Mkulima Platform: An Inclusive Business Platform Ecosystem that Integrates African Small-Scale Farmers into Agricultural Value Chain

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Abstract. The Like many other technological advancements, most African countries have not kept pace with the current developments in the mobile applications ('apps') arena. Among other reasons, this is attributed to lower penetration level of smartphones in these countries. On the other hand, the advancements associated with apps have not spared the agribusiness sphere. This is especially so given that one of the global challenges is that of producing enough food to feed the world population, which will grow to upward of 10 billion people by the middle of the current century. Amidst the scarce and fast reducing resources such as water and arable land, this need is direr in African countries whose economies are largely dependent on rain-fed agricultural sector. Under these circumstances, some of the mechanisms for increasing food production are: (1) increasing farm efficiency to produce more high-quality; (2) creating transparent and sustainable food supply chains; and (3) providing ability to track and trace food ingredients. Mobile apps have reached maturity and penetration levels sufficient to support these goals. The thesis of this paper is that if Africa's small-scale farmers were to benefit from mobile apps, a re-imagined platform-based model approach for developing these apps is required. This was informed by the glaring gaps that were identified through a bibliometric analysis of relevant literacy followed by empirical study of such apps. The platform addresses two key challenges facing Africa's small-scale farmers: (1) non-availability of market information around prices of agricultural produce, buyers, and markets; and (2) lack of accurate weather information. The platform's ability to break geographical barriers is anchored on Platform Ecosystem Canvas and its design puts into consideration the technological realities of Africa's small-scale farmers.

Keywords: Market price information · Mobile application (apps) · Platform ecosystem · Small-scale farmers · Weather forecasting

1 Introduction

From mobile applications (apps) that aid in plastic surgery [1] and those employed in preventing cardiovascular diseases [2], to 10s of apps that keep people connected to

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their loved ones 24–7, apps have completely redefined human's social and business lives as originally perceived a few decades ago [1–5]. This is driven by phenomenal advancements and adoption of smartphones. For instance, by the end of 2nd quarter of 2020, there were 1.85 and 2.56 million different apps available on Google Play Store and Apple App Store, respectively. In the same period, a mind boggling 37.8 billion apps were downloaded. Not surprisingly, the adoption and use of apps is correlated with the adoption and use of smartphones [6]. However, there are peculiar findings that indicate higher usage of mobile applications in the less developed and emerging economies which are known to have lagged in terms of development in the telecommunication sector [5, 7]. This is because such economies have taken lead in leapfrogging internet connectivity using mobile phones [8]. This could explain the apps download and usage statistics that put China (accounting for 45% of global total downloads) way ahead of the other countries and India as the leader in terms of both growth and volume [9]. Relevant to this paper however, the extremely low scores for apps download and use by most African countries is of great concern [5]. This is however not unexpected as the continent continues to be home to the world's poorest countries still grappling with provision of basic needs to their citizens [10]. Given unique contexts such as economies that depend on rain-fed agriculture [11], agricultural apps for African countries require unique considerations.

Platform-based organisations are a result of the need to meet requirements such as demand for products and service customisation, speed delivery and extremely high levels of quality of service [12–14]. The other factor is the need for seamless and single view of the transactions [15]. The top four organisations that have cashed in on this opportunity and completely disrupted the traditional businesses are Google, Facebook, Amazon, and Apple [16, 17]. In [18], platform companies are described as the most valuable in the world today. Despite being relatively established, it is the advancement in the sphere of digitisation that has seen what has been termed as a 'revolution' of platform-based organisations [19, 20]. In tandem with the 'revolution' at the mobile applications level [2, 5], integration of a apps into the operations of these businesses has further accelerated their adoption [21, 22]. Africa's fragile small-scale farming sector can benefit from this revolution if the apps' design incorporates platform approach [12, 23]. This is however only possible through platforms that are designed to suit Africa's contexts. Most existing platforms have been found to promote extractive economic agenda [24] (hence the name "platform capitalism") that is not always in line with sustainable development goals [25].

The agricultural sector remains the dominant source of jobs in Africa, particularly in rural areas where the majority of people live [26]. Over 80% of food grown in these countries is by small-scale farmers who hold less than 2 hectares of land and who depend on rains for their farming [27, 28]. Over the last 10 years, climate-change triggered disasters such as droughts and floods have increased from 47% to 54%, this implies that Africa's small-scale farmers are heavily impacted by climatic variations, especially droughts [29, 30]. It, therefore, follows that, since the agricultural sector contributes over 30% of most African countries' Gross Domestic Product (GDP) [31], investments in climate adaptation solutions, especially targeting small scale farmers, would lead to GDP growth in these countries. In this paper, the adoption of platform-based model in the design of a mobile application for small-scale farmers dabbed 'Mkulima Platform',

is pursued. Mkulima Platform is an extension of ITIKI, a drought prediction tool for small-scale farmers in Africa. ITIKI is an integrated system (artificial intelligent algorithms, weather sensors and a mobile Application) that combines weather data with the traditional knowledge of African farmers to predict droughts. ITIKI stands for Information Technology and Indigenous Knowledge with Intelligence. It sends farmers drought forecasts via an app or SMS message. The forecasts are also accessible through a web portal, emails and audio files [32–35].

It is evident that economic development of most African countries cannot be separated from the development of the agricultural sector. The entire value chain of agriculture has a critical role to play – especially in ensuring right business model for agribusiness entrepreneurs [36]. The driver of commercial viability of agribusinesses is the existence of reliable revenue streams and clear value proposition for the partnerships (Agricultural Value-Added Services - Agri VAS) [37]. The SAP software company, for instance, has created a digital agribusiness model through which they propose three levels to reimagine agribusiness: (1) empowering lines of business, (2) connecting business enterprises to the digital economy and (3) delivering open, agile and flexible apps [38]. Business models that are inclusive of small-scale farmers are described under four categories: producer-driven, supplier-driven, public-driven and intermediary-drive [11, 39]. Of interest to this paper are the intermediary-driven models which have been proven to the profitable part of the business model and have higher potential for triggering inclusive growth among small-scale farmers in Africa. Creation of platforms that promote this will require extending the Africa Union's notion to "African solutions to Africa's problems … by African people". This is because majority of the platforms available today have been proven to promote extractive capitalism [25] that work against Africa. Great strides in the digital innovation for agriculture have been made through the Africa-Europe Innovation Partnership (AEIP) (https://africaeurope-innovationpartnership.net/). Some of the projects here include: (1) AGRINUTS - the development of a timely and robust tool to analyse relations that link crop and livestock diversity and income to nutrition in poor rural areas in Sub-Saharan Africa (https://cordis.europa.eu/project/id/221478); (2) SARNISSA -Sustainable Aquaculture Research Networks in Sub Saharan Africa (https://cordis.europa.eu/project/id/213143) and (3) WAZIUP project (https://www.waziup.eu/) with an Open Innovation Platform for IoT-Big Data in Sub-Saharan Africa that focused on applications in agriculture, aquaculture and cattle rustling. Apart from providing the much-needed funds for procuring digital platforms infrastructure, such projects provide large-scale coverage that mostly span across multiple African countries and several application domains.

Hinged on the unique context of Africa' small-scale farmers, the main features of Mkulima Platform were determined through a rigorous design science process[33]. These features were further refined through empirical study [40] of selected farmers-supporting apps available on Google App Store. In doing this, answers to the following research questions were sought:

1. What is the status of mobile applications that support farmer's decision making process?
2. What are the baseline features of mobile applications that support small-scale farmers' decision making process?

3. How should the platform-based model be integrated into the development of a mobile application for supporting efficient decision-making process by Africa's small-scale farmers?

In answering the research questions above, three research approaches were applied: (1) bibliometric analysis of published scientific articles covering the theme of mobile application in agriculture [41–43]; (2) empirical study [44] of selected apps serving farmers; and (3) design science [45] used in development and testing of a custom-made app for Africa's small-scale farmers.

2 Platform Organisations and Platform Business Models

2.1 Platform Organisations

Platform organisations have existed since the first definition by Moore: "*an economic community of interacting organisations that collaborate and compete across various industries"* [46]. *As they evolved rapidly, this category of organisations has acquired various definitions such as: "… a building block that acts as a foundation upon which other firms can develop complementary products, technologies or services". "… is a business that connects people through technology, making an ecosystem that allows value to be created and exchanged*" [47]. The common feature among platform-based organisations is that they bring people and organisations together in one place where they can interact with one another. The sustained and repeatable interaction leads to an ecosystem whose uniqueness lies in the combinations of modular competencies and federated shared values in operational rules [17]. Companies enter a platform ecosystem for purpose of increasing their revenues and profit [4]. This is enabled by the inherent network effects characteristic of these ecosystems which enable realisation of exponential growth of businesses.

2.2 Business Model for Platform-Based Organisations

The concept of business models was born in the 1990s during the hype of e-commerce. Many decades later, there is still no unified definition of this term. Different authors cited in [48], have used the 'essence' and 'purpose' of the business model to derive its definition. They include describing the concept as an architecture, a description, a narrative, a representation, a structural template, a method, a recipe, a framework, a pattern, a set and a model or conceptual tool. One of the definitions based on the 'concept' reads: "*a conceptual tool that contains a set of elements and their relationships that allows expressing the business logic of a specific firm. It is a description of the value a company offers to one or several segments of customers and the architecture of the firm and its network partners for creating, marketing and delivering this value and relationship capital, in order to generate profitable and sustainable revenues streams*" [49].

In an exploratory research reported in [18], platform companies are classified under either innovation platforms or transaction platforms. In [50], a further category called

investment is introduced. In the innovation category, platform owner and ecosystem partners' interaction is for the purpose of creating "complementary" products and services. An example here is the Android Operating system innovation platforms for creating software for computer and smartphone ecosystems. On the other hand, the transaction type enables buying and selling transactions, or support for sharing information, e.g., Amazon MarketPlace. Organisations that implement both types are called 'hybrids' and they include firms such as Apple, Google, Microsoft, Amazon, Facebook, Tencent, and Alibaba.

Although the main 'visible' feature of most platform-based organisations is the digital platform, it is the business (rather than the technical one) perspective that drives the exponential growth [48]. From this view, therefore, the issue of the underlying business models becomes a critical issue [51]. In particular, the platform-based organisations thrive because of existence of a vibrant business ecosystem (borrowed from a biological ecosystem) consisting of an economic community [52]. It is for this reason that many authors [48, 52–55] have provided literature on why the business model innovation is the main driver of business growth being witnessed by these companies. The aspects covered in this innovation trajectory include value creation, new propositions and value capturing innovations [54].

2.3 Platform Canvas

In recognition of the differences between traditional business models and models relevant to platform-based organisations, through rigorous literature review, identified eight key elements of the latter that are shown in Fig. 1.

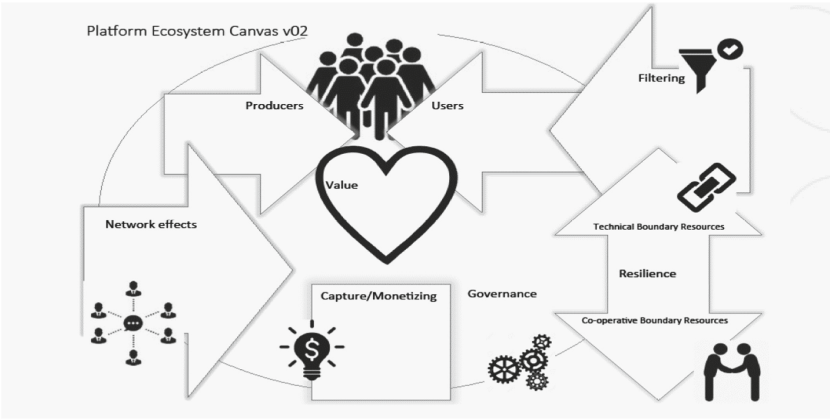

Fig. 1. Platform ecosystem canvas (Source:[17]).

i. **Value** which refers to the description of the platform's value creation potential.
ii. **Monetising** quantifies the value created, e.g., by creating feasible pricing models.

iii. **Producers** and **Users** are grouped together as '**participants**' who have also been described under the phrases "*bilateral market power of the platform*" or "*multi-sided markets*". Producers are also referred to as complementors or "*market side 1*"; while the users also go by the names; consumers, customers, and end users.
iv. **Filtering** and **matching** is the fifth aspect; it is the application of algorithms to sieve through massive data, filter it for different users and match their needs with the services/products [53]. As new users are attracted to the platform, the existing matching of right producers and appropriate consumers is ensured.
v. **Governance**, also referred to as control, rules, access control, and trust, sets out the platform rules [50]. Other aspects covered under governance include issues of how open the platform is, access rights, interaction (among the players) rules and incentives given to the parties on different sides of the platform [54].
vi. **Resilience/Change tolerance and maintainability**, also referred to as modular, evolvable, durable, and plug-n-play; refers to the platform's ability to adapt to the ever-changing environment. The aspect of platform's maintainability includes compatibility with future complementary products, backwards compatibility with past products, and maintaining the platform even in the face of leadership changes.
vii. **Network Effect** is the effect that the scale of business increases significantly with minimal investment [50].

2.4 Role of Blockchain in Digital Platforms

Research on blockchain technology is currently very active and it is predicted that this technology is the main driver of the next generation digital platforms [56]. There is also consensus among researchers [56–61] that blockchain technology has passed its 'hype-cycle' and it is now a driving force in the global economy. blockchain is the most disruptive of all the 4th industrial revolution technology innovations [56]. Though mostly only at experimental and case-study levels, blockchain technology has found its application in a myriad of domains such as healthcare, crowdfunding, finance and banking [57, 60]. Citing the poor representation of agricultural sector in these applications, Yadav and Singh [57] carried out a systematic literature review of blockchain technology in this sector. From the duo's study, it emerged that tracing food for provenance is the most developed application of blockchain in agriculture. In this work [57], case studies such as the tracing of organic coffee in Colombia, tracing of tuna from the waters where it was caught to the plate of the consumer and tracing of a mango from the farm to the fork, are presented. In such applications, blockchain provides support for robust openness, transparency, security, neutrality and reliability. Besides, intertwining blockchain with Internet of Things (IoT) technology where autonomous sensors are used for real-time data recording, completely eliminates manual verification processes. The agricultural sector also stands to gain from blockchain through provision of information in the correct form, right place and right time. This information can be used for tracking, auditing, and monitoring food supply chains. On the other hand, blockchain can be extended to the areas of food safety, sustainable agro-practices, agro-finance, agro-business, payments within food supply systems and enhancement of quality and trust in food supply chains [57, 59].

As blockchain technology approaches its maturity, its inevitable integration into e-commerce is resulting in an inseparable pair. On one hand, blockchain protects e-commerce transactions and e-commerce uses blockchain. Among the common areas where blockchain is used include in payment gateways, control over purchases and B2B transaction ecosystems [56]. The key blockchain technologies that are at the core of these applications include decentralised trust and alternatives to centralised storage and management of data [58, 61]. This enables e-commerce transactions to reap several benefits such as: (1) transparency and collaboration; (2) inventory data management; (3) scalability and availability; (4) security and privacy; (5) customer-provider relationship contract; (6) summary contract of all the transactions; and (7) reduced transaction cost [56].

As the adoption of blockchain technology within digital platforms gains momentum, rethinking of the existing business models becomes critical. Such business models will have to shift from the current orchestration and decision making function by the platform owner to a decentralised participative governance system in multi-stakeholder digital-enabled business ecosystems that are based on consensus mechanisms. In these next generation digital platforms, blockchain then becomes the anchor for the support of membership management, analytic and automation and crypt-economic models [61]. Such digital platforms hold massive potential with an array of value proposition similar to the ones presented in [61]. Presented in form a pyramid, at the top, and most advanced, complex and disruptive value proposition is decentralised governance; made up of distributed ownership, democratic decisions and decentralised autonomous organisation (DAO). With such developments, the Platform Ecosystem Canvas shown in Fig. 1 will have to be redefined to have relevance. An illustration of how such a system can work is presented in [59]. Here, a history of mistrust in food resume and their associated certificates and testing reports is reversed through a traceability system that is implemented using blockchain technology and IoT. In this application, blockchain is also used in implementing an e-commerce aspect for the customers of the food-supply chain.

3 Material and Methods

3.1 Bibliometric Analysis

The use of bibliometric analysis as a method of quantitatively analysing published documents, and their references, has gained popularity in the last 10 years [62–64]. Bibliometric analysis is a cross-disciplinary science that employs mathematical and statistical methods to compute parameters such as pattern of citations and collaboration networks by authors involved [64]. CiteSpace and VOSviewer [42] are the most currently known effective bibliometric tools. On the other hand, core collection of Web of Science (WoS) currently contains the most comprehensive collection of publications' databases [65]. In the section, bibliometric analysis carried out using VOSviewer on publications retrieved from WoS is described.

The data used in this bibliometric analysis was generated from Science Citation Index (SCI-EXPANDED), Social Sciences Citation Index (SSCI), Arts & Humanities Citation Index (A&HCI), Conference Proceedings Citation Index- Science (CPCI-S), CPCI-Social Sciences and Humanities (CPCI-SSH), Book Citation Index, Science (BKCI-S),

BKCI- Social Sciences and Humanities (BKCI-SSH), and Emerging Sources Citation Index (ESCI) in WoS core collection. To enhance the quality of the search, an advanced search of a combination of diverse topics within mobile applications subject was used. The search topics covered areas around platform-based organisation, agriculture, climate, weather, and market price. The search for published scientific papers was restricted to mobile applications, with no restrictions set for the document type or period of review study. The following search rules were used: TS = ("platform based organisation" OR "platform ecosystem" OR "platform organization" OR "platform organisation") AND (TS = ("mobile application" AND "agriculture") OR TS = ("mobile application" AND "farmers") OR TS = ("mobile application" AND "weather") OR TS = ("mobile application" AND "climate") OR TS = ("mobile application" AND "market price"). The search which was done in December 2020, yielded 374 documents that included articles, reviews, books, and conference papers. When downloading the data, the "full record and cited references" option was selected and this included titles, author's information, abstract, keywords, references, and journals information, etc. All the retrieved data, 374 documents, was visualized an analysed using a bibliometric software called VOSviewer [41–43]. The following analyses were performed: annual production of scientific publications infield, the most productive countries and their collaborations and keywords co-occurrence.

Mobile Application Research Trends

Figure 2 illustrates the annual distribution of scientific publications on mobile applications (apps) for agriculture and weather/climate from 2011 to 2020. It can be observed that mobile application has not received a lot of attention from the researcher as only 353 papers have been published in the past 10 years. Overall, it can be observed that apps for agriculture are still at the development stage.

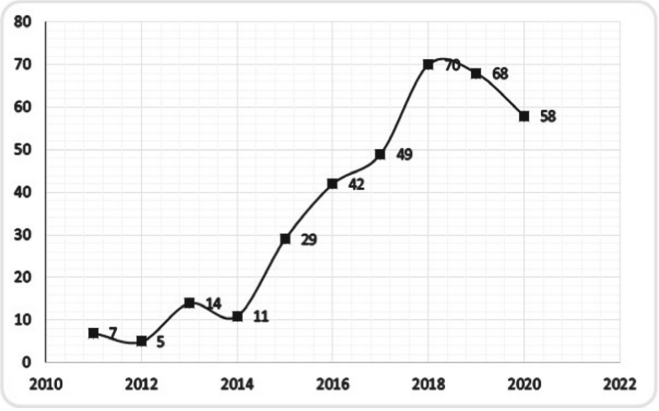

Fig. 2. Annual distribution of scientific publications on Apps for agriculture.

Even though several countries have contributed to mobile application publications, only the top 10 leading countries were considered in this review. The ranking was done

based on the country affiliation of the first author and are depicted in Fig. 3. The most productive country in publications on apps for agriculture is India followed by the United States of America (USA) and then Peoples Republic of China with a contribution of 13.3%, 12.5% and 8.6% respectively. Countries such as Germany, South Korea, Spain, Italy, and Malaysia show a low and almost equal amount of contribution (15 papers each on average). Continents dominating the publication in the mobile application are Europe and Asia. It is worth noting that none of African countries was represented in these statistics.

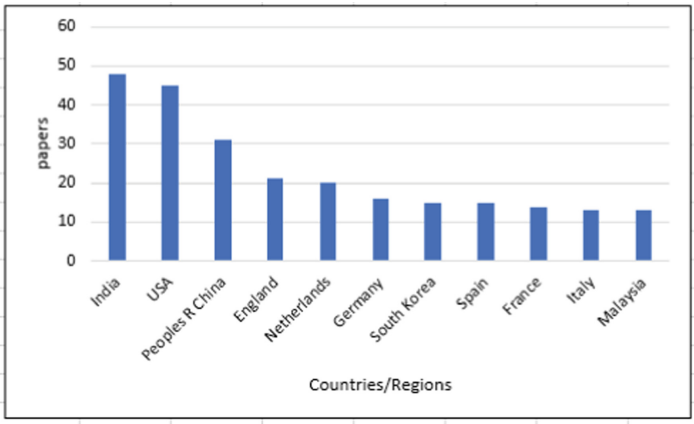

Fig. 3. Countries' contribution of scientific papers in Apps for agriculture.

Network Analysis

Figure 4 depicts the collaboration network of the countries that have contributed to the publication of papers in apps for agriculture. This is presented in terms of association strength of collaborations between the countries. The countries in the same cluster have higher collaboration strength. The collaboration network as seen in Fig. 5, depicts 15 clusters with seven of the 15 clusters each containing only one country. The countries prominent in the network are also the top leading countries as shown in Fig. 3. Although India is the top leading country in publications on apps for agriculture, it is not the most collaborative country. The most collaborative country is the USA, followed by England and Netherlands. Collaborative countries in Africa include South Africa and Ethiopia whereby Ethiopia shows collaboration with South Korea, Italy and Neverland and on the other hand, South Africa shows collaboration only with England and Ghana.

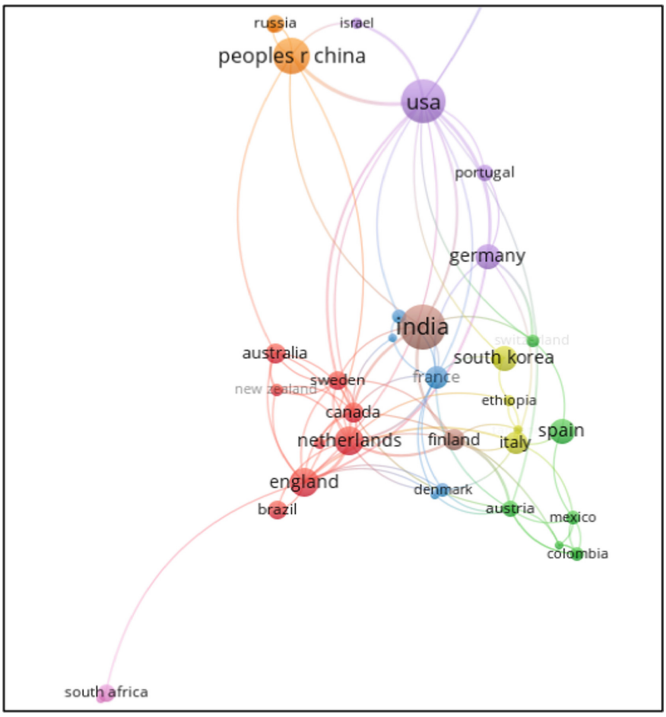

Fig. 4. Country collaboration network. (Color figure online)

Further, in Fig. 5 the keywords co-occurrence network with six clusters is presented. In a keyword co-occurrence network, the relatedness of the keywords is determined by the number of times the keywords appear together in the research papers [42]. The cluster with the highest number of keywords is cluster 1, with keywords such as *mobile application, agriculture, internet of things, mobile computing, machine learning and health.* By default, the search string used during the Web of Science (WoS) search yielded these keywords. The cluster with the second highest number of keywords is the green cluster 2, which is dominated by keywords such as platform, impact, and performance. Others are the dark blue cluster 3, with keywords including strategy, evaluation and information and the yellow cluster 4 with keywords such as technology, architecture, networks, and social media. On the other hand, the fifth cluster (coloured in purple) includes innovation and cloud computing while. cluster 6, (in light blue) has like adoption, model, and climate change.

Overall, the prominent keywords include internet of things, mobile application, model, platform ecosystem, performance, and competition. On the other hand, keywords with less weight indicate immerging topics or topics that have not received significant attention from researchers. These include keywords such as wireless sensor networks, monitoring, precision agriculture, citizen science and climate change. This further affirms the less attention currently being paid to mobile applications for agriculture and/or weather/climate.

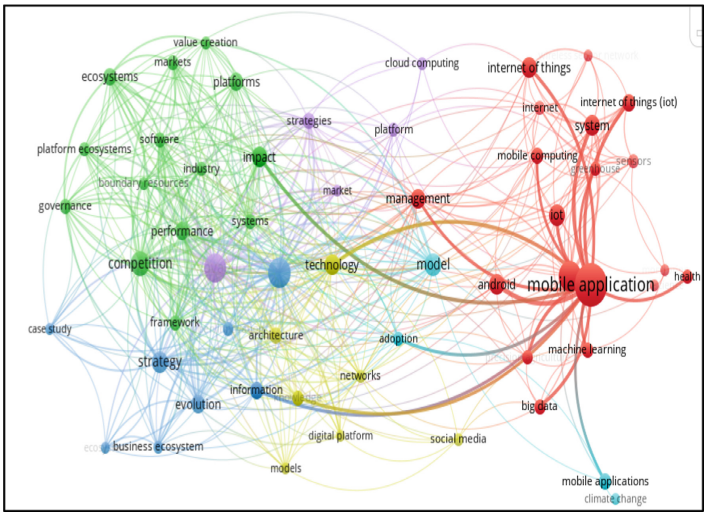

Fig. 5. Keywords co-occurrence network. (Color figure online)

3.2 Empirical Study of Farmers' Mobile Applications

Distribution channels of mobile applications ('apps') such as Google Play Store and Apple App Store provide users' feedback tool which both the users and the developers can use to compare the efficacy of specific apps. This feedback tool enables both quantitative (through rating stars) and qualitative (via text reviews/opinions) measures [66]. This remains the single most used basis on which users adopt apps. On the other hand, although the apps' developers can use this as a means of assessing users' satisfaction and future features of the app, there are several challenges facing the effectiveness of the feedback tools [66, 67]. Such challenges include manual overhead in processing the feedback and overwhelming bias contained in both the text and rating scores. Application of machine learning algorithms in addressing these challenges is currently a very active research topic [68, 69]. Based on the result of bibliometric analysis presented above, data mining of agricultural mobile applications available on Google App Store was carried out. Further data mining was carried out based on freely available machine learning datasets relating to agriculture, e.g., https://www.kaggle.com/. From this, seven relevant mobile applications and two web applications were selected, and the formal context (features) across them experimented over a period of 3 months. Using data from app intelligence websites such as https://www.appannie.com/en/ and https://sensortower.com/, and guided by the results of the bibliometric analysis, a comparative analysis of the seven apps was carried out. Figure 6 for example shows metrics used by Sensor Tower to rank apps which a ranking of A+ being the highest and F the lowest.

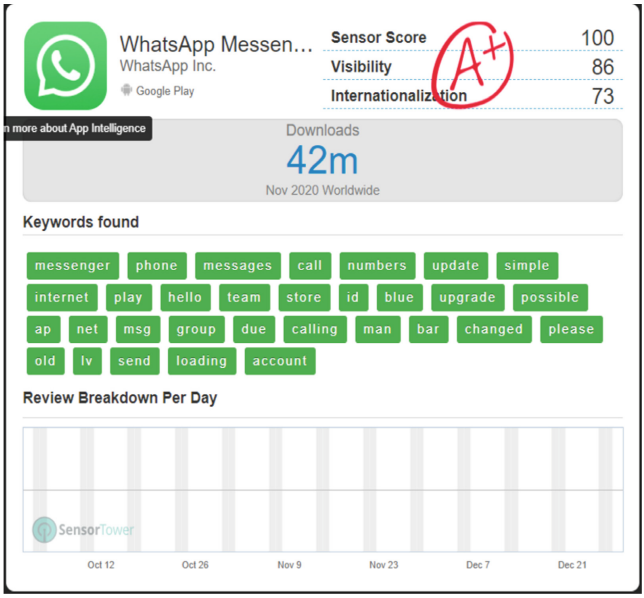

Fig. 6. Ranking of WhatsApp (source: https://sensortower.com/).

Following field work carried out under a related (to this paper) study, six baseline features required by small-scale farmers were identified through three field case studies in Kenya, Mozambique and South Africa [33, 35]. These features are:

i. **M-App** - indicating if this is an app or other platforms such as website. During the empirical study, inclusion of two web-based applications was deemed necessary as most of the apps lacked the basic market prices features required.
ii. **M-Price** – a feature for providing market prices for different agricultural products for a specific date (or range) and place/market/town.
iii. **W-Info** – provision of localised and contextualised weather and drought forecasting information for short (up to 6 months), medium (up to 12 months) and long (over 12 months) term lead-times.
iv. **SMS** – support for options to receive/send information using Short Message Service. This supports users who do not use smartphones.
v. **Farmer-Exc** – this feature refers to the app's exclusive use by farmers. Registration for such apps includes a verification of status of the user as farmer through champions who personally know the farmers.
vi. **Farm Input** – this feature entails support for viewing prices of farm inputs (e.g., fertilizers and seeds) and the ability to purchase these farm inputs on either individual basis or teaming up with other farmers.

The content in the 'description' column was obtained from the respective Google App Store page for each of the apps. The inclusion of popular apps such as Tik Tok [23] and WhatsApp in the analysis is for purpose of contextualising some of the scores,

especially those related to popularity of the apps. The six features were used as the basis for the comparative analysis of the seven selected agricultural apps - the results of this analysis are shown in Table 1 below. Apart from the ratings like the ones shown in Fig. 7, other scores depicted in Table 1 are Sensor Score which is the performance of the App in the respective App Store and Visibility Score which refers to a composite value calculated from searches and chart rankings of the App.

Table 1. Comparative analysis of selected farmer's apps.

Name	Owner	Description	Download and Usage Statistics				Formal features for supporting small-scale farmers					
			Sensor Score	Visibility	Internationalization	Rating	M-App	M-Price	W-Info	SMS	Farmer-Exc	Farm Inputs
Mkulima Online	Mkulima Online, Kenya	A platform where small-scale farmers and those in agribusiness can showcase their farm produce or services.	44	30	15	F	√	X	X	X	X	X
Fresh Farmers Market SA	Offered By iMbali Technologies	Links farmers with their customers for purpose of selling and buying agricultural produce.	21	18	15	F	√	X	X	X	X	X
Today Market Price	Trushar Narodia, India	Provides updated (daily) market price of all the agriculture markets across Gujarat, India.	28	26	24	F	√	√	X	X	X	X
Crop prices	Farmis, Lithuania	To track crop price changes and variations online, market price changes.	0	9	18	F	√	√	X	X	X	X
Farmers e market	Vcode Infotech Limited, India	Dedicated to farmers to display and sell their products	43	35	27	F	√	√	X	X	X	X
Mkulima Young	Mkulima Young, Kenya	Connecting young farmers by providing an exclusive farmers marketplace where producers meet the buyers	40	28	16		√		X	X	√	X
Farming App Kenya	Smart Farm, Kenya	This farming app is designed to provide vital information for crops and livestock farmers in Kenya and the rest of Africa.	59	38	16	F	√	X	X	X	X	X
USA Farmers Markets	Department of Agriculture, USA	A website that provides unbiased, timely, and accurate market information of hundreds of agricultural commodities and their related products, free-of-charge to everyone.	N/A	N/A	N/A	N/A		√	X	√	X	X
Market Information System	Department of Agriculture, South Africa	A website that provides information on market prices related to agriculture, forests and fish	N/A	N/A	N/A	N/A		√		√	X	X
Mpesa	Safaricom Limited	Mobile money application	65	40	15	D+	N/A	N/A	N/A	N/A	N/A	N/A
WhatsApp	WhatsApp Inc.	Social media apps	100	86	73	A+	N/A	N/A	N/A	N/A	N/A	N/A
TikTok	TikTok Pte. Ltd.		100	82	65	A+	N/A	N/A	N/A	N/A	N/A	N/A
Facebook	Facebook		100	91	82	A+	N/A	N/A	N/A	N/A	N/A	N/A

3.3 The Mkulima Platform Designs

Overview
Both the bibliometric analysis and empirical study/experiments of/on existing apps for agriculture revealed glaring gaps. None of them provided relevant weather forecasting information and appropriate market prices, especially those for farm inputs. Given the unique context of Africa's small-scale farmers, Mkulima Platform was informed by the need to fill these gaps. Below is the description of the design and development of this Platform.

ITIKI (itiki.co.za) is a drought early warning system that consists of both software (in form of mobile application, a web portal, and SMS service) and hardware (a network of sensors) that pools weather information and uses it to predict droughts for small-scale farmers. In the backend is a database that contains the indigenous knowledge on one hand and weather-related data captured from the wireless sensors (and professional weather stations) on the other hand. Artificial neural network and mobile agents' algorithms then process these two data sources to come up with short-term, medium-term and long-term drought predictions that are then disseminated to the farmers in form of SMS. The SMS also carry actionable advisory information – this is disseminated in the farmers' local languages such as IsiZulu in the case of South Africa [30, 33, 35]. Mkulima Platform is built on top of ITIKI – it aims to give support to small-scale farmers by enabling them to sell their produce, get needed information on their products to enable better sale decisions and buying produce and farm inputs from other farmers and agro-dealers respectively more easily. The client side of the Platform is implemented in Android Studio and currently runs on phones with at least Android API 14 operating system. Backendless was selected as the Mobile backend as a service (MBaaS), and different routines written for purpose of integrating with the with the ITIKI legacy database.

Using the Platform Canvas [17] presented earlier (see Fig. 1), the main features of Mkulima Platform were designed as follows:

Supplier
Mkulima Platform deals with agricultural produce, products, and farm inputs. The suppliers of these products are, therefore: farmers (as individuals or/and cooperatives) and agro-dealers who sell farm inputs. For the farmers, the main focus is on the small-scale farmers who are known to supply 80% of the food produced in Asia, Latin America and Sub-Saharan Africa. They produce smaller quantities, located in hard-to-reach locations and susceptible to middlemen. On the other hand, cooperatives organise large numbers of small-scale farmers into groups, in order to increase collective bargaining power.

Customers
Three categories of customers were catered for as follows:

Individuals: These customers are reached through social media and word-of-mouth and given that a bigger percent of small-scale farmers are semi-literate, local radio and television advertisements are also used.

Businesses: These include agri-businesses and retailers (shops and supermarkets), hospitality businesses (restaurants and hotels) and public sector organisations (hospitals and schools). Given that most of such customers have their own transport, it is expected that they can collect produce from the farm, farmers' homes or warehouses.

Export: Mkulima Platform supports inter-country transactions through export to buyers in international markets. This allows individual farmers and businesses to sell to a type of buyer, or cater to a particular demand, that might not exist in their local market. For this category, the Platform has put in place additional legal resources to help with regulation and compliance issues in international markets.

Interaction

The digital aspect of the Mkulima Platform is accessible to end users via three input/output channels: Mobile Application (see Fig. 7 below), SMS and Web Portal. Both are accessible to all the customer categories described above. Other interactions out of the digital platform are meant to handle aspects such as customer service for assistance with issues, such as delivery and payment queries, handling (to minimize) of product returns. Further interactions involve logistics (through partnerships with logistic companies), warehousing, quality control (on an individual basis with all farmers, or when they aggregate produce at a purpose-built facility to reduce travel costs.), payment facilitation, regulation (comply with the regulatory environment of the countries in which they operate).

Governance

As described in [17], the modus operand for a Platform is driven by the Platform Governance system. Benchmarking on Alibaba's Governance [70] and calibrating against the platform governance theory presented in [50], the following is the governance structure for Mkulima Platform.

i. **Protection** of consumers, suppliers and intellectual property rights – this is achieved through the application of big data analytics in proactive monitoring the activities of the Platform. Mkulima Platform is designed around high levels of privacy and uses the model of 'privately owned' [50] (almost an exclusive club [21]) where all farmers listing their products are first verified by our team of Mkulima Platform champions called 'Ambassadors'. For this reason, only authentic farmers are being allowed to sell in the Platform. As much as this may slow down our growth, the stringent measures enable us to retain 'quality and authentic products' value proposition. Similar strict rules are applied for customers expressing interest in a particular product. In the South Africa's pilot case, for example, the buyer is requested to supply a valid ID number which the system uses to verify his/her genuineness. In as much as this is not necessarily 100% security proof, it does eliminate most fraudulent buyers. Further, cooperation with government agencies and national and international law enforcement is used for proactive monitoring and removal system for fraudsters. This is also used in the policy and mechanism to deter and punish such fraudsters. E.g., South African Police Service.

ii. **Transparency and collaboration with the industry** – given that Mkulima Platform's success and growth is hinged on very many other players in the agriculture sector and beyond, the governance structure adopts a very open approach to collaboration among various stakeholder groups. Apart from ensuring the protection of Intellectual Property Protection (IPP) of the collaborators, key collaborations are sought at both national and international levels (Fig. 8).

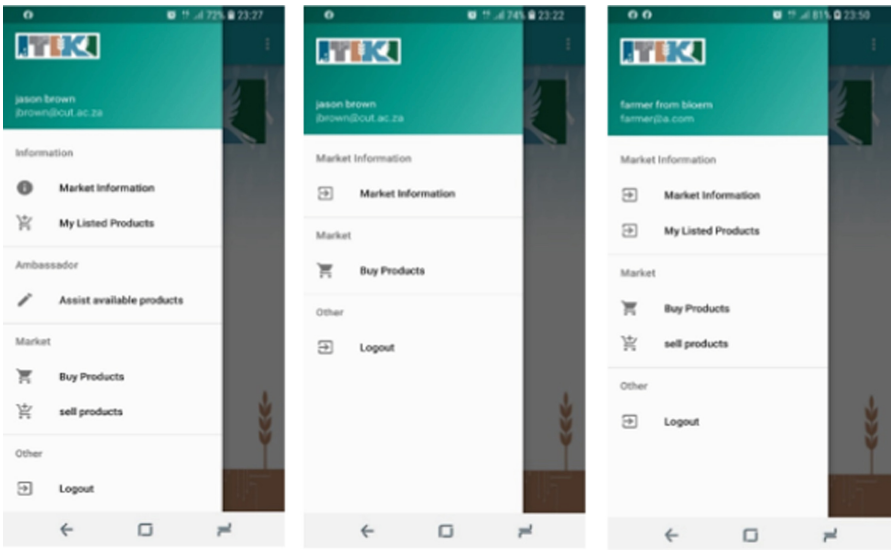

Fig. 7. Mkulima platform mobile App interaction.

Revenue Model

Direct Revenue B2C (Business to Consumers).
These are implemented through the following:

i. **Subscription model** in which the small-scale farmers pay a monthly subscription as well as pay-per-use. This is deducted from their subscriber's pre-paid account (billed through the Mobile Network Operator MNO). A 'freemium' model where the subscribers get free weather forecasts (from ITIKI) is implemented.
ii. **Mark-up model** which is applied to add a margin to the price paid to the suppliers.
iii. **Commission fees** charged to buyers and sellers as an additional fee when they complete a transaction on the platform.
iv. **Memberships fee** which is an optional charge levied on sellers and buyers and offers them premium service such as enabling buyers to directly access farmers selling and to sellers to enable them to list several products each month - saving them money compared to charging a fee per listing.
v. **Advertisements model** where customers can run product display advertisements on the platforms is also considered.

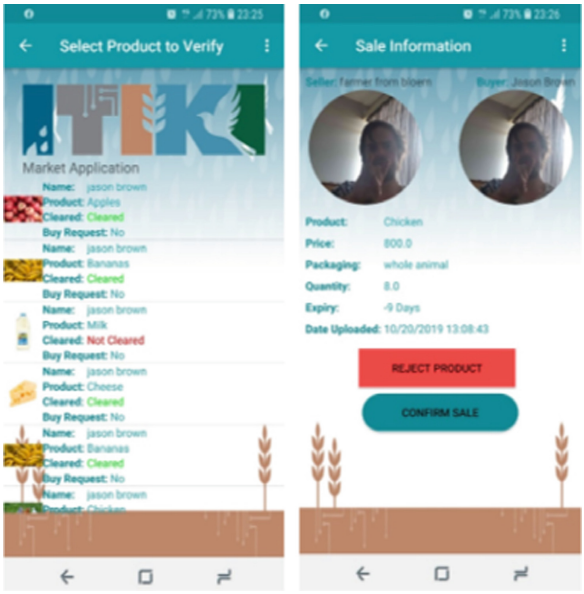

Fig. 8. Mkulima platform privacy implementation.

vi. **Insights monetisation model** to generate revenue from legally sharing user data with third parties is being considered.
vii. **Listing fees** whereby a fee is charged to customers when they upload an item for sale.

B2B Revenue Models

Although the willingness to pay for Mkulima Platform services has been established[33], the targeted rural farmers' ability to pay and donor-dependency syndrome may affect sustainability of business. For this reason, other B2B revenue streams are pursued. An analysis of other actors likely to benefit from empowered small-scale farmers directly and/indirectly was carried out. Such include Agri-dealers who sell farm inputs to the farmers, local/regional/national governments looking to eradicate hunger and micro-financing institutions providing loans to these farmers. Secondly, looking at the unique assets and resources that the Platform has developed, we further leverage these to generate the following alternative sources of revenue:

i. **Contract sales** - bulk purchases or subscriptions ordered by an organisation on behalf of a particular community of farmers.
ii. **Microfinance institutions** needing to provide drought forecasts to reduce crop failure and increase loan repayment rates.
iii. **Agribusiness Firms** such as agri-processors who need constant and reliable supply for farm product. For such firms, increase in farmers' production leads to cost reductions in their manufacturing process/supply chain) or demonstrate increased efficiency for their agriculture extension budget.

iv. **Outsourced Services** in which we take advantage of under-resourced extension services. Here we target governments to offer outsourcing services through our platform. The value offered is cost-saving and wider coverage as the value proposition.

4 Discussion

With the overall objective of determining the best approach for developing a mobile application for supporting small-scale farmers operating in Africa's fragile rain-fed environment, research that entailed answering three research questions was conducted. This design was preceded by an assessment of the status of the existing agricultural mobile applications and their ability to support two critical formal requirements of these farmers: (1) provision of weather/climate information and (2) provision of relevant market prices for both farm produce and farm inputs. This was achieved through bibliometric analysis of scientific publications and empirical study of selected apps. Impressively, both research methods gave similar results that indicated that apps targeting the agricultural sector were poorly developed. The absence of keywords such as small-scale farmers and market prices in the bibliometric analysis further confirmed this assertion. It also emerged that African countries were playing a backbench role in advancement of mobile applications. Besides, the bibliometric analysis indicated that the top ranked countries in terms of publications in this topic (apps for agriculture) were China, India, and the USA. Empirical studies based on the number of downloads and use of mobile apps confirm similar trends.

With these results, the huge design-reality gaps between the needs of Africa's small-scale farmers on one hand and feature of the existing apps were identified. In particular, none of the apps provided information on drought forecasting and market prices for farm inputs, which were ranked very highly as functional requirements by small scale farmers. Filling these gaps is the main contribution of Mkulima Platform. The people-centred approach employed in the development of this Platform and adoption of Platform Canvas model enhances its ability to support inclusive growth of Africa's agricultural sector.

5 Conclusion and Further Work

Like elsewhere in the world, the ongoing mobile app revolution [2, 5] is changing the way things are done in Africa. Although this is at a much lower scale compared to other regions (especially Asia), this trend is leaving a trail of evidence of social-economic development in the content. For instance, mobile technologies and services contributed US$ 110 billion to the GDP of sub-Saharan Africa [7]. It is therefore safe to say that advancement of platform ecosystems for the mobile app sector could accelerate its contribution to Africa's GDP. In order to avoid platforms that do not promote inclusive economic growth of Africa's agriculture sector, the design of such platforms should be done with the context of realities in Africa in mind. The position pursued here is that Africa does not have to follow this old trend that has mostly led to solutions that do not fit her realities as supported by the phrase; "transferring of Northern designs to Southern realities" [71].

Conversely, Africa presents unique opportunities and challenges – platforms for her agricultural sector must therefore incorporate some implicit elements of the continent's status quo, cultural transfers, and mutual learning. It is against this background that the Mkulima Platform was developed.

In this paper, the underlying theory, literature, and design, of Mkulima Platform are presented. Mkulima Platform is a solution designed around inclusive business models (IBMs) that integrate small-scale farmers into agricultural value chains as described in [11]. Mkulima is a Kiswahili word for 'farmer'. Mkulima Platform is targeted to addressing two key challenges facing the farming sector in Sub-Saharan African countries, these are: (1) non-availability of market information around prices of agricultural produce, buyers and markets; and (2) lack of accurate weather/climate information. The Platform takes the advantage of the huge (projected to be more $400 million in 2020) market size for Agri Value Added Services (VAS) [72, 73]. Although the share (of this market) for the Sub-Saharan African countries is marginal, the potential of Mkulima Platform to break geographical barriers in a platform-based ecosystem change all this. This is because the platform is anchored on eight-points platform-specific business model canvas called Platform Ecosystem Canvas [17]. The design of Mkulima Platform is based on five of the 8 points of the Platform Ecosystem Canvas; these are suppliers, customers, interaction (value unit to be exchanged), governance and revenue model.

Testing and evaluation of Mkulima Platform were integrated into the ITIKI app which has been in use in three African Countries for over 3 years. To ensure fast adoption, the services offered in the Platform have been bundled as 'freemium' service over the ITIKI app. This means that the over 15,000 customers of ITIKI app automatically have access to these services. The operational model of ITIKI app has also been adjusted to accommodate the operational requirements of Mkulima Platform; for example, the ITIKI Ambassadors (sales team) now not only capture weather indicators but also have to collect market prices at different outlets in their geographical locations. Although it is envisaged that the Platform will have more-or-less same success as the one recorded in ITIKI and which is documented in [33], field studies to confirm this were underway at the time of writing this paper. These studies adopt metrics similar to those described in [20]. This includes significant increase in crop yields and efficiency in resources utilisation. Furthermore, the use of SMS for communication with the small-scale farmers and ensuring that over 70% of participants of this project are women, the strategy will result in more empowered women who can make sound financial decisions. This way, Mkulima Platform contributes to the sustainable dimensions of SDGs such as SDGs 1, 2, 5, 8 and 12.

Unlike the mega donor-funded project (e.g., https://www.waziup.eu/) that have a Pan-African footprint, Mkulima Platform is currently a rigid case-study that can be difficult to upscale beyond the three communities/countries where is running. This is because some of the elements of Platform governance (especially trust among the customers) is anchored on humans - the ITIKI ambassadors/salespersons who authenticate custom1ip and management of the Platform.

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