively enough to explicate the underlying dimensions and patterns of associations among them. This is despite the numerous publications suggesting such impediments, albeit fortuitously to their study objectives in most cases. Informed by this gap, the objective of this research was to ascertain the underlying structure among impediments to the scale-out of DSAs from the perspectives of likely DSA users to inform focused efforts. The main research question for this study was: "*What is the dimensionality and pattern of association among impediments to DSA scale-out as perceived by likely users in an SSA setting*?" (RQ1). To directly capture the sentiments of likely DSA users for consideration in the inquiry, the study sought to answer a second research question: *"Which themes describe how impediments to DSA scale-out are perceived by likely users in an SSA setting?"* (RQ2).

In the next section, the researchers report on a survey of past relevant work on impediments to DSA scale-out to demonstrate the gaps in extant literature. The article then describes the materials and methods used in the study under section 3. Thereafter the article presents results separately from the discussions under sections 4 and 5 respectively. The article ends with conclusions in section 6.

2. Literature Review: Impediments to DSA scale-out

To build on existing work, the researchers surveyed the literature resulting from the search string "*(digital OR ICT) AND (agriculture OR farmer) AND (impede OR limit OR obstacle OR hinder OR barrier)*" on *Google Scholar* and *ScienceDirect*. The researchers filtered out publications dated earlier than 2010, prioritizing the results by recency and relevance to the topic and the SSA context. The authors included additional relevant literature upon applying a snowballing strategy. The literature synthesis yielded two categories of obstacles to the scale-out of DSAs, namely, technology concerns and market concerns, as outlined in Table 1.

Kabbiri et al. [16] undertook an inquiry into the underlying structure of obstacles to the adoption of mobile phones for agriculture. The researchers argued that the focus of Kabbiri et al. was not on DSAs, and not beyond the basic functionalities of a mobile phone network. Accordingly, Kabbiri et al. did not provide for scale out dynamics arising from the varying characteristics of DSA providers, as observed in Ezeomah & Duncomb [17]. Kabbiri et al. thus fell short of explaining the latent structure of impediments to the scale-out of DSAs; developed and deployed as specific solutions to agriculture sector problems.

The literature also falls short of explicitly addressing the perspectives of likely DSA users in most cases. The exceptions to this are Kabbiri et al. [16], Mittal et al. [18], and Gichamba et al. [19]. These studies drew directly from empirical evidence among agricultural producers, laborers, traders, commission agents, and the workers of organizations directly involved in agriculture. The perspective of such likely DSA users is likely divergent from the viewpoint of DSA providers, as found in Lohento & Sotannde [20] and Crandall & Kieti [21]. Moreover, the co-mingling of these perspectives as secondary evidence in literature reviews can have a blurring effect on the specific concerns of likely DSA users for targeted intervention. For instance, the researchers argue that some impediments to DSA scale-out such as high customer acquisition costs and difficulty raising investments [8,21,22] are unlikely to manifest in the likely DSA users perspectives. Such DSA users are not decision-makers in marketing the DSA or funding it as investors. Moreover, the categories of impediments to DSA scale-out: *technology* and *market concerns* as derived from the literature may not be considered exhaustive by likely DSA users. Therefore, the researchers found no conceptual clarity on the underlying structure of impediments to the scale-out of DSAs in the literature, especially from the viewpoint of likely users.

3. Materials and Methods

3.1. Research Design

This study was part of a larger cross-sectional research about digital platforms for agriculture. As justified in [12], the researchers chose Kenya, the "*SSA country setting with the most deployments of DSAs and with a heightened economic significance of agriculture*" as the context of inquiry. The choice of Kenya instantiates the SSA setting implied in the research questions. This study was not guided by a predetermined theory or model. This is due to the lack of theoretical clarity on the underlying structure of impediments to the scale-out of DSAs among likely users, as described in sections 1 and 2. The study applied existential abduction using Exploratory Factor Analysis (EFA) and Confirmatory Factor Analysis (CFA) for theory generation on the underlying structure and for theory testing, respectively [23,24]. Complementarily, the study applied an inductive approach using thematic analysis on qualitative evidence for theoretical insights [25,26]. Consequently, the study design was of parallel convergent mixed methods, placing the researchers on a path towards heightened knowledge and validity [27]. Fig. 1. illustrates this research design.

3.2. Instruments and Data collection

Similarly to Kieti et al. [12], likely DSA users can be defined as *"individuals engaged in activities along agricultural value chains with access to computing devices and the internet or basic data connectivity"*. The researchers conceived ten statements, five on market concerns and five on technological concerns, for a survey targeting these likely users. This design drew from the literature synthesis and the researchers' experience in the convergence of agriculture and digital technologies. The survey instrument also included open-ended questions for additional qualitative evidence. The researchers further refined the instrument with the inputs of agriculture and digital services experts, deployed on the SurveyMonkey platform, and pre-tested in a focus group setting among farmers as described in Kieti et al. [12]. Among the resulting refinements was simplification for online self-administration, reducing options for

Table 1
Literature survey on impediments to DSA scale-out.

Category	Impediment	Sources
Technology concerns	Internet, and other connectivity challenges especially in rural areas (uneven coverage and unreliable or costly networks)	Ogutu et al. [7]; Karippacheril [65]; Saidu et al. [66]; Lohento & Sotannde [20]; Kos & Kloppenburg [11]
	Choice of technology deployment channels given variable capabilities of computing devices and their affordability	Mittal et al. [18]; Karippacheril [65]; Gichamba et al. [19]; Aker et al. [6]; Rumanyika et al. [67]; Kansiime et al. [68]
	Electricity for charging computing devices being unreliable or costly with uneven coverage	Mutula [45]; Jain et al. [69]; Aker et al. [6]; Saidu et al. [66]; Ezeomah & Duncomb [17]
	Low education levels and language difficulties	Qiang et al. [60]; Okello et al. [55] Karippacheril [65]; Jain et al. [69]; Gichamba et al. [19]; Aker et al. [6]; Saidu et al. [66]; Kabbiri et al. [16];
Market concerns	Low awareness among target users; and low affordability of customer acquisition costs among providers	Mittal et al. [18]; Crandall & Kieti [21]; Deichmann et al. [8]; Fabregas et al. [22]; Kim et al. [59]
	Sectoral fragmentation, DSAs lacking comprehensiveness, missing one-stop-shop, missing ecosystem-wide support and collaboration and among actors	Qiang et al. [60]; Batchelor et al. [70]; Karippacheril [65]; Deichmann et al. [8]; Gichamba et al. [19]; Ezeomah & Duncombe [17]; Lohento & Sotannde [20]; Kim et al. [59]
	Transaction costs and costly or incompatible revenue models	Qiang et al. [60]; Okello et al. [55]; Karippacheril [65]; Gichamba et al. [19]; Fabregas et al. [22]
	Unconvincing usefulness and mismatch of value expectations; including user experience, trust, reliability, efficiency, and action orientedness	Mittal et al. [18]; Wyche & Steinfield [64]; Deichmann et al. [8]; Aker et al. [6]; Saidu et al. [66]; Baumüller, [54]; Kabbiri et al. [16]; Ezeomah & Duncomb [17]; Lohento & Sotannde [20]; Kos & Kloppenburg [11]

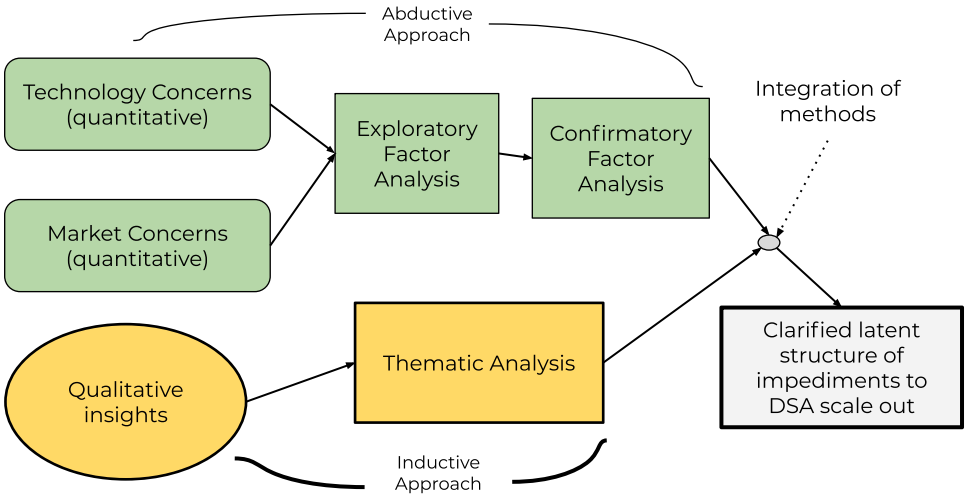

Fig. 1. The research design.

the Likert-like scale questions from five to three: - "*I disagree*", "*I neither agree or disagree*", and "*I agree*". Appendix A shows the instrument arising from these refinements.

The researchers broadcast the questionnaire as a weblink to over 300,000 likely DSA users, leveraging the flourishing of virtual agriculture-themed communities online. This process obtained 887 respondents overall, with 785 remaining valid after data cleaning, as Kieti et al. [12] described. The participant inclusion criteria for this paper were either responding to all ten close-ended statements (552) or providing rich qualitative insights via the relevant open-ended questions (241). Respondents meeting these overlapping criteria totaled 582. Appendix B shows a summary of the respondents.

3.3. Factor Analysis and Thematic Analysis

To apply EFA on the 10-item data, a minimum of 100 observations were required to attain the recommended threshold ratio of 10:1 [28]. The sample (N=552) was five times more than adequate by this threshold. In the ideal situation, a researcher should split a sample, using one half to examine and develop the structure and the other half to validate the structure [29]. The researchers randomly divided the quantitative data into two split-half samples (n = 276), adequate to use on the EFA by the 10:1 criterion. The researchers determined the number of extractable factors using parallel analysis [30], the superior sample-based alternative to the more common Kaiser greater-than-1 criterion [31].

The study used the Kaiser-Meyer-Olkin (KMO) to ascertain sampling adequacy on whether the data could be grouped into smaller sets of underlying factors [28], whereby a score above 0.6 is acceptable [32]. Complementarily, the study used Bartlett's Test of Sphericity, with a chi-square statistic $p<0.001$ to indicate appropriateness to apply EFA. The researchers used the Principal Component Analysis (PCA) extraction method to determine the respective loadings in the EFA. They chose it over Maximum Likelihood (ML) because they measured the items on an ordinal scale, and the data defied the assumption of multivariate normality. The researchers rotated the resulting matrix to clarify loading patterns in the EFA and ease of interpretation. Initially, an oblique rotation method, oblimin, was used whereby the inexistence of values above 0.32 in the inter-factor correlation matrix would imply the absence of a strong correlation [32] hence the use of an orthogonal rotation method; varimax. The study identified highly cross-loading items by evaluating the ratio of their squared loadings and eliminated them from the analysis if the ratio fell below 2.0 [28]. The study dropped Variables with loadings less than 0.30 from the factors and considered loadings greater than 0.50 as practically significant [28].

On the second split-half sample (n=276), the study employed Confirmatory Factor Analysis (CFA) to obtain and validate the factors associated with impediments to the scale-out of DSAs as hypothesized from the

Table 2
EFA of impediments to the scaling out of DSAs.

	EFA1			*EFA2*		
KMO	0.81			0.79		
Bartlett's Test of Sphericity	χ2(45)=709.56 p<0.001			χ2(36)=603.83 p<0.001		
Total Variance Explained	57%			61%		
Measured Items	F1	F2	F3	F1	F2	F3
T1 - Requiring high literacy levels	0.68			0.74		
T2 - Requiring access to the internet	0.84			0.87		
T3 - Requiring the use of smartphones rather than more affordable phones	0.81			0.83		
T4 - Requiring phones to be always charged	0.59		0.30	0.54		
T5 - Incurring expensive data and SMS charges	0.58		0.46	N/A	N/A	N/A
M1 - Awareness about them is low		0.64			0.65	
M2 - There is no one-stop-shop where all of them can all be found		0.84			0.89	
M3 - They do not work together or share data with each other		0.66	0.34		0.66	0.32
M4 - Their charges are too high to keep paying			0.81			0.78
M5 - The value they offer their target customers is not convincing			0.71			0.84

Extraction method = PCA; Rotation method = Oblimin

EFA. The study used the diagonally weighted least squares (DWLS) estimator method rather than Maximum Likelihood (ML) as it was specifically designed for ordinal data and was superior to Robust ML (MLR) in the estimation of factor loadings [33]. The researchers used the Comparative Fit Index (CFI), Tucker-Lewis index (TLI), Root Mean Squared Error of Approximation (RMSEA), and Standardized Root Mean Squared Residual (SRMSR) to assess the goodness of fit. CFI>0.90, TLI>0.90, RMSEA<0.08, and SRMSR<.08 indicate a good fit [34,35]. For EFA and CFA the researchers used *R* [36] as it was affordable, being accessible on open-source licensing.

For the 241 open-ended responses, the researchers conducted thematic analysis using version 9 of *ATLAS.ti [* [[*37-2021*] software for Apple MacBook computers. The researchers followed the seven-step procedure proposed by Friese et al. [38], which adapted the six-step procedure in Braun & Clarke [39] for thematic analysis. The study then integrated the qualitative findings as themes elaborated and aligned to the dimensions confirmed in the factor analysis.

4. Results

Among the participants, the majority were male at 75%. The median age range was 24-34, and 73% had attained a diploma certificate or higher education level. Reliance on agriculture for income among the participants was 83%. Primary agricultural production activities such as rearing animals and growing crops were the most represented value chain activities at 85%. A detailed breakdown of the sample profile is in appendix C.

4.1. The underlying structure

The quantitative ratings of the items on impediments to DSA scale-out were not normally distributed as the study obtained the Henze-Zirkler statistics of 8.5, p-value<0.001. The researchers ascertained three extractable factors using parallel analysis on the first split-half sample (n=276). The study obtained KMO 0.81 and 0.79 and Bartlett's test of sphericity p<0.001 as shown in Table 2, indicating the appropriateness of the EFA procedure. Table 2 also shows pattern matrices obtained with factor loadings rotated using the oblimin method. In the first EFA (EFA1), *"T4 - Requiring phones to be always charged "* cross-loaded on F1 (0.59) and F3 (0.30) but not highly as the square of the loadings yielded a ratio of 3.8, being higher than the 2.0 threshold in Hair et al. [28]. Likewise, "T*hey do not work together or share data with each other*" cross-loaded on F2 (0.66) and F3 (0.34) but not highly with the square of the loadings yielding a ratio of 3.7. However, the item "*T5 - Incurring expensive data and SMS charges*" cross-loaded highly on factors F1 (0.58) and F3 (0.46), with the square of their loadings yielding a ratio of 1.6. Therefore the researchers conducted a second EFA (EFA2) without this item. This increased the total variance explained from 57% to 61% and left no more items highly cross-loading. The three factors extracted were conceptualized as *F1 - technology accessibility, F2 - discoverability*, and *F3 - value proposition* and are discussed in sections 5.1,5.2, and 5.3, respectively, and together as a structure in section 5.5.

Table 3
Measurements for Reliability and Construct Validity.

Construct	Items	CR	AVE	HTMT ratio F1	F2	F3
F1 - Technology accessibility	4	0.84	0.57	1.00		
F2 - Service discoverability	3	0.78	0.55	0.42	1.00	
F3 - Service value proposition	2	0.80	0.66	0.39	0.82	1.00

The researchers used the second half of the data (n=276) for CFA to examine how well the data fit the three-factor structure emerging from the EFA. As indicated in Table 3, the researchers ascertained the internal consistency of the three subscales with the Composite Reliability (CR) measurements being 0.70 or higher, and below 0.95 [28,40]. This reliability and the Average Variance Extracted (AVE) being above 0.50 for all three subscales meant that convergent validity was established [41]. For discriminant validity, the study used the Heterotrait-Monotrait ratio (HTMT) of the correlations, which is superior to the commonly used Fornell-Larker criterion [42,43]. Discriminant validity was established under the $HTMT_{0.85}$ criterion as the HTMT ratios were below 0.85.

The standardized factor loadings estimated in the CFA are shown in Fig. 2. With the CFA, the study obtained χ2(24)=19.23; p-value=0.740. This meant a Chi-square/Degrees of freedom ratio of 0.80; suggesting an acceptable fit. Further, the study obtained fit indices CFI=1.000, TLI=1.010, RMSEA=0.000, and SRMSR=0.055 which indicated this second half-split of the data fit the three-factor structure well. A nine-item measurement scale with three dimensions of impediments to the scale-out of DSAs was established in line with Fig. 2.

With a factor loading of 0.80, "*T2 - Requiring internet access*" was the most impactful indicator item on technology accessibility as an impediment to DSA scale-out. With all factors remaining constant, a unit increase in this indicator increases technology accessibility as an impediment by 80%. Likewise, "*M3 - Low collaboration"* was the most impactful indicator on discoverability at 0.76. The strongest covariance in the CFA was between discoverability and value proposition at 0.83. As such, intervening for a unit change in DSA discoverability impacts DSA value proposition by 83% and vice versa.

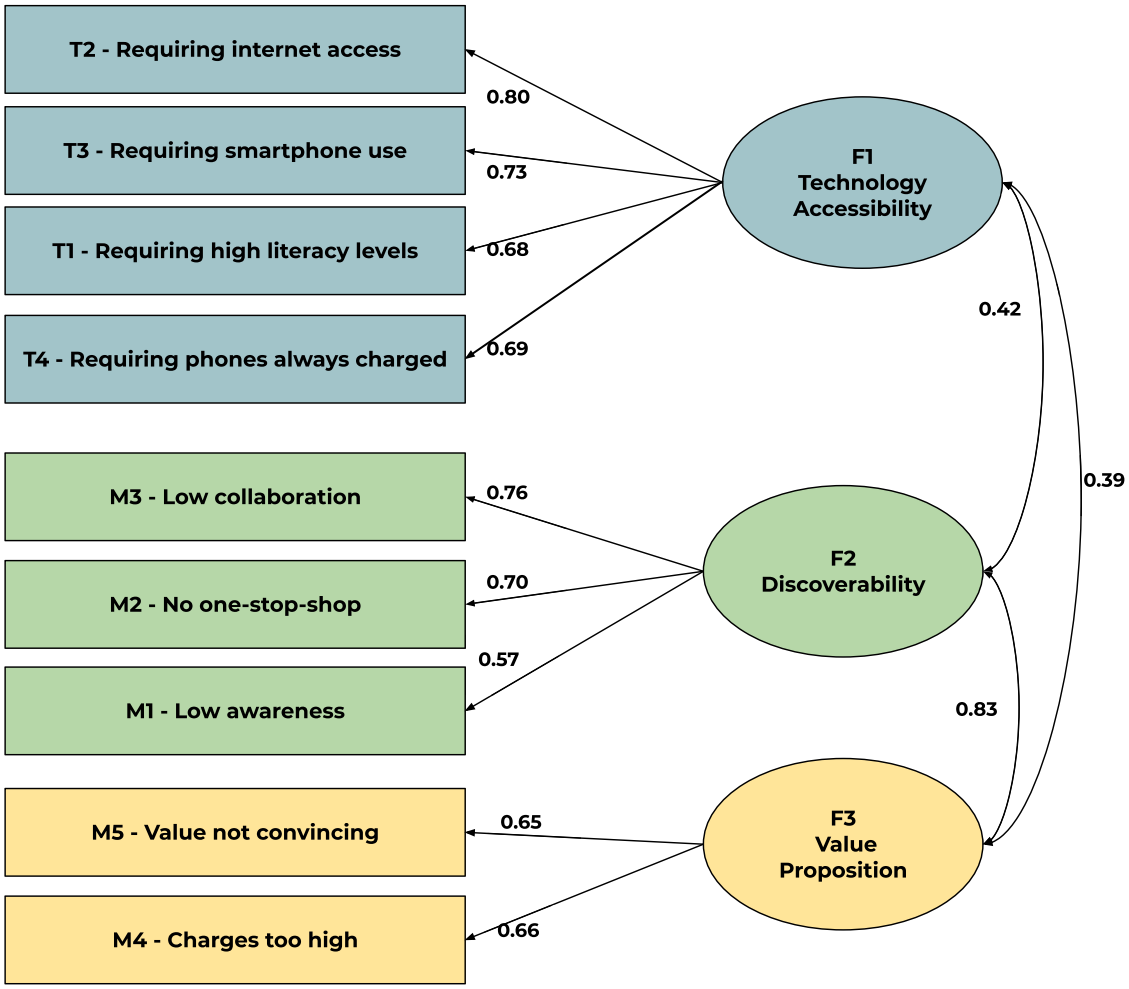

Fig. 2. CFA of 3-factor structure of impediments to DSA scale-out (n=276).

4.2. Themes from qualitative evidence

To answer the research question - "*Which themes describe how impediments to DSA scale-out are perceived by likely users in an SSA setting?*", the researchers undertook a thematic analysis of the respondents' qualitative responses. This yielded six themes, namely: (a) technology infrastructure, (b) digital skills, (c) service discoverability, (d) service usability, (e) service affordability, and (f) the policy environment. The thematic map in Fig. 3 summarises these themes and their subthemes.

4.2.1. Digital Skills

The qualitative evidence indicated that general literacy *per se* was not crucial as an impediment to the scale-out of DSAs. The respondents deemed literacy levels high, with educated people venturing into agriculture after failing to secure professional jobs and de-emphasizing challenges of general literacy. Nonetheless, they considered farmers to lack operational digital skills in using smartphones even when they could afford such devices.

> *"... most of the players in agriculture are rural farmers who most of the time lack the digital literacy to use smartphones" ~ Female respondent aged 25-34 providing specialised advisory services to farmers.*

The respondents considered the unavailability of trainers to facilitate digital skills enhancement among farmers an impediment. They indicated younger people as adaptable to digital technology and more strategic to involve than older people in the scale-out of DSAs. However, the enthusiasm for digital services among young people was deemed untapped for expanding the uptake of DSAs. The respondents considered young farmers not to appreciate the power of DSAs.

4.2.2. Technology Infrastructure

The qualitative responses included difficulties in accessing technology infrastructures such as the internet and basic mobile network coverage as hampering the uptake of DSAs. The respondents noted that geographical inequality in technology access was more pronounced in remote and rural areas where most agricultural production occurs. The qualitative responses linked the technological infrastructure limitations to electricity access and mobile network coverage:

> *"DigiFarm may sometimes not operate in remote areas due to network inaccessibility" ~ male respondent aged 18-24 year involved in agricultural production.*

On the one hand, the respondents indicated that large-scale farmers can access advanced smartphones, including those with enhanced battery life. On the other hand, they argued that small-scale farmers could only afford feature phones for essential communication and mobile money services. The respondents desired universal access to DSAs through low technology channels such as Short Message Service (SMS), Unstructured Supplementary Service Data (USSD), and Interactive Voice Response(IVR), not needing smartphones. Moreover, they suggested that deployment channels other than mobile phones diversify access to DSA benefits.

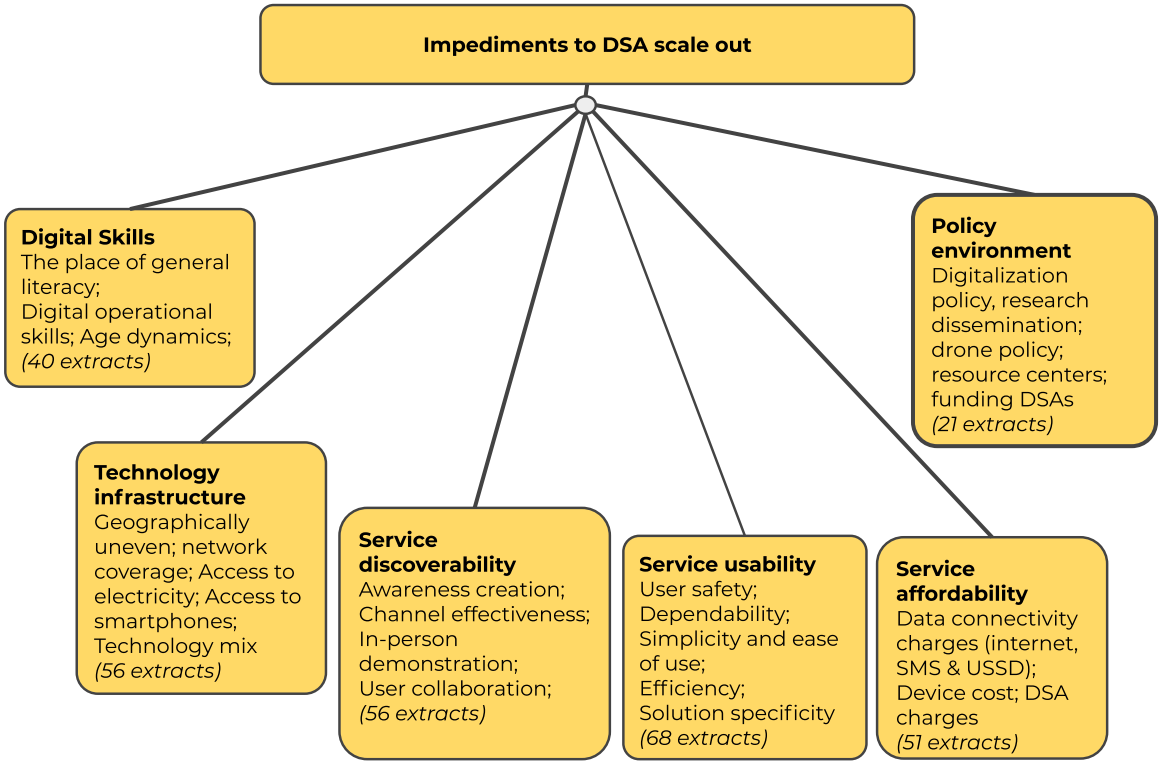

Fig. 3. Thematic map as generated from qualitative evidence (n=241).

4.2.3. Service Discoverability

The qualitative responses indicated low discoverability of DSAs as a limitation to their scale-out. They mainly attributed the low discoverability of DSAs to ineffectiveness among the awareness creation channels used and the absence of collaboration among players in the digital agriculture ecosystem. The respondents observed that farmers were likely to own and use smartphones for communication via social media platforms yet remain blind-sided on the opportunity to use DSAs. As such, the farmers were unaware of DSAs accessible through the same technological infrastructure they were familiar with:

> *"Lack of exposure is one of the biggest reasons for not using digital platforms. I use my smartphone a lot but mostly WhatsApp. How do I know there are other apps that can teach me better agribusiness?" ~ female respondent aged 55-64 years involved in agricultural production*

The respondents went further to suggest an array of possibilities to market DSAs effectively. These included advertisements on websites and social media platforms, including the use of social media influencers. They also suggested offline channels such as newspapers, journals, radio, billboards, school education curricula, and TVs. In-person demonstration of value was deemed effective for the persuasion of farmers to use DSAs. The inexistence of one-stop-shop platform for accessing DSAs was deemed to not only undermine their discoverability. It was depicted to undermine the efficient use of time by agricultural actors as well. Low collaboration at the peer level among farmers was observed, characterized by the prioritization of individual-level effort over the collective effort in the usage of DSAs. This, and weak collaboration among other stakeholders in agriculture were depicted to hinder the growth and uptake of DSAs.

4.2.4. Service Usability

The scaling out of DSAs was depicted as constrained by their low usability. For this, the respondents expressed unmet user expectations, user experience friction, and user safety concerns. They faulted DSAs for not being dependable in fulfilling their promises. The respondents expressed concerns that DSAs offered broad-based solutions with little demonstrable value at a user-specific level. The respondents noted that nuanced preferences and niches remained unaddressed by DSAs, in examples of unmet expectations of solution specificity. Using DSAs was indicated as time-consuming, yet the work of farmers was deemed too laborious to afford distractions of using DSAs. Moreover, the respondents expressed unease about user safety in otherwise useful DSAs. The fears included concerns about protecting user privacy, being hacker-proof, and detecting or eliminating abuse by fellow users:

> *" scammers are very many and have distorted the true platforms from the fake ones, this has led to mistrust". ~ male respondent aged 35-44 years involved in agricultural production*

4.2.5. Service Affordability

Expensive charges for data connectivity to access DSAs, although not payable to DSAs, were deemed to undermine the scaling out of *DSAs*. Likewise, the respondents considered the cost of smartphones to undermine the affordability of DSAs and their scale-out. Beyond the cost of data and devices, the respondents suggested free access to DSAs as websites, mobile applications, and other deployment channels. They expected Government agencies, in particular, to provide essential information-based DSAs for free. While the respondents indicated reluctance among specialists to provide services for free, they called for fair pricing of DSAs, including avoiding undue profiteering.

> *"There should be more customer-based / oriented solutions at a fair price, not (only) after making fame and profit" ~ male respondent aged 25-34 years engaged in agricultural production*

4.2.6. Public Policy

Respondents faulted the Government for not adequately supporting the digitalization of agriculture. They particularly faulted the national and county governments for not leveraging digital services to enhance their input subsidization programs and not adequately supporting the use of drones in agriculture. The respondent also faulted governments

for not supporting the marketing and selling of agricultural produce online and not enhancing markets with transparent and timely information on commodity prices. The respondents faulted government-backed research institutions for not adequately disseminating the information they hold. The respondents went further to call for Government investment to promote transparency of commodity prices and support farmers in marketing their commodities using DSAs. The respondents also suggested that Governments should finance DSAs:

> *"They (DSAs) should get government funding so that they get their services down to the lowest farmers."* ~ *male respondent aged 45-54 involved in agricultural production.*

In addition, the respondents called upon Governments to facilitate training, sensitization, and technology access among agriculture stakeholders to eliminate impediments to the scale-out of DSAs

5. Discussion

For the first research question, the study ascertained three dimensions and their patterns of association by performing factor analysis on two half-split samples and presented the results in section 4.1. For the second question, the researchers generated the six themes in section 4.2 from the qualitative evidence.

This paper's contribution to the literature on DSA scale-out is twofold. Firstly, the study integrates the qualitatively generated themes with the structure arising from the quantitative findings. In subsections 5.1,5.2, and 5.3, the researchers show that five of the themes align with the dimensions of the three-factor structure while highlighting their relation to the existing literature on the digital divide and business model design. In sub-section 5.4, the researchers argue how the sixth theme is implicit in the three-factor structure. The second theoretical contribution in subsection 5.5 is to propose a three-factor structure explaining the dimensionality and patterns of association among impediments to DSA scale-out, including a measurement scale for such impediments.

5.1. Technology Accessibility

Three items loaded highly in the CFA to *technology accessibility*, connoting physical access barriers to the scale-out of DSAs. The items are "*T2 - Requiring internet access*", "*T3 - Requiring smartphone use"*, and "*T4 - Requiring phones always charged*". The essence of these indicators features prominently in the *technology infrastructure* theme in the qualitative evidence. The researchers contend that these three items constitute the technological infrastructure aspect of *technology accessibility* as an impediment to DSA scale-out. The researchers also argue that the prominence of technology infrastructure aspects in the evidence depicts the significance of the first-level digital divide, which comprises material access barriers [44,45]. The respondents' sentiments of rural and remote areas suffering unreliable network connectivity are consistent with the identification by Ernest III et al. [46] of geography as one of the demographic dimensions of the digital divide.

The researchers relate the high factor loading in the CFA of the fourth item, "T1 - Requiring high literacy levels" on technology accessibility, to the significance of the second-level digital divide [47] in impeding DSA scale-out. At this level of the digital divide, skills access barriers impede the use of technology even if material access barriers no longer exist. However, the researchers observe that general literacy *per se* is de-emphasized as an impediment to DSA scale-out in the qualitative evidence under the digital skills theme. Instead, the respondents emphasized operational digital skills among targeted users as missing enablers of DSA scale-out. The researchers contend that literacy is a proxy indicator of the required digital skills as it unlocks the understanding of DSAs and how to apply them to ones' tasks. Furthermore, the researchers link the observed high enthusiasm among young people and negative attitudes among older people regarding technology to the mental access barriers characterizing the digital divide [48]. Hargittai [49] posited these mental access barriers as more manifest among older people than younger people. The researchers contend that mental access barriers undermine acquiring digital skills and the requisite self-efficacy to use technology, comprising technology accessibility impediments to the scale-out of DSAs. This study holds *technology accessibility* as a major dimension of impediments to DSA scale-out encompassing the *technology infrastructure* and *digital skills themes* generated in the qualitative evidence.

A DSA provider may seek to address *technological infrastructure* access concerns among its likely users through "low-tech" deployments. These include basic phones with USSD and SMS technologies where access to the internet and smartphones is limited. The researchers contend that these technological infrastructure concerns are of a broader scope relating to national infrastructure provision and regulation, beyond the purview of the DSA provider. Likewise, while a DSA may provide tutorials and technical support functions to supplement operational skills among its users, digital skills access as an impediment to DSA scale-out is best addressed as a macro-level concern. DSA providers lack the resources and the influence to increase digital skills at a large scale, an intervention in the purview of policymakers and other actors in the larger digital agriculture ecosystem. The researchers position *technology accessibility* as an impediment to DSA scale-out in the first and second levels of the digital divide and contend that it requires interventions at a broad level beyond the efforts of individual DSAs.

5.2. Service Discoverability

This dimension was manifested highly in three items in the CFA namely:- "*M3 - Low collaboration*", "*M2 - no one-stop-shop*", and "*M1 - Low awareness*". The quantitative evidence on this dimension directly aligns with the corresponding theme in the qualitative evidence. Low awareness about DSAs was consistent with the difficulties among DSA providers in creating awareness of their services [21,22]. The weak collaboration observed among actors in the digital agriculture ecosystem was consistent with the fragmentation [8] and lack of ecosystem-wide collaboration support among actors [20]. The findings indicate an extended collaboration concern to cover not only DSA providers complementing the work of network operators and device providers [50] among the high-level stakeholders. Collaboration among end-user actors called for as an intervention area for increased scale out of DSAs is noteworthy. It is indicative of the awareness creation potential of end-user collaboration and the potential for data-level collaboration as with agricultural data cooperatives and coalitions in the clamor for data sovereignty [51]. The absence of a one-stop-shop contributing to DSA scaleout impediments as evidenced in this study is consistent with the clamor for comprehensiveness among DSAs and DPAs [17,19]. The researchers further argue that service discoverability as an impediment to the scale-out of DSAs relates to the *channels* and *partnerships* components of the DSA business model [52]. Low awareness relates to the channel effectiveness, while the collaboration or its absence between the DSA provider and other digital agriculture ecosystem actors relates to partnerships. The DSA provider may forge new or join existing partnerships that contribute to its enhanced visibility and discoverability.

The researchers contend that large corporations can leverage their marketing budgets and distribution networks to overcome *service discoverability* challenges of the DSAs they acquire, develop or advance in partnership with digital entrepreneurs. Moreover, these large organizations with a global or nationwide presence, including mobile network operators, device manufacturers, software platforms, and agricultural inputs firms, are considered major drivers of digital agriculture [53]. Further, the researchers argue that an Aggregator Platform for Digital Services in Agriculture (AP4DSA), as conceptualized in Kieti et al. [12], can address service discoverability concerns. An AP4DSA can be a collaboration platform and a one-stop-shop where all DSAs may be located, accessed, reviewed, and rated. Such a digital platform can be a market-

place for DSAs. It can foster openness, collaboration, and competition among digital agriculture ecosystem actors in ways that enhance DSA benefits to populations at the base of the pyramid [50]. The collaboration can include actor intermediation and automated sharing of data, subject to appropriate data protection provisions. Such collaboration can constitute alliances of specialized DSAs, and mobile network operators brought together by entrepreneurial support programs, as with the case of *Mercy Corps' AgriFin accelerator*[5] giving rise to the *DigiFarm* platform in Kenya. Moreover, the thriving of an AP4DSA can lead to enhanced awareness creation about its constituent actors. This is more so if the AP4DSA design minimizes search costs related to discovering and using constituent DSAs [12]. The researchers add a caveat that an AP4DSA can independently suffer the impediments of "*M1 - Low awareness*" and "*M3 - Low collaboration"* if its implementation does not consciously address them. For instance, an AP4DSA not collaborating with other actors in a digital agriculture ecosystem undermines any leverage it may have to foster such collaboration among its constituent DSAs.

5.3. Service Value Proposition

The high factor loading of *"M4 - charges too high*" on *Service Value Proposition* as an impediment to DSA scaleout can be linked to the *Service affordability* theme generated in the qualitative evidence. Service affordability is a manifestation of the income demographic dimension of the digital divide [46]. As such, likely users may not always afford fees charged by the DSA despite compelling value. This study's finding is consistent with Gichamba et al. [19], who found that in low resource settings, agricultural actors preferred low-cost DSAs that they could afford even during seasons of financial hardship. Furthermore, the ability of DSAs to charge their users, more so for information-based DSAs, is undermined in economic theory by information as a commodity being non-rival [22]. The researchers further argue that service affordability as an aspect of service value proposition relates to the *cost structure* and *revenue streams* components of a DSA's business model [52]. Moreover, affordability relates to whether the DSA can collect revenue from delivering the service enough to cover their costs and earn a surplus.

Similarly, *service value proposition* as manifested in the high factor loadings for the item "*M5 - value not convincing*" can be linked to the *Service usability* theme in the qualitative evidence. The service usability theme is indicative of the prospects of the user to derive value from using the DSA. Such value has to be compelling enough to exceed the costs and inconveniences of accessing it. According to the qualitative evidence, impediments to DSA scale-out in the form of impaired service usefulness such as the lack of solution specificity, user-experience friction, and lack of user safety make a DSA's value unconvincing. This finding concurs with past studies where usefulness of DSAs was not always convincing [6,17,54]. It is also consistent with the characterization of the digital divide to comprise usage-related barriers [44,48].

Consequently, *Service value proposition* as an impediment to DSA scale-out is an evaluation of benefits versus the costs incurred by users beyond overcoming the initial technology accessibility and service discoverability impediments. It relates directly to the *value proposition* component in a business model by the taxonomy in Osterwalder & Pigneur [52]. The researchers contend that a cyclic relationship exists between the usefulness and affordability of DSAs as the value derived by users can lead to increased income generation and economic empowerment, hence increased affordability. Such increased service affordability yields increased demand and value derivation [55], hence usefulness. The researchers contend that such a virtuous cycle leading to increased intensity of DSA access and beneficial use can bridge the third-level digital divide on technology impact as well as address usage access barriers in the second-level of the digital divide [47,56].

[5] https://www.mercycorpsagrifin.org/project/digifarm-a-digital-platform-made-for-farmers/.

5.4. Public policy as an implicit theme

This theme generated from the qualitative evidence was consistent with extant literature on the important role played by the policy and regulatory environment in e-business diffusion [62]. Moreover, the importance of this role has been argued to be more pronounced in developing than developed countries [57]. The findings tally with Birner et al. [53], who argue for public efforts to leverage private-sector efforts in digital agriculture for a vibrant industry with benefits distributed fairly among actors in developing countries. This theme was not explicitly manifest in the three dimensions resulting from the factor analysis. However, the researchers argue that public policy concerns are implicit across the three dimensions. For instance, *technology accessibility* as an impediment to the scaling out of DSAs can be minimized through increased public policy interventions to improve the telecommunications infrastructure for universal access and to reduce the digital divide [58]. This is especially in rural areas where most primary agricultural production occurs, as suggested in Aker et al. [6] and concurring with Kim et al. [59]. Technological infrastructure access interventions by Governments could also be through rural ICT community centers as suggested by the respondents. Promoting the large-scale acquisition of digital skills through public formal education systems can also enhance *Technology accessibility*. Public policy investment in an AP4DSA through the funding, coordination or public endorsement of such a platform can also minimize *Service discoverability* as an impediment to DSA scale-out. In concurrence with Kim et al. [59], governments can also invest in enhanced awareness creation and distribution frameworks for existing beneficial DSAs. Governments can also promote collaboration among actors to advance initiatives that produce common good benefits such as open data and data cooperatives. Subsidizing DSA costs to reduce service affordability challenges for essential DSAs can minimize impediments related to their V*alue proposition*. Fabregas et al. [22] uphold the case for Government subsidization of DSAs as social investments given the expected difficulties for providers charging for information-based DSAs. From a DSA provider perspective, Lohento & Sotannde [20] argue that funding limitations hinder DSA success. The authors contend that public policy can inform the funding of DSAs by the Government as suggested by the respondents. This could be in financial and talent development support to DSA providers to enhance service usefulness hence their value propositions. Regulatory and enforcement mechanisms for data security and the elimination of user safety-related barriers can enhance the value propositions of DSAs. Moreover, this study concurs with Qiang et al. [60] on the need for regulatory forbearance in digital agriculture. This can include granting space for DSAs providers to experiment with new services, be innovative, and be rewarded for taking risks. Furthermore, policy and regulatory interventions are also needed to manage potential threats to digital agriculture, such as market imperfections [58,59] and unhealthy dominance by agricultural input providers [53].

5.5. The proposed three-factor Structure

In answering the first research question of this study, the researchers submit their "*the three-factor structure of impediments to DSA scale-out*" illustrated in Fig. 2 for evaluation and use by researchers and practitioners alike. The researchers explained the three dimensions of *technology accessibility, service discoverability,* and *service value proposition* by integrating the qualitatively generated themes in the preceding subsections. The study established the unidimensionality of variables in the three-factor structure after dropping the item "*T5 - Incurring expensive data and SMS charges*". A probable reason for this item's highly cross-loading on *technology accessibility* and *service value proposition* is that it combined cost aspects of physical infrastructure and individual DSA pricing. It depicts the inability among users to distinguish internet data and SMS costs charged by network providers from the extra costs charged by DSAs on a one-off or recurring basis. The authors contend that while all these costs remain implicit in both *technology accessibility* and *service value proposi-*

tion, fees charged by a DSA provider explicitly relate to their service's affordability, hence uniquely impacting its value proposition.

The authors also propose adaptation and use of the three-factor, nine-item measurement scale for impediments to DSA scale-out. This is building on the reliability and construct validity ascertained in Table 3. Guidelines by Hair et al. [28] suggest three or more manifest items per factor for maximized construct reliability and adequate coverage of the construct's theoretical domain. Hair et al. [28] also encourage the use of the least number of items for parsimony. On the one hand, the two items in the structure covering the value *proposition* result in adequate composite reliability at 0.80. This compares favorably with the generally recommended composite reliability above 0.70 and not above 0.95 in Hair et al. [28]. Conversely, it can be argued based on the qualitative evidence that the item "*M5 - value not convincing*" may not adequately cover aspects of *service value proposition* such as user safety, user-experience friction, dependability, and service relevance. The researchers contend that their consolidation of such concerns into "*M5 - Value not convincing*" avoids creating sub-factors, possible with inadvertent focus on the service usability aspect of "*value proposition",* as cautioned against in Hair et al.

The strong and positive covariance between *service discoverability* and *service value proposition* is noteworthy. A probable reason is that increased discoverability can result in expanded usage, network effects, economies of scale, and user feedback which can, in turn, enhance the service's value offerings. Improved value propositions of DSAs can also gain social validation such as media coverage, and the virality likely with peer-to-peer referrals among gratified users, leading to increased discoverability. Moreover, these strongly co-varying dimensions are typically in the DSA provider's purview since they constitute aspects of the provider's business model. As discussed in section 5.1, this is not necessarily the case with *technology accessibility*.

5.6. Implications for policy and practice

Policymakers can use the findings of this study to prioritize and designate intervention areas by addressing environmental aspects impeding the scale-out of DSAs in SSA countries. As elaborated in section 5.4, policy and regulatory interventions should address impediments implicit in the three dimensions of the three-factor structure. Increasing digital inclusivity by eliminating access barriers is implied as a policy intervention for technology accessibility, especially in rural areas where most agricultural production is situated. Subsidizing or funding DSAs activities is also implied to eliminate *service value proposition-related* bottlenecks. So is policy and regulatory effort to catalyze the digitalization of agriculture through DSA uptake and to protect the industry from exploitative actors. *Service discoverability* impediments call for policy interventions in awareness and collaboration enhancing initiatives such as an AP4DSA.

The authors recommend that digital entrepreneurs and intrapreneurs in SSA facing agriculture sector-related business model innovation and DSA scale-out challenges exploit the cyclic relationship between affordability and usefulness under *service value proposition*. The authors recommend leveraging marketing budgets and distribution networks among managers of large organizations with a nationwide physical presence for enhanced discoverability of DSAs. Further, the authors recommend collaboration among digital agriculture ecosystem actors towards a thriving AP4DSA as described in section 5.2.

5.7. Limitations and directions for future research

Using three options on the survey's Likert-like scale rather than five or seven possibly limited the findings in this study. However, the trade-off for this limitation paid off in more timely and cost-effective acquisition of reasonably large samples of the qualitative and quantitative evidence than if the researchers designed the study differently. The proposed measurement scale for impediments to the scale-out of DSAs may provide a reference point for further research analyzing impediments to DSA scale-out to unlock the promise of DSAs in SSA settings. The authors recommend the incorporation of the qualitative findings in further adapting or enhancing the measurement scale. Further research may also ascertain whether the qualitatively generated theme of the *public policy* can stand on its own as a fourth independent dimension. This study's findings can be analytically replicated in other human development sectors such as education and health. The researchers also recommend further research into the prospects of AP4DSAs to facilitate organizing and consolidating DSA benefits in SSA settings at the digital agriculture ecosystem level.

6. Conclusion

This study is one of the first research efforts examining the underlying structure of impediments to the scaling out of DSAs from a users' perspective. It uses parallel convergent mixed methods, including factor analysis and thematic analysis, combining inductive and deductive approaches, to pursue conceptual clarity. Quantitatively, the study ascertained a three-factor structure underlying impediments to DSA scale-out. The three dimensions of the structure are "technology accessibility", "service discoverability", and "service value proposition". Qualitatively, the study identified six themes on impediments to DSA scaleout. These themes include "technology infrastructure" and "digital skills" which correspond to the technology accessibility dimension in the three-factor structure. Other themes are "service usability" and "service affordability" which correspond to the "service value proposition" dimension. The fifth theme named "service discoverability" aligned directly with the corresponding dimension in the three-factor structure. The researchers argued that the sixth theme of "public policy" is implicit within the three-factor structure. The researchers also proposed a scale for measuring impediments to DSA scaleout based on the ascertained structure.

With the increased conceptual clarity through the three-factor structure, interventions in policy and practice can be suitably crafted for focus and effectiveness as suggested in sections 5.4 and 5.6. This is more so to reinvigorate efforts in Kenya and other SSA countries, unlocking the promise of digital transformation for agriculture, a sector whose growth offers the promise to eliminate poverty in low and middle-income countries.

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Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. The instrument*

*This was part of a longer questionnaire in the larger research.

(Q9) Do you agree or disagree that the following can be preventing digital services for agriculture from being successful enough to attain the scale of M-PESA, Uber, Ali baba etc? (Technology Concerns)

	I Disagree	I Neither Agree Nor Disagree	I Agree
T1 - Requiring high literacy levels among users	☐	☐	☐
T2 - Requiring access to the internet	☐	☐	☐
T3 - Requiring use of smart phones rather than more affordable phones	☐	☐	☐
T4 - Requiring phones to be always charged	☐	☐	☐
T5 - Incurring expensive data and SMS charges	☐	☐	☐

Please type the additional views you have on technological concerns with respect to success of digital services in the space below.

_____

_____

(Q10) Do you agree or disagree that the following can be preventing digital services for agriculture from being successful enough to attain the scale of M-PESA, Uber, Ali baba etc (Market concerns)

	I Disagree	I Neither Agree Nor Disagree	I Agree
M1 - Awareness about them is low	☐	☐	☐
M2 - There is no one-stop-shop where all of them can all be found	☐	☐	☐
M3- They do not work together or share data with each other	☐	☐	☐
M4 - Their charges are too high to keep paying	☐	☐	☐
M5 - The value they offer their target customers is not convincing	☐	☐	☐

Please type the additional views you may have on this in the space below.

_____

_____

Appendix B. Respondents Summary

Table B1.

Table B1
Summary of Respondents and their Affiliations.

Social Media Group / Category	Platform	Membership Size in Feb' 2019	Total Participants	Valid for larger research[a]	Valid for this study[b]
Africa Farmers Club	Facebook	126,364	14	13	8
Dairy Farmers Forum	Facebook	64,129	5	5	2
Dairy Farmers Kenya	Facebook	299,000	233	204	147
Digital Farmers Kenya	Facebook	307,498	530	505	384
Farming Gurus	Facebook	120,000	4	4	2
Kenya Farmers Market	Facebook	51,000	2	2	1
Kienyeji Poultry Farming	Facebook	220,000	8	7	7
Poultry farming group Ghana	Facebook	23,000	43	0	0
Direct invites by DSA Providers	N/A	N/A	2	2	2
Whatsapp and telegram groups	Mixed	N/A	46	43	29
Total		N/A	887	785	582

[a] In the scope of the larger research - beyond examining impediments to DSA scale-out.
[b] Participants who either had no missing values on numerically measured statements or gave additional views on impediments to DSA scale out.

Appendix C. Sample Profile

Table C1.

Table C1
Demographic distribution of the respondents in the study.

Category	Measure	Frequency	Percentage
Gender (n=575)	Female	146	25%
	Male	429	75%
Age range (n=574)	18-24	114	20%
	25-34	209	36%
	35-44	137	24%
	45-54	83	14%
	55-64	26	5%
	65+	5	1%
Highest education level attained (n=578)	Did not complete any formal education	4	1%
	Primary School	11	2%
	Secondary School	61	11%
	Short Course Certificate After Secondary School	78	13%
	Diploma Certificate	151	26%
	University Degree	221	38%
	Master's degree	48	8%
	Doctor of Philosophy (PhD)	4	1%
Income reliance on agricultural activities (n=567)	Fully reliant	280	49%
	Partial reliant	193	34%
	Not reliant	94	17%
Involvement in Agricultural value chain activities (n=582)	Farm inputs provision	67	12%
	Production - crops and animals	492	85%
	Post harvest logistics	46	8%
	Marketing and brokerage services	69	12%
	Specialized services	84	14%
	Finance and insurance	21	4%

References

[1] AGRAAfrica Agriculture Status Report: The Business of Smallholder Agriculture in Sub-Saharan Africa (Issue 5), Alliance for a Green Revolution in Africa (AGRA), Nairobi, Kenya, 2017 Issue No. 5 https://agra.org/wp-content/uploads/2017/09/Final-AASR-2017-Aug-28.pdf .

[2] Christiaensen, L., & Martin, W. (2018). Agriculture, structural transformation and poverty reduction: Eight new insights. https://doi.org/10.1016/j.worlddev.2018.05.027.

[3] M. Ivanic, W. Martin, Sectoral productivity growth and poverty reduction: National and global impacts, World Development 109 (2018) 429–439.

[4] E. Ligon, E. Sadoulet, Estimating the relative benefits of agricultural growth on the distribution of expenditures, World Development 109 (2018) 417–428, doi:10.1016/j.worlddev.2016.12.007.

[5] A. Shimeles, A. Verdier-Chouchane, A. Boly, Building a resilient and sustainable agriculture in sub-Saharan Africa, Springer Nature (2018), doi:10.1007/978-3-319-76222-7.

[6] J.C. Aker, I. Ghosh, J. Burrell, The promise (and pitfalls) of ICT for agriculture initiatives, Agricultural Economics 47 (S1) (2016) 35–48, doi:10.1111/agec.12301.

[7] S.O. Ogutu, J.J. Okello, D.J. Otieno, Impact of information and communication technology-based market information services on smallholder farm input use and productivity: The case of Kenya, World Development 64 (2014) 311–321, doi:10.1016/j.worlddev.2014.06.011.

[8] U. Deichmann, A. Goyal, D. Mishra, Will digital technologies transform agriculture in developing countries?, The World Bank, 2016, doi:10.1596/1813-9450-7669.

[9] L. Klerkx, E. Jakku, P. Labarthe, A review of social science on digital agriculture, smart farming and agriculture 4.0: New contributions and a future research agenda, NJAS-Wageningen Journal of Life Sciences 90 (2019) 100315, doi:10.1016/j.njas.2019.100315.

[10] M. Trendov, S. Varas, M. Zeng, Digital technologies in agriculture and rural areas: status report, Digital technologies in agriculture and rural areas: status report, 2019 http://www.fao.org/3/ca4887en/ca4887en.pdf.

[11] D. Kos, S. Kloppenburg, Digital technologies, hyper-transparency and smallholder farmer inclusion in global value chains, Current Opinion in Environmental Sustainability 41 (2019) 56–63, doi:10.1016/j.cosust.2019.10.011.

[12] J. Kieti, T.M. Waema, E.B. Ndemo, T.K. Omwansa, H. Baumüller, Sources of value creation in aggregator platforms for digital services in agriculture - insights from likely users in Kenya, Digital Business 1 (2) (2021) 100007, doi:10.1016/j.digbus.2021.100007.

[13] X. Han, V. Martinez, A. Neely, Service in the Platform Context: A Review of the State of the Art and Future Research, in: Collaborative Value Co-creation in the Platform Economy, Springer, Singapore, 2018, pp. 1–27, doi:10.1007/978-981-10-8956-5_1.

[14] A. Gawer, Bridging differing perspectives on technological platforms: Toward an integrative framework, Research policy 43 (7) (2014) 1239–1249, doi:10.1016/j.respol.2014.03.006.

[15] P. Langley, A. Leyshon, Platform capitalism: the intermediation and capitalisation of digital economic circulation, Finance and society 3 (1) (2017) 11–31, doi:10.2218/finsoc.v3i1.1936.

[16] R. Kabbiri, M. Dora, V. Kumar, G. Elepu, X. Gellynck, Mobile phone adoption in agri-food sector: Are farmers in Sub-Saharan Africa connected? Technological Forecasting and Social Change 131 (2018) 253–261, doi:10.1016/j.techfore.2017.12.010.

[17] B. Ezeomah, R. Duncombe, The role of digital platforms in disrupting agricultural value chains in developing countries, in: International Conference on Social Implications of Computers in Developing Countries, Springer, Cham, 2019, pp. 231–247, doi:10.1007/978-3-030-18400-1_19.

[18] S. Mittal, S. Gandhi, G. Tripathi, *Socio-economic impact of mobile phones on Indian agriculture* (No. 246), Working paper, 2010 http://hdl.handle.net/10419/176264.

[19] A. Gichamba, P. Waiganjo, D. Orwa, R. Wario, B. Ngari, Prototyping mAgriculture applications among smallholder farmers, in: 2016 IST-Africa Week Conference, IEEE, 2016, pp. 1–7, doi:10.1109/istafrica.2016.7530687.

[20] Lohento, K. & Sotannde, M. (2019). Digital Start-ups Servicing the Agro-food Industry in West Africa: Analysis of Business Models and Key Success Drivers. Retrieved from https://www.researchgate.net/publication/33621045.

[21] A. Crandall, J. Kieti, Startup business models and challenges for east african magriculture innovations, in: 2013 IST-Africa Conference & Exhibition, IEEE, 2013, pp. 1–10. https://ieeexplore.ieee.org/abstract/document/6701795.

[22] R. Fabregas, M. Kremer, F. Schilbach, Realizing the potential of digital development: The case of agricultural advice, Science 366 (6471) (2019), doi:10.1126/science.aay3038.

[23] B.D. Haig, Exploratory factor analysis, theory generation, and scientific method, Multivariate Behavioral Research 40 (3) (2005) 303–329, doi:10.1207/s15327906mbr4003_2.

[24] G. Schurz, Patterns of abduction, Synthese 164 (2) (2008) 201–234, doi:10.1007/s11229-007-9223-4.

[25] N.M. Heydarian, Developing theory with the grounded-theory approach and thematic analysis, APS Observer 29 (4) (2016) - https://www.psychologicalscience.org/observer/developing-theory-with-the-grounded-theory-approach-and-thematic-analysis .

[26] M.E. Kiger, L. Varpio, Thematic analysis of qualitative data: AMEE Guide No. 131, Medical teacher 42 (8) (2020) 846–854, doi:10.1080/0142159X.2020.1755030.

[27] J. Schoonenboom, R.B. Johnson, How to Construct a Mixed Methods Research Design Wie man ein Mixed Methods-Forschungs-Design konstruiert, KZfSS Kölner Zeitschrift für Soziologie und Sozialpsychologie 69 (2) (2017) 107–131, doi:10.1007/s11577-017-0454-1.

[28] J.F. Hair, W.C. Black, B.J. Babin, R.E. Anderson, Multivariate Data Analysis, Pearson Education, Harlow, 2014 (new int. ed.) https://www.pearson.com/store/p/multivariate-data-analysis-pearson-new-international-edition/P100000057627 .

[29] J.C. Anderson, D.W. Gerbing, Structural equation modeling in practice: A review and recommended two-step approach, Psychological Bulletin 103 (3) (1988) 411–423, doi:10.1037/0033-2909.103.3.411.

[30] J.L. Horn, A rationale and test for the number of factors in factor analysis, Psychometrika 30 (2) (1965) 179–185, doi:10.1007/bf02289447.

[31] J.C. Hayton, D.G. Allen, V. Scarpello, Factor retention decisions in exploratory factor analysis: A tutorial on parallel analysis, Organizational research methods 7 (2) (2004) 191–205, doi:10.1177/1094428104263675.

[32] B.G. Tabachnick, L.S. Fidell, J.B. Ullman, in: Using multivariate statistics, 5, Pearson, Boston, MA, 2007, pp. 481–498. https://www.pearsonhighered.com/assets/preface/0/1/3/4/0134790545.pdf.

[33] C.H. Li, Confirmatory factor analysis with ordinal data: Comparing robust maximum likelihood and diagonally weighted least squares, Behavior research methods 48 (3) (2016) 936–949, doi:10.3758/s13428-015-0619-7.

[34] D. Hooper, J. Coughlan, M.R. Mullen, Structural equation modelling: guidelines for determining model fit, Electron J Bus Res Methods 6 (2008) 53–60, doi:10.21427/D7CF7R.

[35] L.T. Hu, P.M. Bentler, Cutoff Criteria for Fit Indexes in Covariance Structure Analysis: Conventional Criteria Versus New Alternatives, Structural Equation Modeling 6 (1) (1999) 1–55, doi:10.1080/10705519909540118.

[36] R Core TeamR: A language and environment for statistical computing, R Foundation for Statistical Computing, Vienna, Austria, 2020 https://www.R-project.org/.

[37] ATLAS.ti. Version 9 (2020-2021). ATLAS.ti Scientific Software Development GmbH. Qualitative Data Analysis.

[38] Friese, S., Soratto, J., & Pires, D. (2018). Carrying out a computer-aided thematic content analysis with ATLAS.ti. https://www.researchgate.net/publication/324720405_Carrying_out_a_computer-aided_thematic_content_analysis_with_ATLASti.

[39] V. Braun, V. Clarke, Using thematic analysis in psychology, Qualitative research in psychology 3 (2) (2006) 77–101, doi:10.1191/1478088706qp063oa.

[40] D. McNeish, Thanks coefficient alpha, we'll take it from here, Psychological Methods 23 (3) (2018) 412, doi:10.1037/met0000144.

[41] C. Fornell, D.F. Larcker, Evaluating structural equation models with unobservable variables and measurement error, Journal of marketing research 18 (1) (1981) 39–50, doi:10.2307/3151312.

[42] M.R. Ab Hamid, W. Sami, M.M Sidek, Discriminant validity assessment: Use of Fornell & Larcker criterion versus HTMT criterion, Journal of Physics: Conference Series In, 890, IOP Publishing, 2017 https://doi.org/, doi:10.1088/1742-6596/890/1/012163.

[43] J. Henseler, C.M. Ringle, M. Sarstedt, A new criterion for assessing discriminant validity in variance-based structural equation modeling, Journal of the Academy of Marketing Science 43 (1) (2015) 115–135, doi:10.1007/s11747-014-0403-8.

[44] C. Fuchs, E. Horak, Africa and the digital divide, Telematics and informatics 25 (2) (2008) 99–116, doi:10.1016/j.tele.2006.06.004.

[45] S.M. Mutula, Digital divide and economic development: case study of sub-Saharan Africa, The Electronic Library (2008), doi:10.1108/02640470810893738.

[46] J. Ernest III, E.J. Wilson, E.J. Wilson III, The information revolution and developing countries, MIT press, 2004 https://mitpress.mit.edu/books/information-revolution-and-developing-countries.

[47] A. Scheerder, A. van Deursen, J. van Dijk, Determinants of Internet skills, uses and outcomes. A systematic review of the second-and third-level digital divide, Telematics and informatics 34 (8) (2017) 1607–1624, doi:10.1016/j.tele.2017.07.007.

[48] J. Van Dijk, K. Hacker, The digital divide as a complex and dynamic phenomenon, The information society 19 (4) (2003) 315–326, doi:10.1080/01972240309487.

[49] Hargittai, E. (2001). Second-level digital divide: Mapping differences in people's online skills. *arXiv preprint cs/0109068*. https://arxiv.org/abs/cs/0109068.

[50] T.G. Karippacheril, F. Nikayin, M.D. Reuver, H. Bouwman, Serving the poor: Multisided mobile service platforms, openness, competition, collaboration and the struggle for leadership, Telecommunications Policy 37 (1) (2013) 24–34 http://doi.org/10.1016/j.telpol.2012.06.001.

[51] A. Fraser, Land grab/data grab: Precision agriculture and its new horizons, The Journal of Peasant Studies 46 (5) (2019) 893–912, doi:10.1080/03066150.2017.1415887.

[52] A. Osterwalder, Y. Pigneur, Business model generation: a handbook for visionaries, game changers, and challengers, John Wiley & Sons, 2010, doi:10.1111/j.1540-5885.2012.00977_2.x.

[53] R. Birner, T. Daum, C. Pray, Who drives the digital revolution in agriculture? A review of supply-side trends, players and challenges, Applied Economic Perspectives and Policy (2021), doi:10.1002/aepp.13145.

[54] H. Baumüller, The little we know: an exploratory literature review on the utility of mobile phone-enabled services for smallholder farmers, Journal of International Development 30 (1) (2018) 134–154, doi:10.1002/jid.3314.

[55] J.J. Okello, O.K. Kirui, Z.M. Gitonga, G.W. Njiraini, J.M. Nzuma, Determinants of awareness and use ICT-based market information services in developing country agriculture: The case of smallholder farmers in Kenya, Quarterly Journal of International Agriculture 53 (2014) 263–282 (892-2016-65235), doi:10.22004/ag.econ.195738.

[56] A.J. Van Deursen, E.J. Helsper, The third-level digital divide: Who benefits most from being online? Communication and information technologies annual In, Emerald Group Publishing Limited, 2015, doi:10.1108/s2050-206020150000010002.

[57] K. Zhu, K.L. Kraemer, J. Dedrick, Information technology payoff in e-business environments: An international perspective on value creation of e-business in the financial services industry, Journal of management information systems 21 (1) (2004) 17–54, doi:10.1080/07421222.2004.11045797.

[58] G. Myovella, M. Karacuka, J. Haucap, Digitalization and economic growth: A comparative analysis of Sub-Saharan Africa and OECD economies, Telecommunications Policy 44 (2) (2020) 101856 http://doi.org/10.1016/j.telpol.2019.101856.
[59] J. Kim, P. Shah, J.C. Gaskell, A. Prasann, Scaling up disruptive agricultural technologies in Africa, World Bank Publications, 2020.
[60] Qiang, C. Z., Kuek, S. C., Dymond, A., & Esselaar, S. (2012). Mobile applications for agriculture and rural development. http://hdl.handle.net/10986/21892.
[62] J.L. Gibbs, K.L. Kraemer, A cross-country investigation of the determinants of scope of e-commerce use: an institutional approach, Electronic markets 14 (2) (2004) 124–137, doi:10.1080/1019678041000167507 7.
[64] S. Wyche, C. Steinfield, Why don't farmers use cell phones to access market prices? Technology affordances and barriers to market information services adoption in rural Kenya, Information Technology for Development 22 (2) (2016) 320–333, doi:10.1080/02681102.2015.1048184.
[65] Karippacheril, T. G. (2015). Serving the Poor: Designing a Mobile Service Platform for Smallholder Farmer Inclusion in Global Value Chains. https://doi.org/10.4233/uuid:16cb0a84-fbbf-438b-ab0f-0025298cfbe4.
[66] A. Saidu, A.M. Clarkson, S.H. Adamu, M. Mohammed, I. Jibo, Application of ICT in agriculture: opportunities and challenges in developing countries, International Journal of Computer Science and Mathematical Theory 3 (1) (2017) 8–18 https://iiardpub.org/get/IJCSMT/VOL.%203%20NO.%201%202017/Application%20of%20ICT.pdf.
[67] J. Rumanyika, M. Tedre, M. Apiola, S.S. Oyelere, N.R. Mramba, Contemporary Challenges in Street Trader-Customer Interaction Through Mobile Devices in Dodoma, Tanzania, in: International Conference on Social Implications of Computers in Developing Countries, Springer, Cham, 2019, pp. 76–88, doi:10.1007/978-3-030-18400-1_7.
[68] M.K. Kansiime, A. Alawy, C. Allen, M. Subharwal, A. Jadhav, M. Parr, Effectiveness of mobile agri-advisory service extension model: evidence from Direct2Farm program in India, World Development Perspectives 13 (2019) 25–33, doi:10.1016/j.wdp.2019.02.007.
[69] L. Jain, H. Kumar, R.K. Singla, Assessing mobile technology usage for knowledge dissemination among farmers in Punjab, Information Technology for Development 21 (4) (2015) 668–676, doi:10.1080/02681102.2013.874325.
[70] Batchelor, S., Scott, N., Valverde, A., Manfre, C., & Edwards, D. (2014). Is there a role for Mobiles to support Sustainable Agriculture in Africa?. https://doi.org/10.2991/ict4s-14.2014.33.
[71] Michael Blaschke, Kazem Haki, Stephan Aier, Robert Winter, Taxonomy of Digital Platforms: A Platform Architecture Perspective, 14th International Conference on Wirtschaftsinformatik (2019) https://aisel.aisnet.org/cgi/viewcontent.cgi?article=1220&context=wi2019.