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Innovative Food Price Collection in Developing Countries

Focus on Crowdsourcing in Africa

Heidrun Zeug, Gunter Zeug, Conrad Bielski, Gloria Solano-Hermosilla, Robert M'barek

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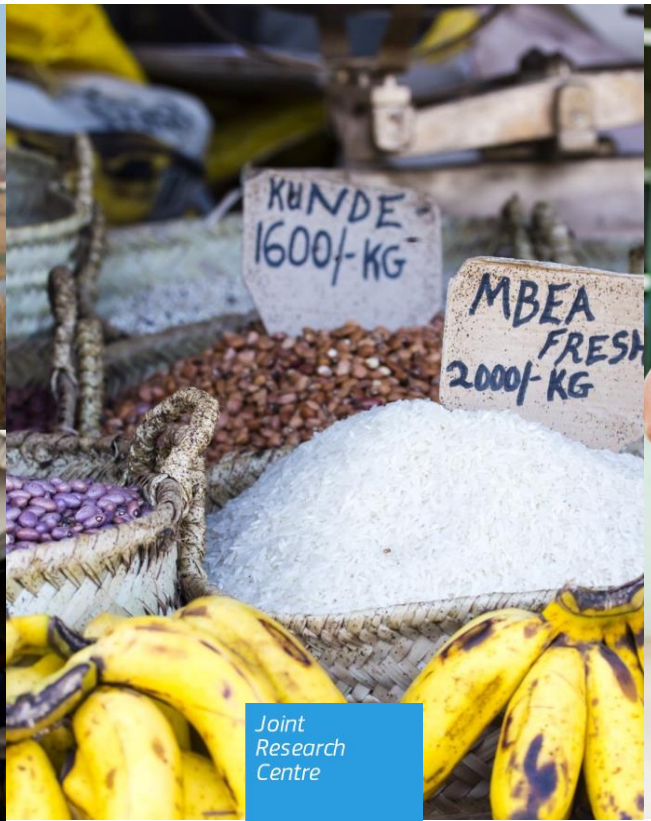

Joint Research Centre

EUR 28247 EN

Contact information
Name: Robert M'barek
Address: Edificio Expo. c/ Inca Garcilaso, 3. E-41092 Seville (Spain)
E-mail: JRC-D4-SECRETARIAT@ec.europa.eu
Tel.: +34 954488318

JRC Science Hub
https://ec.europa.eu/jrc

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Innovative Food Price Collection in Developing Countries: Focus on Crowdsourcing in Africa

Abstract

Recent food crises have revealed the importance of timely and reliable food price information for food security monitoring and to support informed policy decision making. The increasing number of mobile phone users in Africa, combined with improved networks and broadband coverage, makes it increasingly possible to use mobile-based crowdsourcing to obtain accurate and up-to-date food price information. The use of mobile technologies also affords the possibility of reaching a large number of volunteers (crowd workers) in specific geographic locations, thus enhancing the available sets of information.

This study provides a literature review of the concept of crowdsourcing and an overview and analysis of previous and on-going innovative food price collection initiatives in developing countries, particularly in Africa. Based on the research and interviews with relevant stakeholders, potential benefits and challenges have been identified and a set of recommendations has been drafted.

The research shows that there is not a single crowdsourcing solution. The main challenges are encouraging crowd participation, and ensuring that data collected are trustworthy and of high quality, which in turn depends on offering the right incentives. Although the financial rewards offered to the crowd are often low, completely unpaid voluntary work is not common, which to some extent limits the potential cost advantage of crowdsourcing methods of data collection.

New technologies empower people, and crowdsourcing might in future have potential to provide additional earnings and skills in poor communities, where skill development and ensuring access to technology are both potentials and challenges.

Table of contents

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Executive summary

Policy context

Food prices are key indicators of the availability and affordability of food. Such indicators are especially important in countries where the population spends the majority of their income on food, because any fluctuations in price can have significant effects on people's ability to purchase sufficient food for their needs. Recent food crises have revealed that timely and reliable food price information is essential as an input into early-warning systems for early detection of food price pressures in different geographical regions. Food price information also supports analysis and informed policy and humanitarian aid decisions, especially in developing countries and regions susceptible to food insecurity. Unfortunately, it is in just these areas that such data are often not available; therefore, novel technologies, i.e. the internet and mobile-based technologies and innovative data collection methods, such as crowdsourcing, are increasingly being researched.

Over the last two decades, the internet and new mobile phone technologies have evolved into powerful tools that can be used for the rapid exchange of information and that allow greater collaboration, even with those living in poor and remote regions. The aim of this study was to better understand current innovative food price data collection methods and technologies, e.g. mobile-based crowdsourcing, in developing countries, with a particular focus on Africa. It also addresses the drawbacks of traditional price collection methods, such as systematic observation and surveys, for drawing an accurate real-time picture of the food security situation that supports sound decision making.

Key conclusions

The increasing number of mobile phone users, even in low-income countries, combined with improved mobile networks and broadband coverage in Africa, makes it possible to utilise crowdsourcing and new technologies to obtain food price data in this region. The use of mobile technologies affords the possibility of reaching a large number of volunteers in specific geographic locations.

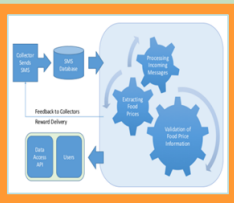
A variety of initiatives have successfully used crowdsourcing to capture information on food prices and availability in real time, including in remote and food-insecure areas. Such approaches offer added value by creating networks of data collectors who can respond rapidly to data needs, taking advantage of the growing number of people who own or have access to a mobile phone. Challenges include ensuring crowd participation, choosing the right technology, obtaining data of sufficient quality, communication and gaining the confidence of data collectors, e.g. by offering incentives. Financial issues, such as cost-efficiency and long-term sustainability also need to be addressed in the chosen solution, along with country-specific and rural–urban disparities.

The proposed approach cannot be considered a replacement for traditional food price data collection methods. Rather, it is intended to supplement available food security information by increasing the frequency of data collection and the geographic coverage. Crowdsourcing also has the potential to offer a welcome source of additional earnings for participants, especially in poor communities; however, lack of adequate skills and of access to appropriate technology have been identified as important barriers to this and are both a challenge and a potential for development.

Many factors affect the success of crowdsourcing projects in developing countries (see figure below). Although the financial rewards offered for participation can be relatively low, it is uncommon in food price crowdsourcing for volunteers to be unpaid for their work; this, to a certain extent, limits the potential cost advantage.

Enabling environment

- In Africa the mobile network is currently the most stable ICT infrastructure and SMS the cheapest mean of communication. The expected mobile-broadband expansion and smartphone adoption will facilitate the use of apps
- Increasing awareness and promoting public food price information systems (release of budgets) while supporting technological innovation, technology access and development of digital skills can catalyse the process

	 **Data collection**	 **Management of service**	 **Dissemination**	 **Financial model**
Participants/Users	• Understand the motivation of the potential crowd (extrinsic/intrinsic) & alignment of incentives • Although payment can be low, unpaid voluntary work is not common practice. Minimal financial compensation (monetary, airtime, commodity) is expected	• Both the crowd and the service learn by doing. The service management needs to be willing to adapt the service and/or reward structure based on the evolving crowd • Effective crowd moderation/communication and sharing best practices	• Added value to other agricultural information services in demand by users (weather alert, insurance, microcredit, etc.) • The dissemination channel according to user preferences (mostly SMS, when no internet available)	
Organisation	• For the methodology to work the number of collectors must be large enough ('crowd wisdom') • Recruit through locally used social media tools while using local advertisement and direct SMS to address lack of internet/media launch event • Partner local and international non-profit organisations (building trust) • Clear and well-defined tasks. Use locally appropriate units and precise definitions of food items (include pictures) • Task training and access to necessary tools is important	• Implementing organisation must place a high value on a strong work ethic • Quality process: a mixed approach of automatic and interactive data validation methods is recommended (Automatic filtering and flagging potential errors, manual inspection through moderator, use of control data, peer review of review through third parties) • Self-correcting mechanism through majority agreement ('crowd wisdom'). Discover minimal required number of contributors per location for the methodology to work • Checking profiles and ranking participants according to the number and quality of contributions to avoid fraud and improve quality		• While public price information systems rely on volatile donor money or inflexible government budgets and private service providers work with either paid subscription models or integrated price information in a bundle of other paid agri-services, there is still a need to research viable financial models that can create a sustainable food price crowdsourcing service. • Data collection is the biggest cost driver, crowdsourcing has the potential of being more cost-efficient, nevertheless it does incur costs, both monetary and resources. • A realistic budget aligned to the quantity of work and quality of the end product is necessary in crowdsourcing
System	• Find right incentive mix to attract qualified people to master technology and collect reliable prices. A survey is recommended • Easy to use technology and structured data entry process: short codes (SMS) or standardised forms (smartphone app) • Smartphone apps offer the advantage of the guided entry of information, but infrastructure challenges (e.g. lack of internet) make SMS more suitable in some areas	• A fully automated service is required to minimise costs • A robust back-end infrastructure is required for data collection, processing and dissemination. It is recommended the use of existing platforms for incoming-outgoing (SMS, app) price info	•Open data model or linked open data model provides a variety of techniques to deliver food price data quickly. Downstream users can decide the most adequate form of dissemination • Price information service needs to be regular. Current social media outlets such as Twitter can be used to disseminate food prices regularly	• More research recommended regarding the adequate level of financial incentives, the number of contributors required per location and the interaction with other motivations such as social rewards, acquiring and showing skills, personal interests, altruism

Main lessons and recommendations for creating and sustaining food price crowdsourcing in developing countries.

Although many of the factors associated with crowdsourcing success are common to any scheme to obtain price information using mobile-based technologies, crowdsourcing does have some advantages over the use of hired professional enumerators. In particular, provided the sources are trustworthy, the use of a large number of geographically dispersed providers enables the collection of more detailed information, and at relatively

low cost. However, ensuring sufficient numbers of participants and maintaining the quality of contributions, while preserving the cost advantage, are important challenges.

The use of crowdsourcing for data collection takes advantage of the 'wisdom of the crowd' by assigning the task of collecting food prices from the same location to multiple individuals. There is a trade-off between crowd size and cost advantage, and the question of how many contributors are required at each site to assure the quality of the data is crucial. Therefore, before initiation of a crowdsourced data collection project, it is essential to develop a methodology that addresses the issues of participation and data quality.

Main findings

The next two figures summarise the results of the nine interviews conducted with representatives of organisations in Africa that use mobile-based food price collection systems. The third figure summarises the results of initiatives using crowdsourcing and information and communication technology for food price collection.

	Novus Agro Nigeria	**ACE Malawi**	**Farmerline Ghana**	**Esoko Ghana**	**Sonagess Burkina Faso**
Collection	Android App SMS	Android App SMS	Android App SMS	Android App SMS	Android App
Dissemination	Email Phone	SMS IVR Newspaper Radio	SMS Phone	SMS Call centre Web Radio, TV, print	Radio Email SMS
Validation	Collectors training Random spot checks Collector manager market visits	Price capture strategy Platform validation features Administrator review	Platform validation features Administrator review Cross check with sellers in the market Cross check in markets by external consultants Cross check in markets by own staff	Price capture strategy Platform validation features Administrator review Cross check with independent person in market Exchange with Ministry about price trends	Review by an analyst
Pros Tech	Availability of 2 techs faster process than SMS	Availability of 2 techs App more user friendly better data accuracy	Availability of 2 techs App more user friendly better data accuracy faster process than SMS	Availability of 2 techs Faster price collection, Data published within 1 day Cheaper than traditional methods	Faster price collection, Data published within 1 day
Cons Tech	Internet down time SMS character limitation	Internet down time	Internet down time SMS character limitation	Internet down time SMS character limitation Memorizing SMS codes	Internet down time App allows sending of quantitative data but no qualitative data (paper based)
Challenges	Financial Technical	Financial Technical Operational	Financial Operational Human resources	Technical Operational Financial External	Technical Operational Financial

App-based food price data collection systems.

	ODR Madagascar	CPC Togo	SIMA Niger	Rongéad Côte d'Ivoire
Collection	SMS	SMS	SMS	SMS (no standardized technology)
Dissemination	Website Newspaper Radio	Website Radio	Website Radio	Email SMS Call centre
Validation	Cross checks within 2 weeks	Review at regional level Review by central controller	Review at regional level Review by national analyst	Review at local level Review by chief-analyst
Pros Tech	SMS less costly than traditional method SMS accelerates time between collection and dissemination	SMS accelerates time between collection and dissemination Platform allows accuracy checks	SMS reduced data errors, more user friendly SMS less costly and less workload	Cost-efficient with no training needs of any external data collectors and no customized service technology for data collection
Cons Tech	SMS character limitation Risk of typing errors	SMS character limitation	SMS character limitation Intensive training for collectors in SMS Not easy server recognises syntax errors	SMS data collection method but no standardized method the local analyst needs to work with different technologies and information channels to gather data
Challenges	Financial Political	Financial Technical Operational Institutional	Financial Technical Managerial Political	Human resources Technical Financial

SMS-based food price data collection systems.

	World Bank (coop with JANA) Kenya, Nigeria & others	AFPC (JRC & AfDB in coop with Knoema)* Kenya, Uganda & Sierra Leone	SCB (coop with Premise) Nigeria	mVAM (WFP) Refugee camps in Kenya	FAO, WFP (coop with Premise) Indonesia
Crowd	Non-professional recruited through social media	Volunteers contacted through non-profit organisations and social media	More than 350 volunteers	Volunteers called by operators hired by the WFP	Volunteers recruited through social media
Motivation	Differed by countries leading to increasing monetary incentives in some countries	Financial compensation	No feedback	6% response rate, low but WFP claims that monitoring prices does not need an exhaustive sample of respondents	
Incentive	Mobile airtime and monetary paymens	Monetary payments	Mobile phone credits	Mobile airtime credits	Mobile phone credits or mobile money
Tech	PC and mobile phones	web and smartphone app	Smartphone app	SMS, live telephone calls, Interactive Voice Response (IVR) calls	Smartphone app
Quality	Semi-automated process. Collectors were scored on behaviour.	Automatic and manual checks.	Handling of data outliers; adoption of locally appropriate units	Improving questions and adding the response 'don't know' to avoid false guessing; automated statistics engine	Mixture of automatic and manual approached to detect fraud. Fraud was an issue.
Implementation	Legal, cultural and language challenges; designing the level of incentive was complex and the appropriate database and validation systems	Better definitions for commodities were needed; consistency checks to avoid fake prices were needed; infrastructure challenges (Internet or electrical power interruption); payment challenges due to lack of banks accounts.	No info	Monthly monitoring of the performance of the survey. User-friendliness captured by the response rates and call duration. A helpline for feedback was installed	Recruitment challenges; confusion with commodities needed to be dealt with by sending photos
Dissemination	Web	Web database	Web data portal	Web portal in the future	No info

Mobile-based crowdsourcing food price data collection systems.

From the results of the initiatives it can be concluded that crowdsourcing is an innovative and feasible method of collecting real-time food price data more quickly than by other means, including in remote and food-insecure areas; the technique has benefited from the increasing mobile phone ownership seen worldwide, even in low-income countries. Validation mechanisms to ensure data quality and adequate incentives must be in place for successful crowdsourcing. Important challenges associated with this method that need to be addressed are participation and communication with the crowd; building confidence with the crowd; infrastructure challenges; and lack of bank accounts. The system should not replace, but complement, traditional data collection methods. Furthermore, the crowdsourcing approach offers added value by creating networks of collectors that can respond rapidly to data collection requests.

Key findings refer to the concept, the technology, the actors, and operational, institutional, political and financial perspectives. Definitions and types of crowdsourcing differ depending on the complexity of the task and the target crowd, e.g. whether not a specific group is required. In addition, the following factors need to be considered:

- The technology chosen (see table below) should take into account both local network coverage and the availability of devices.
- Recruiting tools and awareness-raising activities should be tailored to the local community.
- The right mix of incentives (e.g. financial) must be in place and adjusted if required.
- The task must be well defined (including specifying the correct local units of measurement and food packaging type).
- Collectors should be trained and communication processes put in place.
- A system of automatic and manual checks is needed to ensure data accuracy and prevent fraud.

In addition, in order to build trust, partnering with local and/or well-known organisations is an option. A robust back-end infrastructure for receiving, transmitting and processing information is needed. From a political perspective, increasing awareness of the importance and advantages of food price information systems for market observation and analysis regarding food security could increase intrinsic motivations. Finally, a realistic budget must be available. Collections costs have been identified as a major cost driver in food price information services; crowdsourcing does incur costs, but can potentially be more cost-effective than other data collection methods.

Pros and cons of technologies for food price data collection

	SMS	**Smartphone app**
Advantages	+ No internet connectivity necessary + Relies on the presence of an extensive and stable mobile network	+ More user-friendly + Higher data accuracy + Less time-consuming
Disadvantages	– Limit on the number of characters – Time-consuming – More complex for users to handle	– Internet connection necessary – Cost of devices and of connectivity

Related and future JRC work

The exploratory nature of the study refers to the innovative subject of the study, namely using 'crowdsourcing' and mobile phone-based technology for food price data collection in Africa; the cases analysed are not exclusive, but provide valuable input. Future steps are to (1) implement the methodology in selected areas of sub-Saharan Africa, i.e. areas lacking timely and reliable food prices, (2) develop a robust, crowd trusting or quality assurance methodology and (3) search for ways to use the crowdsourced data to contribute to food security early warning analysis and to allow for ex ante and ex post economic impact analysis and domestic policy support.

Quick guide

The report researches innovative food price collection methods in Africa, and their potential for capturing real-time prices including in remote and food-insecure areas, while identifying challenges and recommendations.

The research follows a 'mixed method' approach, combining the results of a literature review with findings from interviews and insights into experiences using mobile technologies and/or crowdsourcing.

The study refers to 'innovative' and 'traditional' methods. Use of smartphone apps and SMS are innovative methods, while 'going to the market and writing prices down' or 'calling people on the phone' are traditional methods. Crowdsourcing refers to the collection of data or completion of tasks voluntarily by a large group of citizens (the 'crowd'), potentially for a financial reward.

1 Introduction

Food prices are a key indicator of changes in food supply and demand, as they signal the availability and affordability of food, factors that are important in countries where people spend a high proportion of their income on food. Food prices have been rising in the last decade, with spikes in 2008 and then again in early 2011 and mid-2012. Between 2005 and early 2008, real aggregate food prices rose by more than 60% globally (Binswanger-Mkhize, 2009). The effects on standard of living have been significant, particularly in Africa. According to the World Bank (2013), as a result of the 2008 food price spike, 105 million people in low-income countries were kept in poverty or pushed into poverty. The rise in food prices in 2011 is estimated to have affected more than 40 million people in low- and middle-income countries. As large movements in food prices have a disproportionate impact on developing countries, particularly the low-income ones, special measures may be needed to prevent food insecurity in these countries. Thus, timely and reliable food price data are essential as input to early-warning food security monitoring systems and to support analysis and policy making. However, in contrast to developed countries, where food price data are often captured comprehensively, frequently and accurately, in many less developed countries, especially in Africa, timely and accurate food price data are lacking.

In the last two decades, first the internet and then, more recently, new mobile technologies have evolved into powerful means of rapid information exchange, enabling active collaboration of people around the world. Exploiting these new technologies to gather near-real-time food price information in developing countries provides enormous potential for policy decisions, humanitarian aid organisations and crisis-affected communities to anticipate and deal with potential crises[1]. According to the WFP (World Food Program) and the UN (United Nations) Global Pulse, 'big data' generated by mobile and online communications have the potential to complement traditional data sources (e.g. face-to-face surveys, 'going to the market and writing prices down' or 'calling people on the phone'). This phenomenon is commonly referred to as crowdsourcing, a term coined by Howe (2006).

In recent years, several initiatives have employed new technologies to collect food price information at different stages of the supply chain (e.g. farm gate, wholesale, retail stage), using either professional collectors or volunteers. However, the collection of price data by volunteers, i.e. crowdsourcing, may reduce the both, the cost of collecting data and the time lag between real-time data collection and the publication of the data series.

These initiatives aim to address the known drawbacks of classical methods of collecting survey data, such as the significant time delays between data collection and publication of the data series, or the low frequency of data collection. Most national offices in developing countries and some international organisations [e.g. the Food and Agricultural Organization (FAO[2]) and the WFP[3]] are willing to supply expertise and publish valuable open access data on commodity prices; however, in almost all cases the frequency of data collection is low, i.e. not more often than monthly. Furthermore, the published data from national offices are often indices rather than the actual prices of individual goods, and methodologies and definitions (commodities, locations) are often not clearly documented.

[1] *Potential, Pitfalls of 'Big Data' for Humanitarians* [analysis]. AllAfrica.com, SyndiGate Media Inc., Washington, 2013.
[2] Global information and Early-Warning System (FAO GIEWS).
[3] World Food Program's Vulnerability Analysis Mapping (WFP VAM).

In order to assess the feasibility of timely/high-frequency data collection in Africa, the JRC conducted a data collection study[4]. A network of professional data collectors on the ground visited market locations and collected agricultural commodity prices on a weekly basis in several African countries[5]. The data were reviewed and submitted to a centralised data repository using a web-based data platform or a smartphone app. A weekly food price database was built for a large set of countries and for a basket of commodities. The collection took place from 2014 to mid-2015 and continues today funded by the African Development Bank (AfDB). The prices are made available to researchers, policymakers and the general public.

The initiative initially focused on building (professional) data collector networks across all African countries. Subsequently it was decided to outsource the task of data collection to individuals who need not necessarily be professional data collectors. As the objective was to obtain multiple data for the same food items and locations, we aimed to use crowdsourcing to recruit multiple individuals in five specific locations. However, it became clear that establishing the crowdsourced data collectors in a city or area is challenging and there is a need for further research into the relatively new phenomenon of crowdsourcing using information and communication technology (ICT).

In this context, the aim of the present study is to better understand new data collection methods that are able to fill the gap in the availability of timely, accurate, cost-efficient and high-frequency food price data in developing countries, particularly in Africa.

The study extensively reviews the literature and identifies and investigates innovative data collection initiatives and methodologies in developing countries that utilise crowdsourcing and/or ICT tools.

Using the findings from the literature review and insights from current and previous experiences of innovative food price data collection activities, potential benefits and challenges have been identified and a set of recommendations for collecting food price data based on crowdsourcing methods has been drafted.

[4] Africa Food Prices Collection Portal (http://africafoodprices.io). An initiative of the European Commission's Joint Research Centre and the African Development Bank Group. (AfDB), in partnership with Knoema.

[5] Benin, Burkina Faso, Cape Verde, Côte d'Ivoire, Ethiopia, Gambia, Ghana, Guinea (from Sep 2014), Guinea Bissau, Kenya, Liberia, Mali, Mauritania, Niger, Nigeria, Rwanda, Senegal, Sierra Leone, Togo, Uganda and Zambia.

2 Scope and approach

2.1 Definition of terms

The study uses the terms 'innovative' and 'traditional' to describe methods of food price data collection. From the perspective of current and future ICT tools, smartphone applications or 'apps' and SMS-based messaging technologies are considered innovative approaches. In contrast, methods such as collecting price data by 'going to the market and writing down prices', 'calling people on the phone' or 'transmitting data via a form over the internet or email' using either registered/authorised users or anonymous users (which could be anyone) are all considered traditional methods.

Crowdsourcing is the collection of data or the accomplishment of a task voluntarily by a large group of citizens, called the 'crowd', potentially for a reward (money or any kind of payment). The crowdsourcing methodology is thoroughly described in the study. The term 'crowd' generally refers to a group of non-professional volunteers, in this case data collectors (without a hierarchy/contractual relationship), paid or unpaid, recruited through a crowdsourcing initiative. The 'crowdsourcer' refers to the organisation that initiates a crowdsourcing activity.

2.2 Methodology

Two of the primary tasks of this project were (1) to screen previous experiences in price collection in Africa and (2) to produce a literature review on the topic of crowdsourced data collection. A 'mixed methods' approach was applied based on the methodological research done by Miles and Huberman (1994). In order to triangulate data sources and methods for strengthening the validity of research, a literature review and personal interviews were planned (Cresswell, 2003).

To start, a literature survey was conducted based on an analysis of the results from internet searches. The search findings provided links to market information and price information systems, reports, and a range of actors such as research institutions, development agencies, donors, and public- and private-sector organisations. In order to focus in particular on scientific research, several academic search engines were used[6].

The 'snowball method' (Goodman, 1961) was also applied to find relevant projects and actors based on the literature references that were found. While screening the literature, references to other sources were also followed up and analysed. The search ended when no more relevant project references were found. Furthermore, the database *Beyond Market Prices*, which is maintained by the School of Information at the University of California, Berkeley, was consulted[7]. This repository provided an overview of 228 different projects including market price information systems in the academic, commercial and aid sectors in developing countries. Key literature sources that provided references to different food price information initiatives were the World Bank's *ICT in Agriculture Sourcebook* (World Bank, 2011) and the report *Les systèmes d'information sur les marchés agricoles en Afrique subsaharienne* of the Agence Française de Développement (AFD, 2012).

[6] ScienceDirect, a full-text scientific database offering articles from nearly 2 500 journals and chapters from 26 000 books; dblp, the computer science bibliography of the University of Trier, which provides open bibliographic information on major computer science journals and proceedings; Google Scholar (http://scholar.google.com/).
[7] https://markets.ischool.berkeley.edu/projects/

The search for potential key stakeholders for interviews resulted in a list of more than 100 stakeholders from the IT sector, the non-profit sector, the public sector, research institutions and donors. As a result of the large number of possible interviewees, it was decided to revise and adapt the original methodology of carrying out personal interviews with all stakeholders. The largest group of stakeholders (the public sector) was approached through an online survey. A selection of stakeholders from the private, public and non-profit sectors were contacted and interviewed directly.

An online questionnaire was designed for the identified public sector organisations. Rongéad, an African partner during the study, held a conference about market information systems attended by public organisations in Western Africa in Abidjan, Ivory Coast, in December 2015. Rongéad facilitated the outreach to these actors to encourage them fill out the online questionnaire (available in both English and French). The findings based on the questionnaire and the desk research were used to conduct follow-up interviews with the different public, private and non-profit sector organisations that were identified, to gather further details about their experiences with innovative price data collection initiatives.

The online survey was designed using the Survey Monkey platform[8]. This questionnaire was structured into several sections: an introductory section, a food price information system section and a food price data section. The introduction asked for details about the respondent and his or her role/experiences. The food price information system section included questions covering the predefined parameters for the classification of data collection activities provided by the JRC, as well as questions related to the public organisations and the food price information system they use. The questions in the last section aimed to elicit information about the pros and cons of the food price information system used, and factors related to its success or failure.

The formulation of questions included in the survey was guided by thematic building blocks, such as the crowd, the data collection process, the planning and management of the information system and the users of price information systems.

Both open and closed question types were used in the questionnaire. An advantage of closed questions is that less effort on the part of the respondent is required to answer them and therefore they are less time-consuming to answer. Open questions, however, give the respondent complete flexibility to answer and can provide new information that can be followed up subsequently (Johnson and Christensen, 2013).

The online survey and the desk research identified nine organisations using innovative methods in food price data collection (Table 1); representatives of these organisations were interviewed by telephone by our local project partners. The objective of these interviews was to collect more comprehensive information about each organisation and their applied methodologies. The answers to the online questionnaires were used to guide the interview questions; the interviews were recorded and transcribed.

The organisations using modern technologies come from eight different African countries and make use of either smartphone apps, SMS technology, or both. Four service providers come from the private sector, three service providers are linked to the public sector and two service providers are from the non-profit sector.

[8] http://www.surveymonkey.com

Table 1: List of organisations identified through the online survey and desk research that apply smartphone Apps and/or SMS for the collection of food price data

No	Name	Sector	Country	Data collection methods
1	Novus Agro	Private industry	Nigeria	Smartphone app, SMS
2	ACE	Private Industry	Malawi	Smartphone app, SMS
3	Observatoire du Riz	National government	Madagascar	SMS
4	SIM CPC	NGO	Togo	SMS
5	SIMA	National government	Niger	SMS
6	Rongéad	NGO	Côte d'Ivoire	SMS, other
7	Farmerline	Private industry	Ghana	SMS
8	Sonagess	National government	Burkina Faso	Smartphone app, SMS
9	Esoko	Private industry	Ghana	Smartphone app, SMS

In addition, representatives of the following institutions were also interviewed in order to broaden the study's perspective:

- The AfDB provided insight into food price data interests as a donor.
- The WFP, as a UN agency, provided an overview of innovative food price data collection initiatives established in many developing as well as conflict countries around the world.

3 Literature review on crowdsourced data collection

3.1 What is crowdsourcing?

Crowdsourcing has attracted great attention as an emerging phenomenon of the information society. It is a relatively new field and therefore only limited research into its achievements has been carried out to date (Zhao and Zhu, 2014). Definitions of the term vary.

A generic definition describes crowdsourcing as a "collaboration model enabled by people-centric web technologies to solve individual, organisational and societal problems using a dynamically formed crowd of people who respond to an open call for participation" (Pedersen et al., 2013). Hamadeh et al. (2013) describe crowdsourced data as data collected and reported by the user community using information and communication technologies. Howe (2006) coined the definition for crowdsourcing as 'the act of taking a job traditionally performed by a designated agent (usually an employee) and outsourcing it to an undefined, generally large group of people, the crowd, in an open call'. There is a major difference between outsourcing and crowdsourcing — the contract. Outsourcing involves a supplier providing a good or a service based on a contract, while, in crowdsourcing, the provision of services is usually on a voluntary basis that may be paid or unpaid (Zhao and Zhu, 2014). Howe's definition also includes the idea that such a model has value for businesses and it is therefore often used in a commercial sense. However, while some authors emphasise the non-scientific and non-commercial purpose of crowdsourcing, there are many examples of the use of crowdsourced data in both scientific and commercial applications. Mao et al. (2013) differentiate crowdsourcing types. They describe 'unstructured and organic' crowdsourcing, such as the amalgamation of knowledge in Wikipedia, whereas software applications created by open source projects are described as 'structured' crowdsourcing, connecting participants with well-defined tasks.

Surprisingly, few crowdsourcing definitions mention the reward system even though the reward, monetary or of other type, is recognised as one of the most important drivers of crowdsourcing (Estellés Arolas and González Ladrón-de-Guevara, 2012; Zhao and Zhu, 2014). Based on the different aspects included in the various definitions available today, the main elements of the concept of crowdsourcing can be summarised as follows (Estellés Arolas and González Ladrón-de-Guevara, 2012):

- Tasks of different levels of complexity are offered by an open call.
- Tasks are assigned by individuals or organisations from the public, private or non-profit sectors.
- Tasks are allocated a large group of people with varying levels of knowledge called the 'crowd'.
- The people in the crowd are not employees (non-professional) and, therefore, there is no contractual relationship and work is on a voluntary basis.
- Innovative ICTs, such as web-based tools, smartphone apps or SMS, are used.
- Tasks are performed for a reward (the incentive) of monetary payment or of another type.
- Tasks match an extrinsic motivation (e.g. financial or social reward) and/or intrinsic motivation (not tangible).

All these elements are discussed in further detail below in sections 3.3 to 3.5, in which we look at crowdsourcing from the perspective of the participant (the crowd), the organisation (the initiator) and the system (incentives and technology).

3.2 Crowdsourcing types

Alternative terms for crowdsourcing include 'peer production', 'user-generated content', 'smart mobs' and others (Haythornthwaite, 2009; Doan et al., 2011). These variations are to be expected, given the nascent state of the concept and its application (Pedersen et al., 2013). Yadav et al. (2013) speak about crowd sensing, focusing on the technology in use, as work that expects people to participate and collect appropriate sensor data using their smartphones and contribute it for a common purpose.

Another term for crowdsourcing activities, and one that is often used when the public participates in organised research, is 'citizen science'. Haklay (2012) classifies citizen science projects based on the strength of the engagement between scientists and volunteers. At the most basic level, participation is limited to data collection without any cognitive engagement. The second level is 'distributed intelligence', in which the cognitive ability of the participants is the resource that is being used. Participants are provided with some basic training before being asked to collect and potentially interpret data. The third level allows participants to help develop the problem definition and, together with scientists, plan the data collection method. The participants are then engaged in the data collection but require the assistance of the experts in analysing and interpreting the results. The final level of crowdsourcing of data collection is understood as collaborative science. It is an integrated activity in which scientists and hobbyists are involved in deciding on which scientific problems to work and the nature of the data collection methods to be used.

As new data collection innovations emerge, the crowdsourcing concept will continue to evolve. Ching (2012) experimented with new crowdsourcing approaches such as 'flocksourcing' and 'fleetsourcing'. Flocksourcing is the attempt to organise and motivate a specific group of participants to collect data in a distributed way for a specific purpose. It incorporates social organisation to set targets and hold a (usually smaller) group of individuals accountable. In contrast, traditional crowdsourcing relies on a pool of largely anonymous online or virtually connected volunteers. Fleetsourcing is a data collection approach that simply pairs any fleet of shared vehicles with smartphones. Human sensors with smartphones collect data at all times, retrofitting the fleet with intelligence. Different to crowdsourcing, the 'Voix des Kivus' initiative (Livingston, 2011) uses 'crowdseeding', which is defined as 'the strategically planned placement of mobiles with selected individuals and the establishment of long–term relationships with each user'.

Volunteered Geographic Information (VGI) is another term that has emerged from the geographic literature (Goodchild, 2007). It refers to volunteers gathering spatially referenced data and includes digitising, attributing and rectifying maps. The Geowiki.org approach is to involve volunteers in the validation of existing spatial information. VGI is also being successfully applied in crisis responses. During the past several years, digital volunteering networks have been set up to support the information management needs of humanitarian organisations. The activities include rapid geo-location of event data and infrastructure data, creation of live crisis maps for decision support, data collection and cleaning, and GIS analysis.

The collection of data through volunteers, especially for environmental projects, is also not a new concept and existed long before the internet; however, access to the internet and mobile computing has supported the rise of crowdsourcing projects. They are usually carried out through online communities as a participatory and voluntary activity. This is enabled through Web 2.0 technologies, which allow users not only to passively view static websites but also to interactively participate and transmit data back to webservers. Moreover, today's smartphones are equipped with a number of sensors allowing people to collect and submit data. The proliferation of software development frameworks makes developing new applications easy and, therefore, facilitates the creation of tools for specific data collection campaigns.

Not all crowdsourcing projects require active involvement. Crowdsourcing can even be implemented in such a way that citizens can contribute the computing power of their personal computer for a dedicated project, such as climate prediction[9].

The main elements of the definition of crowdsourcing can be analysed from the perspective of the initiating organisation, the participant crowd and the system, combining incentives, technology and community interaction. These three perspectives are derived from Zhao and Zhu's (2014) research on critical factors influencing crowdsourcing.

3.3 Who is the crowd? The participant's perspective

Crowdsourcing can provide opportunities for individuals to work with organisations that will increase their exposure and transform their working experiences into something potentially more beneficial. Participation in crowdsourcing projects can help improving individuals' skills, as well as strengthen their sense of community (Zhao and Zhu, 2014). The current section highlights critical aspects of crowdsourcing from the participant perspective (the crowd), focusing in particular on participants' motivation to contribute to a crowdsourcing project.

Many factors come into play when creating and sustaining a productive crowdsourcing project/platform; understanding what motivates the targeted crowd is imperative. Although volunteers have their own reasons for contributing to a crowdsourcing campaign, the potential for success of each new project is based on identifying the underlying motivation of the crowd and maintaining participation. This is one of the most important and challenging parts of organising crowdsourcing projects.

Many studies have examined the factors that motivate individuals to participate in crowdsourcing; however, this question continues to be explored as there is as yet no clear answer. Understanding the motivation of users to contribute to crowdsourcing exercises helps to optimise the attraction and retention processes, and also provides information on how trust develops within the community of users. Researchers have tried to divide crowd motivation into extrinsic and intrinsic motivation. Extrinsic motivation provides the user with an immediate payoff, a delayed payoff or a social payoff (Kaufmann et al., 2011). Intrinsic motivation is linked to rewards for participation that are intangible (Pedersen et al., 2013); intrinsic rewards can include 'fun', 'enjoyment', and 'social interaction' (Kaufmann et al., 2011). There is no consensus in the literature as to whether intrinsic or extrinsic motivation is more relevant for successful crowdsourcing. Kaufmann et al. (2011) developed a model of extrinsic motivation that is divided into three categories:

- **Immediate payoff** is a financial compensation received for completing a task as a crowd worker.
- **Delayed payoff** describes the signalling effect of a worker who joins a platform in order to show presence and be noticed by potential employers. Furthermore, crowd workers may benefit from skills they develop through crowdsourcing tasks.
- **Social payoff** is based on three aspects. A worker can be motivated by (i) values, (ii) a third party from outside the crowdsourcing community or (iii) feedback on the delivered work results by other individuals.

Intrinsic motivational factors are built around enjoyment-based and community-based aspects according to the model of Kaufmann et al. (2011). Skill variety boosts motivation: the better a task is completed, the greater the motivation of a crowd worker. In addition, task autonomy is crucial. The greater the influence of the crowd worker over

[9] http://www.climateprediction.net

his or her own ideas, the greater will be the motivation. Direct feedback upon task completion also increases motivation, and even carrying out tasks to just 'pass the time' can be a motivator. Identifying the crowdsourcing community is another motivational factor, as is the potential to make social contacts through the completion of crowdsourcing tasks.

A simpler model by Müller et al. (2010) identifies four motivations for users to participate in crowdsourcing activities: money, altruism, usefulness and fun. Table 2 summarises eight different reasons, identified by Coleman et al. (2009), why people volunteer for crowdsourcing projects.

Table 2: Motivations to contribute to crowdsourcing projects according to Coleman et al. 2009

Motivations	**Explanation**
Altruism	Contributing purely for the benefit of others with no promise of gain or improvement of one's own personal situation.
Professional or personal interest	Making a contribution as part of an existing job, mandate or personal project.
Intellectual stimulation	Improvement of technical skills, knowledge and experience gained through contributions.
Protection or enhancement of a personal investment	Offering a practical solution to a shared problem provides an immediate payback for participation through shared improvement of a common resource.
Social reward	By being part of a larger network or virtual community contributors, through collaboration, discussion and development of the resource, acquire a sense of common purpose and belonging that unites them into one community and encourages further sharing.
Enhanced personal reputation	Providing the opportunity for registered contributors to develop online identities that are respected, trusted and valued by their peers, thereby increasing their own sense of self-worth.
Creativity	Provides an outlet for creative and independent self-expression.
Pride of place	Where adding information about one's own group or community may be good for public relations, tourism, economic development, or simply demonstrating that one's own street or establishment is 'on the map'.

The different crowd motivation models show that a variety of aspects can influence the way citizens become involved in crowdsourcing. Motivations are diverse, individual and unique to the given crowdsourcing context; crowdsourcing initiatives should consider these when rolling out a crowdsourcing activity in order to keep workers motivated.

Reports that address crowdsourcing failures mainly focus on the results produced by the crowd and do not address the issue of how and why the crowd is or is not productive (Van Meer and Meuleman, 2011). Bott and Young (2012) comment on this, emphasising that the factors motivating the crowd must align with the long-term objectives of the crowdsourcing initiative to ensure consistent, good-quality participation.

3.4 Implementing crowdsourcing: the organisation's perspective

This section describes the critical aspects of crowdsourcing from the perspective of those organising a crowdsourcing campaign. In this context, the organisation is defined as an entity that has a problem to be solved: this can include government agencies, businesses and individuals. The organisation has almost full control of the crowdsourcing process, including defining the problem, communicating needs and information to the crowd, determining the process and the governance mechanisms to be followed, evaluating submissions, and selecting solutions (Pedersen et al., 2013).

3.4.1 Implementation and governance

Sharma (2010) founded a model of critical success factors for crowdsourcing based on the earlier research of Carmel (2003), Heeks and Nicholson (2004), and Farrell (2006). He highlights *motive alignment* of the crowd as the central idea for his model. Only when the motivations of the crowd are aligned to the long-term objectives of the crowdsourcing project participation will be ensured. Viswanath et al. (2003) have defined the following parameters as determinants for the motivational alignment of the crowd in their unified theory of acceptance and use of technology:

- **Performance expectancy.** The extent to which an individual believes that using the system will help him or her to attain gains in job performance.
- **Effort expectancy.** The degree of ease associated with the use of the system.
- **Social influence.** The degree to which an individual perceives that others believe he or she should use the new system.
- **Facilitating conditions.** The extent to which an individual believes that organisational and technical infrastructure exists to support use of the system.

In Sharma's model, vision and strategy of the crowdsourcing initiative, linkages and trust, external environment, infrastructure and human capital are considered peripheral factors that affect the specific determinants of the motivational alignment of the crowd.

- **Vision and strategy** of a crowdsourcing project is crucial; crowd workers must see the value of the initiative.
- **Linkages and trust** minimise costs. These can be geographic, cultural or linguistic linkages, which improve knowledge transfer and sharing of best practices within a crowd.
- **External environment** builds the framework for any project. This includes political governance, economic and business climate, openness towards entrepreneurship, or the general living conditions. A favourable regulatory environment and ease of doing business can encourage crowdsourcing initiatives.
- **Infrastructure** in digital crowdsourcing is based on internet or mobile phone technology; easily accessible and reliable communication technology is imperative.
- **Human capital** is the basis of the entire crowdsourcing process. Adequate expertise and skills are crucial for success. It is recommended that projects do not require too much training of participants and that minimal intervention is required to guide the crowd.

These peripheral factors are not exclusive or exhaustive. Table 3 shows Sharma's (2010) Effect Determination Matrix, showing the effect of the peripheral factors on the determinants of the motive alignment of the crowd.

Table 3: Effect Determination Matrix from Sharma (2010)

Determinants/peripheral factors	Performance Expectancy	Effort Expectancy	Social Influence	Facilitation Conditions
Vision and strategy				
Human capital				
Linkages and trust				
Infrastructure				
External environment				

Although crowdsourcing initiatives are increasing, there are few scientific studies dealing with the challenges organisations face when implementing such projects. Failures and lessons learned from crowdsourcing are more often found in press articles or through social media channels, which organisations use to leak sensitive information about governance challenges. John Cataldi, a serial entrepreneur who has managed crowdsourcing projects in the fields of technology, think tanks, financing and creative projects, shares on his blog the crowdsourcing lessons he has learned through experience. They deal with the critical factors associated with managing crowdsourcing activities (Cataldi, 2013).

Based on his practical experience, he emphasises the following aspects:

- A successful crowdsourcing project needs sufficient research and planning ahead by the organisation.
- Only highly skilled workers will produce results of high quality.
- A realistic budget, aligned to the quantity of work and quality of the end product, is necessary.
- Incentives are effective when they are based on short-term deliverables; the incentives need to be aligned with the participants.
- Moderating the crowd is highly important to enhance productivity.
- Crowdsourcing projects require an organisation with a good perception of work ethic.
- Only with significant online credibility and community trust can crowdsourcing activities become successful.

Johann Füller (2012), Professor at the University of Innsbruck's (Austria), highlights the importance of addressing the crowds' expectations. Communication can help to keep workers attracted to the task; not listening to crowd workers can lead to crowd resistance. Fair and transparent terms and conditions for crowd workers are necessary.

In developing countries, crowdsourcing experiments are increasing, but the work environment may differ to crowdsourcing activities in industrialised countries. Therefore, a roll-out in such countries may require additional management capabilities. Bott and

Young (2012) highlight various risks and challenges around the management of crowdsourcing initiatives based on experiences from low-income country contexts.

- **No active crowd.** When the wrong incentives are provided and there is a lack of communication with the crowd, involvement may suffer.
- **Participant inequalities.** Universal technology access is not a reality in many countries; this digital divide may be reflected in a rather 'elite' crowd.
- **Manipulation of the crowd.** This unwanted process can be a hindrance but through meaningful deliberation, by using semantic tags, levels of control or scoring to mediate disputes and legitimated moderators, this can be controlled.
- **Attacks on the crowd.** Especially in a context of human rights violations and conflict, crowd workers can be exposed through their engagement.
- **Ineffective crowdsourcing process.** Proper management of contributions in crowdsourcing is a huge challenge. Adequate data quality management is also of great importance.

Ching (2012) emphasises that aspects such as affordability, ease of understanding and ease of deployment are critical to managing crowdsourcing initiatives within less advanced technology contexts.

As research about management and governance of crowdsourcing initiatives is still quite limited, priority should be given to this field of research. Companies tend to be very cautious about sharing lessons about management failures. In a field that is growing quickly, the sharing of knowledge from innovate data collection initiatives will be helpful to improve the roll-out of future crowdsourcing projects.

3.4.2 Quality control

Crowdsourcing can be a powerful option for data collection. Some studies have compared professional data with crowdsourced data; for example, a comparison of OpenStreetMap[10] data and professional or official data found that the crowdsourced data provided valuable results and could compete with professional data (Girres and Touya, 2010; Haklay, 2010; Zielstra and Zipf, 2010). However, in general, the reliability and quality of crowdsourced data are often unclear. Authoritative data, in contrast, must follow specific controlled data collection norms that guarantee some measure of quality. Nevertheless, to make full use of crowdsourced data, they must be reliable and appropriately validated. This requires a careful design of the project and the application of suitable quality assurance methods.

There are different ways to measure and/or control the quality of crowdsourced data (See et al., 2016):

- Automated quality assurance methods should be used where possible to filter out data falling outside an allowed range and/or to detect fraudulent behaviour.
- Reliance on the self-correcting mechanism of the crowd through majority agreement, where more than one citizen is given the same task. This approach assumes that the majority of the crowd will provide the correct information and makes it possible to identify erroneous information. In the crowdsourcing context this is usually referred to as the 'wisdom of the crowd' (Surowiecki, 2005). Research on how many volunteers are needed to map an area well from the VGI research area (Haklay et al., 2010) concluded that there is a non-linear relationship between the number of contributors and the quality of data; when the number of contributors exceeds 15, accuracy becomes very good. Haklay et

[10] https://www.openstreetmap.org/

al. (2010) found that the number of contributors can act as an intrinsic measure of the quality of crowdsourced datasets without the need for reference datasets.

- Use of control data that are collected by experts, against which the crowd data can be compared. This is a typical approach in the scientific world. Control data are usually collected for a small sample only, but the procedure can provide information about the performance of individuals and can be used to weight individual contributions. Well-established databases with lower data frequencies can be used as a benchmark.
- Peer review, in which expert reviewers evaluate the information produced by others, is a common tool in the scientific community, and is also applied to web services such as TripAdvisor[11], allowing consumers to evaluate and rank the services of hotels and restaurants. This method would require the use of an independent group of reviewers and, in the context of food price data collection, would be considered unrealistic because of the very large area under observation and the many different markets from which data should be provided in an ideal case.
- Third-party organisations could be hired to evaluate the quality of crowdsourced data. This would require additional time and financial resources to train the third-party organisation to understand the quality requirements. Such an organisation would have to formulate a set of test questions, check responses against others and track individual data collectors to investigate their collection history and the related quality.

A reliable quality assurance framework would probably need to consider a mixed approach, utilising both automatic and interactive data checks. Owing to the large number of data, an automatic solution is needed.

The uncertainty of crowdsourced data should be highlighted and data users must be made aware of this. One potential solution is to teach the crowd about data quality issues; training is one way of producing higher-quality results and helps reduce errors in valuable information.

3.5 Incentives and technology: the system's perspective

A crowdsourcing system evolves around the incentives and the technology applied. This section describes the critical crowdsourcing aspects from the system's perspective.

3.5.1 Incentives

Incentives are critical to win over crowd workers and gain valuable results from their work. A good incentive strategy will include motivational elements that match the behaviour of the crowd. Pertinence and appropriateness drive effective incentive mechanism design (Zhao and Zhu, 2014). Bott and Young (2012) emphasise that the most effective collaborators can be attracted only with the right mix of incentives. Zhang (2008) highlights the importance of psychological, cognitive, emotional and social aspects in the design of ICT and its link to crowdsourcing to find the right incentive strategies.

In crowdsourcing systems, crowd incentive alignment is a critical factor influencing the crowd's behaviour and interaction with the system. Sharma (2010) emphasises that, for a crowdsourcing system to be sustainable, the motives of the crowd need to be aligned to the long-term objectives of a crowdsourcing initiative. These findings highlight how critical the incentive structures are for the operation of crowdsourcing activities. Furthermore, although payments can be low, unpaid crowdsourcing is not common

[11] http://www.tripadvisor.com

practice (Schenk and Guittar, 2011). Compared with paid crowdsourcing, non-paid crowdsourcing is limited because tedious tasks are unlikely to attract volunteers, especially if benefits are seen only by the implementing organisation (crowdsourcer); even if non-monetary incentives exist, it is difficult for the organisation to control and adjust them (Horton and Chilton, 2010).

The complexity of the issues related to the appropriateness of incentives is reflected in the research on this topic. Scientists have tried to understand whether the behaviour of crowd workers is primarily driven by economic incentives, by social incentives, or by a combination of both; however, the relationship between incentives and expected behaviour is not well understood (Zhao and Zhu, 2014).

Finally, the differences, in terms of accuracy, error types, task completion speed and crowd engagement, that are seen when different financial incentives are used need to be considered.

Paid crowdsourcing

Crowdsourcing systems that provide monetary remuneration to participants can pay a fixed fee per output, a variable amount per hour, or pay through quality bonus payments. A study by Mao et al. (2013), using the MTurk[12] crowdsourcing system, revealed that, with proper incentives, paid crowd workers can achieve comparable accuracy to (non-paid) volunteers working on the same task, and perhaps even work at a faster rate. Different payment schemes lead to significant differences in the quality of work produced and the amount of time spent on a task. Financial incentives can be used to control trade-offs between accuracy, speed and overall effort within a fixed budget.

A study by Mason and Watts (2010) found that workers completed more tasks for a higher fixed payment, but that quality did not improve with higher payments. Rogstadius et al. (2011) made a similar observation in their research. Yin et al. (2013) found that increasing and decreasing payments increased and decreased the quality of work, respectively. Harris (2011) studied performance-contingent financial incentives (both rewards and penalties) and showed that the quality of work was higher in the presence of such incentives than in their absence.

The influence of different payment schemes on the quality and quantity of work produced has been less studied. Mason and Watts (2010) studied piece-rate payment schemes and quota-based schemes. In piece-rate payment schemes workers are paid for each task they complete. In quota-based payment schemes workers are compensated after a bundle of tasks have been completed. Results show that the quota-based approach elicited higher effort from workers; under the piece-rate scheme workers completed fewer tasks.

Organisations implementing crowdsourcing systems need to thoroughly plan what type of incentives will be most appropriate for solving their problem and to match them to the expectations of the crowd. Some alternatives to monetary remuneration are mobile phone airtime and remuneration through commodities (food or other).

Mobile phone airtime

One of the few food price data collection projects that had implemented crowdsourcing techniques was carried out by the World Bank (Hamadeh et al., 2013) in several countries. Price collectors used their smartphones to collect prices and send them to a web-based platform. These collectors were paid not in money but in mobile phone

[12] https://www.mturk.com/mturk/welcome

airtime vouchers. The ongoing mobile Vulnerability Analysis and Mapping (mVAM) project of the WFP (WFP, 2015) in Kenya follows a similar approach; the WFP investigates food prices by asking refugees living in camps to provide the prices paid for specific food items. They compensate contributors with airtime for 10 text messages. As many people, particularly those from the low-income communities, will not have a bank account and depend on mobile phones for communication, using airtime instead of money as an incentive lowers the contribution barriers. Implementing crowdsourcing in a low-income setting would benefit from non-monetary incentives.

Commodity items

Another alternative to monetary remuneration is the rewarding of work through commodity items. Some research findings underline the advantages of commodity-based compensation over monetary equivalents (Kurosaki, 2008). This approach may be useful in developing countries. Samdaria et al. (2012) tested a model in which workers were given the opportunity to carry out micro-tasks whenever they needed a commodity item. A commodity item might be a good or a service. On completion of the micro-tasks the desired commodity was provided as remuneration. This was driven by the hypothesis that getting a commodity 'for free' when there is a need for it is a better micro-task motivator than simply working for money. The model also integrated a commodity provider. For examples of commodity providers, Samdaria et al. (2012) refer to auto-rickshaw drivers providing discounts on transport. They started the experiment with three auto-rickshaw drivers in Bangalore.

The auto-rickshaw drivers were given a Java-enabled mobile phone pre-loaded with a micro-tasking app. Each driver was instructed to offer their passengers (the crowd workers) an opportunity to receive a discount on the fare in return for completing the micro-tasks. A discount on the fare was given only if the task completed by the passenger was worth more than five 5 Indian rupees. The maximum discount a passenger could receive could not exceed the journey fare. For their service as a commodity provider, the rickshaw drivers received a 20% commission on the work being done by the passenger. The results showed that many passengers took part in this crowdsourcing model. The scientists concluded that a commodity-centric crowdsourcing model might complement the conventional financial incentive model and reach a much more diverse crowd without the complexity and cost of paying them with money.

3.5.2 Technology issues

Different crowdsourcing technologies are available today and the choice of technology depends on the particular project. Organisations can either develop their own technical crowdsourcing systems or use third-party crowdsourcing systems or platforms. According to Alpheus Bingham, founder of the crowdsourcing company InnoCentive[13]: 'The technology choices are an important element of a successful crowdsourcing operation, not just in reaching the right people, but in ensuring that the end-to-end process works effectively.' It is possible to crowdsource through an organisation's website, by using social media or a specifically programmed platform. Crowdsourcing through mobile phones is very common as mobile phones provide voice and SMS messaging for sourcing information and intelligence. Smartphones provide a set of embedded sensors, such as accelerometer, digital compass, gyroscope, GPS, microphone and camera that can be applied to crowdsourcing projects. Both mobile phones and smartphones provide a huge mobile sensing network. The world can collect and analyse data far beyond the scale of what was possible even a few years ago (Yang et al., 2012). Nevertheless, the selection of the right technology should be linked to the

[13] https://www.innocentive.com/

problem at hand. Ching (2012) emphasises that successful crowdsourcing requires the use of an affordable, understandable and easy to deploy technology.

In the recent EducEO project[14] funded by the European Space Agency, a group of companies developed several pilot projects to demonstrate the value of crowdsourcing for application in Earth observation, scientific research, education and citizen engagement. The project reported that building a good app gives the user personal satisfaction and has an engaging, 'fun' feel. However, a good app is not always sufficient, as it must be part of a holistic approach providing high levels of satisfaction with the project concept, the community, the incentives and the level and ease of communication. Before starting such a project, the community expectation is that a reliable testing strategy was put in place and that when the crowdsourcing begins there should be no significant bugs in the app. Furthermore, training should be offered to the crowd in order to guarantee a high-quality result. Smartphone software and hardware are regularly updated, and maintaining the latest versions can become very expensive. Therefore, technology choices are also important and affect the longevity of the developed tools. Crowdsourcing projects often occur in waves following advertising or social media campaigns. Consequently, a robust and scalable backend infrastructure must be available to accommodate spikes in data upload at times when participation is high following recruitment activity.

Finally, communication is a key challenge at all stages of the project: during the recruitment campaign, when developing an intuitive app that provides useful feedback, and when disseminating the results. It has been suggested that new crowdsourcing projects should be launched with a media event (e.g. a press conference), targeting, in particular, special interest groups and grassroots organisations, and ideally making use of contacts in these organisations as well social media platforms. Therefore, when planning project expenses a marketing budget should be included, to fund the cost of targeted campaigns. For example, a Facebook campaign would require funds to generate direct website clicks, mobile downloads, etc.

3.6 Overview of crowdsourcing projects

A large number of crowdsourcing and citizen science projects have been undertaken or are in progress, and detailed examination of their documentation would go beyond the scope of this project. Roy et al. (2012) reviewed a set of 30 citizen science projects as part of a study undertaken for the UK Environmental Observation Framework. The majority were projects related to biodiversity and nature conservation.

A number of inventories of crowdsourcing projects provide further information. SciStarter[15] contains a database of over 600 projects and initiatives; the site provides information about ongoing projects for interested volunteers. Scientists can use the site to advertise current initiatives and recruit citizens. Citizen Science Central[16] is a site hosted by the Cornell Lab of Ornithology. The projects described on the website are characterised by theme and range from water and air quality, weather and climate change to biology and astronomy.

The Citizen Science Alliance[17] operates a number of citizen science projects covering topics such as the classification of galaxies and images of the moon (Galaxy Zoo and Moon Zoo), the search for planets (Planet Hunters), OldWeather, which involves

[14] http://educeo.info/
[15] http://scistarter.com
[16] http://www.birds.cornell.edu/citscitoolkit
[17] http://www.citizensciencealliance.org

searching ships' log books for weather information, and Whale FM, which asks volunteers to group similar-sounding whale calls together.

VGI-net[18] is an inventory of VGI-related projects completed by Elwood et al. (2012); however, the project list has not been updated since 2009, which is the date of the last entry. Socientize is an EU-funded project that provides a forum for all stakeholders within the citizen science domain. A green paper (Socientize, 2013) provides a list of 17 EU-funded citizen science projects. Finally, Wikipedia[19] has a page devoted to citizen science projects.

3.7 Potential of crowdsourcing in the development context

3.7.1 Potential for mobile-based food price crowdsourcing in Africa

Crowdsourcing holds huge potential for data collection. It offers access not only to a wealth of data, but also to the individual problem-solving skills of the crowd (Schenk and Guittar, 2011). Howe (2006) describes a range of categories for crowdsourcing applications, such as co-creation, crowd creation, crowd voting, crowd wisdom and crowd funding. Crowdsourcing has benefited a wide range of sectors. Some initiatives have received high media coverage. For example, after the earthquake in Haiti, a crowdsourced mapping approach helped guide aid agencies in their disaster relief effort (Zook et al., 2010), while Ushahidi, a crowdsourced web platform, recorded the post-election riots in Kenya (Meier, 2015) and Google Translate™ service utilises a community of volunteers to improve Google's translation quality, serving every user of the service (Vijayan, 2015). One of the most prominent crowdsourcing initiatives is Wikipedia, the decentralised online encyclopaedia whose content is produced, reviewed and amended by volunteers.

Crowdsourcing has a huge potential for collecting and processing data, making it possible to elicit the help of a large number of volunteers, thus building a workforce that would be difficult and expensive to recruit using formal methods. The volunteers are likely to have specific local geographic expertise that can help improve the quality of the collected data. Moreover, many areas of the world are data sparse because neither official government data nor data collected by the private or public sector are available. Crowdsourcing has the potential to fill such data gaps. For example, although some organisations have invested in mobile technologies to improve price data collection in Africa, the burden of training field staff remains. The use of new approaches to data collection, involving crowdsourcing and ICT tools, could reduce this burden (FAO et al., 2016).

Critics of the validity and representativeness of crowdsourced data need to consider also that other data collection methods (surveys, participatory rural assessments, training participants or involvement of local partner organisations) face similar challenges (Bott and Young, 2012). Crowdsourced data must be seen as complementary to professional collection approaches and not as a direct competitor of or replacement for traditional approaches (Zielstra and Zipf, 2010). Crowdsourced food price data have the potential to enhance and complement authoritative data (Coleman et al., 2009) by increasing the frequency and spatial coverage of data collection.

The potential uses of crowdsourcing in developing countries are numerous. The mobile revolution is transforming people's lives in many regions. Between 2000 and 2012 the number of mobile phones subscriptions in developing countries grew from 1 billion to around 6 billion (World Bank, 2012). Particularly in Africa, mobile networks have grown

[18] http://spatial.ucsb.edu/dev/vgi-net
[19] http://en.wikipedia.org/wiki/List_of_citizen_science_projects

exponentially in the last 10 years and, according to a report of Groupe Speciale Mobile Association (GSMA, 2015), Sub-Saharan Africa has been the region of the world exhibiting the greatest growth in mobile communication in the last five years. Mobile phone subscription service growth rates in the region are more than twice the global average.

Rates related to internet access are also growing, but at a much slower rate. The International Telecommunication Union (ITU[20]) (ITU, 2015) estimated that 20.7% of all Africans have used the internet in 2015. However, as many Africans access the internet in public spaces such as internet cafes and call shops, this number does not reflect household connection rates. Compared with the low rate of penetration of fixed broadband in Africa (< 1%), the number of African mobile broadband (wireless internet access) subscriptions continues to grow at double-digit rates and is expected to reach a penetration rate of 29% in 2016, up from 17.4% in 2015 (ITU, 2015). These developments are consistent with mobile broadband services becoming more affordable than fixed broadband services all around the world (30.8 vs. 67.3 purchasing power parity dollars in 2015 in developing countries) (ITU, 2015). In Africa, it is expected that the number of mobile broadband connections will almost triple over the next five years, with 3G (more suitable for smartphones) predicted to overtake 2G (more suitable for classical phones) in 2019 and reach 60% of total connections by 2020 (GSMA, 2016). In line with the mobile broadband developments, the rate of smartphone adoption is expected to increase from an average of 13% in 2014 to an estimated 30% in 2016, and is expected to rise to 57% by 2020 (ITU, 2016). The growth seen so far has occurred mainly in Egypt, Kenya, Nigeria and South Africa (the more technologically advanced mobile markets), as well as in Algeria, Cameroon and the Democratic Republic of Congo (relatively new 3G markets).

Current adoption rates of smartphones are still low, but it is thought that the increasing availability of low-cost devices will drive the expected increasing adoption trend. The limited network coverage remains a key barrier to mobile internet adoption in Africa. In 2015, mobile broadband networks covered around 50% of the population of the African continent and 43% of Sub-Saharan Africa (GSMA, 2015).

Significant differences exist between African countries, as well as between rural and urban areas. In Africa there is a strong inverse correlation between 3G coverage and the proportion of the population living in rural areas. These differences must be taken into consideration when organising crowdsourcing initiatives. Table 4 provides an overview of the key digital statistics for Egypt, Nigeria and South Africa. Such figures must be carefully examined when considering the technical design of crowdsourcing campaigns in different African countries. These statistics provide an important insight into technology trends and existing ICT challenges and limitations.

Table 4: Digital services uptake statistics for Egypt, Nigeria and South Africa (WeAreSocial, 2015)

	Egypt	**Nigeria**	**South Africa**
Active internet users of total population	53%	38%	46%

[20] United Nations specialised agency for ICTs.

	Egypt	Nigeria	South Africa
Active social media accounts of total population	25%	7%	22%
Mobile phone subscriptions of total population	113%	75%	146%
Growth in internet users since January 2014	25%	26%	24%
Growth in social media accounts since January 2014	33%	21%	20%
Growth of mobile subscriptions since January 2014	2%	21%	16%
Prepaid mobile subscriptions	96%	97%	83%
Broadband subscriptions	32%	17%	36%

3.7.2 Potential for development

Access to mobile communication technology empowers individuals, and stimulates growth, entrepreneurship and productivity throughout the economy as a whole. Crowdsourcing is often criticised for being a source of cheap labour without regulation, labour rights and standards as well as minimum wages (Chen, 2015). On the other hand, some people view paid crowdsourcing as a potential vehicle for global development, improving earnings and livelihoods in poor communities around the world (Thies et al., 2011). Despite the digital revolution, crowdsourcing has not so far been shown to be an influential accelerator of development. Thies et al. (2011) studied paid crowdsourcing through MTurk in developing countries and found that its impact has remained limited. MTurk is a crowdsourcing internet marketplace. Employers can post jobs online and crowd workers complete jobs for monetary reward. According to a study by Thies et al. (2011), over one-third of MTurk workers are based in India, which demonstrates the extent to which crowdsourcing has penetrated the developing countries. Nevertheless, MTurk workers are generally of relatively high socio-economic status.

The idea of using paid crowdsourcing for socio-economic development assumes that several requirements are met, which include a reduction in the costs of access to computers or mobile phones as performing work online requires some type of internet access. Only a minority of citizens in the developing world own a home computer. Although the rate of mobile phone ownership is higher, many people still own only very basic phones without the features of a smartphone. Moreover, data collection often requires specific apps to be installed on the smartphone, which again requires access to the internet. As shown in Table 4, access to the internet varies widely across African

countries andalso rural–urban disparities exist within countries. Figure 1 shows the number of smartphones per 100 inhabitants in a selection of African countries (Esselaar and Storck, 2015).

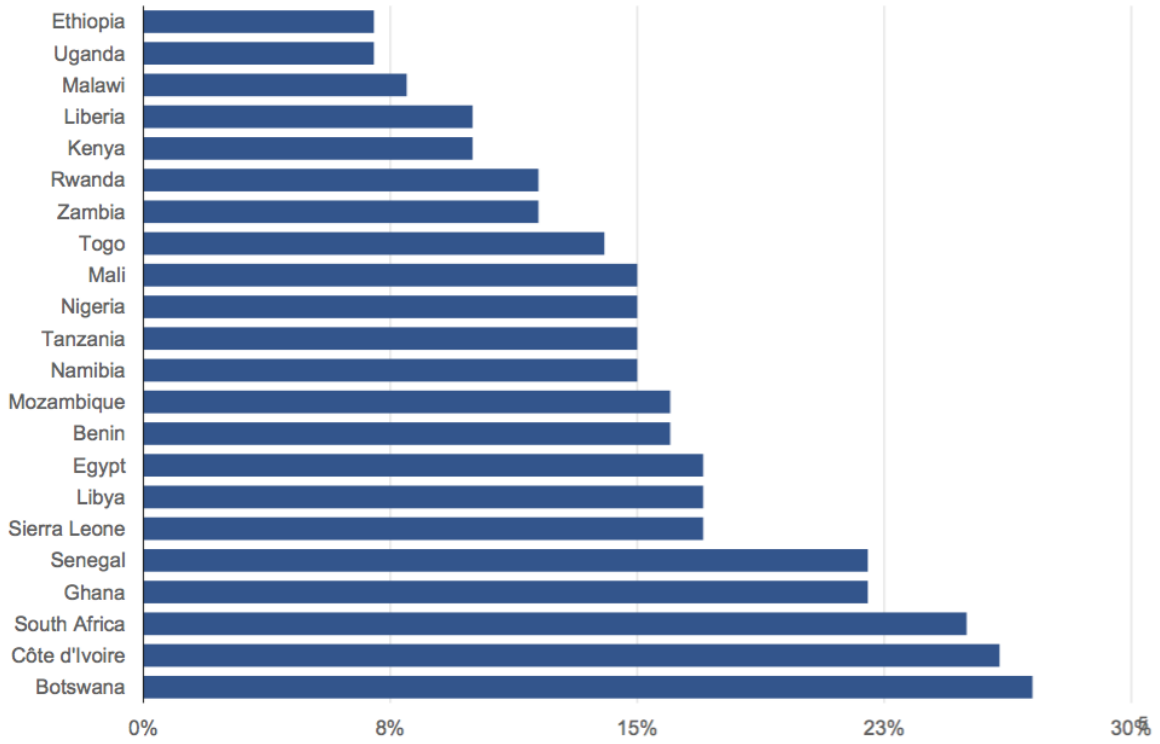


Figure 1: Smartphone penetration in Africa. Smartphones per 100 inhabitants (Esselaar and Storck, 2015).

Network coverage in rural or remote areas has been identified as one of the four key challenges to increasing digital inclusion in Africa. Affordability of internet access and devices is also a challenge. The increasing availability of low-cost devices will contribute to the predicted increased smartphone adoption, while a reduction in sector-specific taxation could make internet access more affordable (GSMA, 2016). Another challenge is that people in developing countries often do not have a bank account to which payments can be made (Donmez et al., in preparation). Alternative means of remuneration for crowdsource participation, such as airtime, could be a suitable option in such cases. The launch of electronic payment systems through mobile phones, such as Kenyan telecom company Safaricom's M-PESA system, has improved access to financial services for the poor who normally would not open a bank account. With an M-PESA account, people can transfer and receive funds over the phone (Safaricom, 2016).

If crowdsourcing is to have a significant impact on people's livelihoods, it will be necessary to create an environment in which it can thrive. To accelerate the impact of crowdsourcing in low-income and high-unemployment communities it will be necessary both to raise awareness of the phenomenon and foster the necessary skills to carry out online work. Achieving these aims would improve the reliability of data collection, increase the quality of the data collected and provide stable earnings for participating households.

It is likely that data collection initiatives at grass-roots level face less complex barriers than crowdsourcing via online platforms such as MTurk. In Kibera, an informal settlement of Nairobi, the Voice of Kibera Programme trained residents in digital data

collection and produced a detailed map of the area[21]. Data on many different themes, including security, water and sanitation, and health and education, were collected through the aggregation of local citizen reports and geospatial and attribute data. Another example of effective crowdsourcing is the creation of a map of bus routes in urban Dhaka, Bangladesh. This again shows that empowering people to collect data via a smartphone can have important results, in this case achieving something that neither government nor bus operators had managed to do (Ching, 2012).

[21] http://mapkibera.org

4 Current and previous experiences on innovative data collection methods

This chapter presents a critical examination of innovative food price data collection initiatives in developing countries, with particular focus on Africa, by surveying the landscape of government agencies, international institutions and organisations — both non-profit and for profit — that are active in this area. The landscape was analysed in three different groups:

- food price data collection activities using innovative technologies in Africa;
- crowdsourcing initiatives related to innovative food price data collection; and
- crowdsourcing initiatives from other sectors.

4.1 Food price data collection activities using innovative technologies in Africa

This section presents innovative food price data collection activities based on the online survey and telephone interviews conducted during the course of this project.

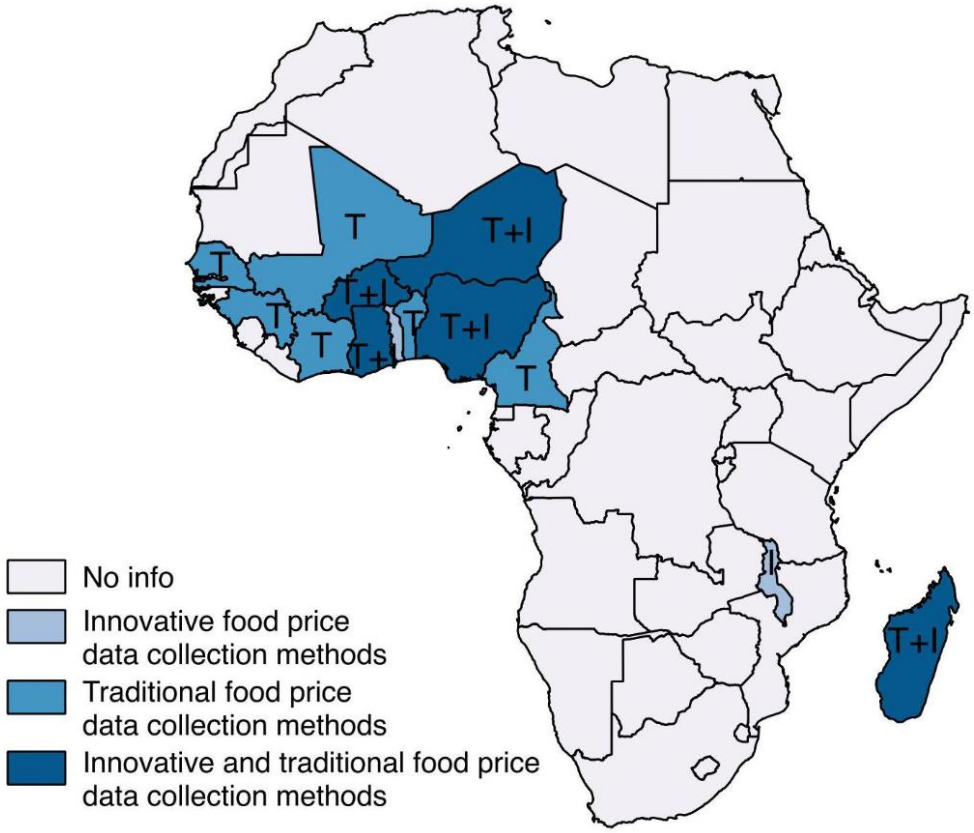


Figure 2: Location of organisations using innovative (I) and traditional (T) food price data collection methods.

Figure 2 depicts the locations of organisations using innovative and traditional food price data collection methods across Africa. Figure 3 and Figure 4 summarise the findings of the nine interviews described in this section; Figure 3 relates to app-based data collection approaches, whereas Figure 4 refers to SMS-based data collection projects.

	Novus Agro Nigeria	ACE Malawi	Farmerline Ghana	Esoko Ghana	Sonagess Burkina Faso
Collection	Android App SMS	Android App SMS	Android App SMS	Android App SMS	Android App
Dissemination	Email Phone	SMS IVR Newspaper Radio	SMS Phone	SMS Call centre Web Radio, TV, print	Radio Email SMS
Validation	Collectors training Random spot checks Collector manager market visits	Price capture strategy Platform validation features Administrator review	Platform validation features Administrator review Cross check with sellers in the market Cross check in markets by external consultants Cross check in markets by own staff	Price capture strategy Platform validation features Administrator review Cross check with independent person in market Exchange with Ministry about price trends	Review by an analyst
Pros Tech	Availability of 2 techs faster process than SMS	Availability of 2 techs App more user friendly better data accuracy	Availability of 2 techs App more user friendly better data accuracy faster process than SMS	Availability of 2 techs Faster price collection, Data published within 1 day Cheaper than traditional methods	Faster price collection, Data published within 1 day
Cons Tech	Internet down time SMS character limitation	Internet down time	Internet down time SMS character limitation	Internet down time SMS character limitation Memorizing SMS codes	Internet down time App allows sending of quantitative data but no qualitative data (paper based)
Challenges	Financial Technical	Financial Technical Operational	Financial Operational Human resources	Technical Operational Financial External	Technical Operational Financial

Figure 3: App-based food price data collection systems.

	ODR Madagascar	CPC Togo	SIMA Niger	Rongéad Côte d'Ivoire
Collection	SMS	SMS	SMS	SMS (no standardized technology)
Dissemination	Website Newspaper Radio	Website Radio	Website Radio	Email SMS Call centre
Validation	Cross checks within 2 weeks	Review at regional level Review by central controller	Review at regional level Review by national analyst	Review at local level Review by chief-analyst
Pros Tech	SMS less costly than traditional method SMS accelerates time between collection and dissemination	SMS accelerates time between collection and dissemination Platform allows accuracy checks	SMS reduced data errors, more user friendly SMS less costly and less workload	Cost-efficient with no training needs of any external data collectors and no customized service technology for data collection
Cons Tech	SMS character limitation Risk of typing errors	SMS character limitation	SMS character limitation Intensive training for collectors in SMS Not easy server recognises syntax errors	SMS data collection method but no standardized method the local analyst needs to work with different technologies and information channels to gather data
Challenges	Financial Political	Financial Technical Operational Institutional	Financial Technical Managerial Political	Human resources Technical Financial

Figure 4: SMS-based food price data collection systems.

4.1.1 Novus Agro, Nigeria

Institutional set-up: Novus Agro, based in Lagos, Nigeria, is an agricultural market and professional services firm, founded in 2009, offering agro-based information and consulting services to the agricultural sector.

Method of data collection: Novus Agro uses modern SMS and an Android app-based methods of food price data collection. Novus Agro collects price information on 20 agricultural commodities across 60 markets in 23 states in Nigeria. Price information is collected via a network of enumerators situated in major markets in its coverage area. Prices are collected on market days, whether daily or weekly. Agents transmit commodity prices, in the form of SMS short codes, to the back-office team for validation and upload on the web platform. Agents can also use an app that shortens this process as prices are uploaded directly on the web platform. When internet access is unavailable, agents revert to the SMS method for transmission of price data.

Method of data dissemination: Novus Agro has found that adoption of pricing data by Nigerian farmers is low. The reasons for this are thought to include problems reading message content, due to high rates of illiteracy, and a lack of willingness to pay for the service, as many donor services are provided for free. In response, Novus Agro currently is developing a system that will allow farmers to call to obtain daily and weekly market prices, although institutional partners such as banks, investors, buyers and exporters will continue to receive this information by email.

Data validation: Enumerators receive intensive training on the Novus Agro price collection methodology, to enable precise data capture at both retail and wholesale level, as well as training on profiling markets, enabling them to capture unique characteristics that influence commodity prices in individual markets. A rigorous verification strategy, thorough back-up in-market enumerators, on-the-spot checks and market visits by enumeration managers, ensures that the prices are highly accurate.

Date, frequency, time gap: Novus Agro food price data collection began in 2009 and, as of October 2016, it is still ongoing. Food price data are collected and updated daily to weekly.

Type of data and location: Novus Agro collects a range of food price types, including wholesale food price, retail food price, food price at farm gate and retail food price at the market. Novus Agro collects the price of 20 commodity items. Food prices are collected across the country (national). Novus Agro's dataset also includes actual commodity–location pairs. Food prices are collected on a daily basis in 36 markets, and on a weekly basis in 24 markets.

Cost drivers: Novus Agro's cost drivers of the service are initiating new market observations, training enumerators and maintaining the platform.

Access: Users need to register for the food price information service.

Funding: Novus Agro is a private company funded by private investors.

Pros of the service

- The SMS method can be used even in the absence of internet access.
- Use of the app reduces the time and effort needed to make price data available as agents can upload the data directly to the web platform.

Cons of the service

- The SMS system is subject to a character limit and is more time-consuming.

- The app requires a good internet connection, which is not always available.

Challenge of service: Novus Agro faces a number of financial and technical challenges for operating the service. Opening in new markets is costly, as personnel must set up operations and develop infrastructure. Furthermore, the wages of the price agents, who are paid monthly, as well as the costs of phone calls and data transfer, have to be covered. Technical challenges relate to unreliable internet connection. In urban areas internet downtime averages 30 minutes to 1 hour per day, but, in rural areas, internet connection can be lost for days. Novus Agro's service revenue does not cover the service costs. Novus Agro relies on donor support and a diversified business model offering a range of services to farmers, traders, buyers and exporters. Despite these challenges it is expected that, by the end of 2016, Novus Agro price agents will be operating in 113 markets.

4.1.2 The Agricultural Commodity Exchange (ACE) for Africa, Malawi

Institutional set-up: ACE is an agricultural commodity exchange that facilitates trade. It was established in July 2004 with a grant from USAID (US Agency for International Development) through the National Smallholder Farmers' Association of Malawi (NASFAM), which identified a need to bring greater order to the marketplace. It generates real-time market information based on the bids and offers generated through a live exchange trading platform. ACE also provides extension services for farmers and storage facilities in warehouses.

Method of data collection: ACE collects price information using modern approaches. ACE started food price data collection by using a SMS approach to upload prices, which was cheap and straightforward. However, SMS sometimes failed and agents who were unable to send the data in the correct format would sometimes run out of airtime. ACE developed a website to which data could be uploaded. However, this approach was also not user-friendly and resulted in data errors. ACE's latest development is an Android app that supports users in uploading data, guiding them through the uploading process using a series of forms. Prices are now more accurate than with the earlier methods as the forms are standardised. ACE is also investigating the potential of USSD (unstructured supplementary service data) with its network providers.

Method of dissemination: The service started by using SMS approach to disseminate price data to farmers. It is not easy to maintain the user database as users often change phones. The SMS text is written in English, but the commodity names are given in the local language, Chichewa. Another method used for price data dissemination is email and publication on the website. The latest development is the introduction of an interactive voice response system (IVR), which allows users to dial in and hear the prices. ACE also uses traditional forms of dissemination, such as newspapers and radio announcements as about 50% of farmers in Malawi still prefer traditional sources of information. However, newspapers and recorded radio programmes are not as accurate as other methods because of the time delay between data collection and dissemination, resulting in the price information becoming outdated.

Data validation: ACE's enumerators collect a minimum of three prices for each commodity. When the three prices have the same value, this value is recorded. When the three prices vary, another three prices are collected and the median is used. The administrator receives an alert once an agent has sent prices. ACE's marketing information platform has validation features that allow the administrator to either approve the prices sent by the food price collector if these are consistent with other market price information or reject them if they are inconsistent with other data.

Date, frequency, time gap: ACE began food price data collection in 2011 and, as of October 2016, it is still ongoing. Food price data are collected weekly and published on the same day.

Type of data and location: ACE collects the wholesale and retail food price of seven commodity items. Food prices are collected in markets across the country (national) and from several sources within a single city. There are several data points available and these are published as the median or the most quoted price (common price). ACE's dataset includes actual commodity–location pairs.

Cost drivers: ACE's cost drivers are operational and the cost of personnel. Running expenses include salaries, smartphones and transport costs for enumerators. ACE cooperates with a developer team in India that programs the system. These costs cannot be covered by the service and are usually funded through a donor agency. Another important cost factor is the dissemination of the price data through SMS; ACE attempts to reduce these costs by buying a monthly bundle plan from network providers.

Access: Users need to register for the food price information service, which is free.

Funding: ACE has been subsidised by the Competition and Trade Expansion Program of USAID, AGRA (Alliance for a Green Revolution in Africa) and the EU.

Pros of the service

- The app is user-friendly, guiding enumerators through a series of forms to upload the data.
- Use of the app results in higher data accuracy because the process is standardised.
- The app is less time-consuming to use than sending a SMS or uploading data through a web platform.

Cons of the service

- Issues with internet connectivity are a problem and can create delays in sending collected data.

Challenges: ACE considers technical, financial and operational issues to be major challenges to its service. Internet downtime is a common problem that can delay the data collection process. Agents may be able to collect the data but struggle to find a place with sufficiently good connection to submit the data to the platform. Timing of market hours is another obstacle for timely data collection; some markets are active in the morning while others are evening markets. The service is not profitable, as the subscription revenues do not cover all expenses.

4.1.3 Observatoire du Riz (ODR), Madagascar

Institutional set-up: ODR is a sub-organisation of the Rice Observatory of Madagascar, which is part of the National Action Plan for Rural Development, coordinating all relevant activities. The ODR is based in Antananarivo, Madagascar.

Method of data collection: ODR used to collect food price data through a regional agent, who called 22 agents, covering 199 districts, to gather information. The regional agent transferred the data through email or over the phone to ODR. As this approach was costly and time-consuming, ODR introduced an SMS method. An agent takes the modal price for each commodity in a specific area and reference market for one year. A syntax grid assists in writing the SMS, which is sent to a mobile number linked to a server. Software extracts the prices and records them in a database. Food price data used to be published with a time delay of three days; data are now sent within one day. In addition to being more efficient in speed of publication, the cost of the SMS method is lower than the overall cost of the calls that had to be made when using the previous system. Issues with the SMS method are related to the character limits and the risk of data errors while writing long series of SMS. ODR may change the data collection

method from SMS to a smartphone app to eliminate the character limitation and increase automated control of the collected data.

Method of data dissemination: Data are disseminated free of charge on websites, in newspapers and on radio programmes (this mainly during the lean season). So far there is insufficient interest in receiving price information by SMS for this service to be made available.

Data validation: ODR collects data weekly. Crosschecks are carried out in case of significant variations between food prices within 2 weeks.

Date, frequency, time gap: ODR started food price data collection in 2005 and, as of October 2016, it is still ongoing. Food price data are collected weekly. The time gap between data collection and publication is usually less than a week.

Type of data and location: ODR collects wholesale food price, retail food price, and market retail food price for seven commodity items. Food prices are collected across the country (national). The data are collected weekly at markets in important locations in each district. ODR's dataset does not include commodity–location pairs.

Cost drivers: The overall cost of the data collection is US$ 25 000 per year and it is the biggest cost driver of the service.

Access: Users do not need to register for the food price information service and the data are freely available.

Funding: ODR is a public entity and is funded by international donors such as AfDB, the EU and the World Bank.

Pros of the service

- The SMS approach has reduced the time between data collection and dissemination.
- The SMS method is less costly than the traditional method of using paper, pen and phone.

Cons of the service

- The SMS approach is limited by the maximum number of characters allowed per message.
- Typing errors can negatively affect data quality.

Challenges: ODR cites financial challenges as a major issue related to data collection. The payment of enumerators is not budgeted for by the local government and ODR depends on external sources of funding, such as donors and development projects; when these development projects expire, a funding gap arises. Funding from central government to cover the cost of maintenance and the salaries of enumerators could secure the future operation of the service. Greater advocacy of food price information is needed to increase awareness among political decision-makers about its importance in food security, trade facilitation and agriculture.

4.1.4 Centrale des Producteurs de Céréales du Togo (CPC), Togo

Institutional set-up: The CPC is a national network of cereal producers, founded in 2008, with about 30 000 members organised in 1 000 cooperatives.

Method of data collection: CPC uses a SMS method for collecting food price data. Members of the organisation are asked to visit markets in relevant regions on behalf of

the network and to assess average prices for commodities. Based on a customised syntax, data are sent to the organisation's server and the information is extracted automatically. Initially the SMS information was entered manually in an Excel file but this was prone to errors.

Method of data dissemination: The price data are sent to service subscribers by SMS and published online. The information is also disseminated to a wider audience through local radio programmes which are broadcasted in local languages to reach audiences that do not understand French.

Data validation: Data are checked at a regional and central level to prevent typing errors and to compare the new data with historical values for the agricultural commodities. At the regional level the collected food price data are checked for the first time. At the central level the food price data of the collectors and the results of the regional level check are verified by a central controller. The cleaned data are then sent to the service users.

Date, frequency, time gap: CPC started food price data collection in 2010 and, as of October 2016, it is still ongoing. Food price data are collected weekly. The time gap between collection and publication is one week.

Type of data and location: CPC collects a range of food price types, including food prices at the farm gate, retail food prices at the market and modal daily prices at the market. CPC collects the price of five commodity items. Food prices are collected across the country (national). CPC's dataset includes commodity–location pairs. CPC did not disclose the locations of the markets where the data are collected.

Cost drivers: Technical costs include server operations. Operational costs are related to the costs of infrastructure and communication and financial incentives for collectors. Each of the 48 collectors and the five regional agents is provided with a phone that costs less than €50. Communication costs are about €3 per food price collector per month and the financial incentive is about €15 per collector per month. The internet costs for dissemination are based on the fixed charges of the website and internet connection service, and funding the rural radio service. The greatest expenses incurred are related to the data collection, the budget for server communication and infrastructure costs, such as server configuration and operation.

Access: Users do not need to register for the food price information service.

Funding: CPC is a private organisation and gets funding from the Togo government and international partners such as FAO and USAID.

Pros of the service

- The SMS method has increased the speed with which data can be collected and allows them to be published on the day of collection.
- The server platform allows data to be checked for accuracy.

Cons of the service

- The SMS method has a character limit.
- Before an automated system was introduced, the SMS information was entered manually in a database, and this led to errors.

Challenges: CPC noted financial challenges in maintaining its service. Price collection is voluntary as they do not pay collectors a salary, but they are offered financial incentives to cover the costs of transport and to compensate for the time and effort expended in

data collection. CPS also provides airtime credit and a mobile phone. Initially, issues relating to reputation were encountered when officials doubted the quality and accuracy of the information. This has changed over time and CPC's service now has a reputation for being a reliable tool to better understand markets. Financing the infrastructure in the first place was a challenge. The continuous operation of the server is critical. Mobile network failures are frequent and are a barrier to the timely transmission of food prices by data collectors.

4.1.5 Système d'Information sur les Marchés Agricole (SIMA), Niger

Institutional set-up: SIMA is a specialised government service funded by the Ministry of Commerce and Private Sector Development. Its purpose is to collect, process and disseminate agricultural market information to support better decision-making and promote food security. Since 2000 SIMA has collected the prices of cereals and other agricultural products.

Method of data collection: In the past, SIMA used a traditional data-collecting method; a central collector in each region manually gathered data from local collectors and the data were sent by courier to the organisation. As this process took at least 10 days, the data were already out of date on arrival. The introduction of an SMS method, with messages being sent to a server, led to a reduction in both data transmission time and the risk of price data errors. Quality control is undertaken to check for typing errors. The software is open source, but the customised version is not available to the public. The organisation has experimented with smartphone app technology and, once a robust method has been designed, SIMA plans to implement and scale up its use.

Method of data dissemination: SIMA uses various methods to disseminate price data. Weekly price information is disseminated through radio programmes, and a bulletin of prices for fruits, vegetables and grains is published on the website. A monthly document, called 'Albichir', which summarises food price data, is also made available.

Data validation: In each area a representative of SIMA carries out a plausibility control and validates the data for each market in the context of the price developments. This individual also checks for syntax error, particularly with respect to the units of measurement. A second level of validation occurs at the national level, where a system analyst assesses the findings of the area representatives.

Date, frequency, time gap: SIMA started food price data collection in 1990 and, as of October 2016, it is still ongoing. Food price data are collected weekly and the time gap between the data collection and publication is one week.

Type of data and location: SIMA collects a range of food price types including wholesale food price, food price at the farm gate and retail food price at the market. SIMA collects the price of 21 commodity items. Food prices are collected across the country (national). SIMA provided no information about commodity–location pairs or from which markets food price data are recorded.

Cost drivers: SIMA provided detailed information about cost drivers (Table 5).

Table 5: Cost drivers seen by SIMA

Cost data collection	Cost data dissemination
• 66 feature phones: around €80 each • 1 desktop computer: around €400 • 1 server (hosting a SIM card for receiving the SMS): around €50 • mobile services: around €410 per collector per year • collectors' bonus (transportation and incentive): around €11 per week, per collector	• annual contract with several radio stations: around €4 600 per radio station • internet costs: estimated at €200 per month, but are not related only to the dissemination

Collecting data in one individual market costs about €4 600 per year per market.

Access: SIMA did not say if users need to register for the food price information service.

Funding: SIMA is a public entity and funded by the national government of Niger, the European Commission, Mercy Corps, Catholic Relief Services, Oxfam and Save the Children.

Pros of the service

- The SMS method has reduced data errors and is easier to handle.
- The SMS technology has reduced the workload and costs of the service.

Cons of the service

- The character limit of the SMS method does not allow the collectors to capture additional qualitative data.
- The introduction of SMS technology required intensive training for enumerators.
- The issue of server interpretation of syntax errors is not easy to solve.

Challenges: SIMA noted technical, managerial, financial and political challenges to provide its service. The character limit of SMS required the introduction of commodity codes. Managerial challenges relate to ensuring sufficient investment in training the enumerators. The introduction of an SMS method required additional funding, which presented a financial challenge. Promoting food price information services as a useful tool among political decision-makers for better management of food security is critical. A sustainable operation of the service is possible only through continuous tracking of the system and solving of IT issues.

4.1.6 Rongéad, Côte d'Ivoire

Institutional set-up: Rongéad is a non-profit organisation, founded in Lyon (France) in 1983, which runs country programmes in Côte d'Ivoire and Burkina Faso. It aims to help small-scale farmers to access markets and to build the capacity of producer organisations. Its initiative, Nkalo, improves the marketing of agricultural products in West and Central Africa. Rongéad educates, informs and advises participants in the

value chain (production, processing and marketing) on the market situation at the local, sub-regional, regional and international levels.

Method of data collection: Rongéad has experience with the use of both traditional and modern methods of food price data collection with the Nkalo service. The national market analyst collects prices by contacting his network within the value chain (farmers, salespersons, processors, exporters and government officers) using phone, SMS, email and fact-to-face communication. The collected data are analysed at the national level and sent to the chief analyst for review and the addition of international market information. The information is provided using Word and Excel software. In 2010, Rongéad attempted to use a smartphone app for food price data collection. After the pilot phase the organisation decided to revert to the traditional method of data collection. Providing each data collector with access to a smartphone, training and solving internet connectivity issues in rural areas restricted the scaling-up of the coverage of the service. In addition, customising the app to accommodate new trends in the market was considered to be too time-consuming and expensive.

Method of data dissemination: Rongéad disseminates market information in three ways: by email, by SMS or via a call centre. In Côte d'Ivoire, Mali, Senegal, Burkina Faso, Chad and Gambia price information is sent by SMS to subscribers. Agricultural commodity bulletins can be received by email; for traders and exporters email is a convenient information channel. In contrast, in rural areas the usability of email is limited as many farmers do not have internet access. Tests with an IVR were not successful as it was apparently too complex for users and the platform faced interruptions. A call centre has been established where agricultural advisors provide users price and other agricultural information.

Data validation: The data validation process is based on the expertise of the French market information system 'Offre et Demande Agricole' giving advice to farmers. The validation methods depend on the specific parameters of the market for a particular commodity. The collected data are reviewed by the local analyst and the chief-analyst. In case of unclear information, measures of verification are taken.

Date, frequency, time gap: Rongéad started food price data collection in 2011 and, as of October 2016, it is still ongoing. Food price data are collected weekly. The time gap between data collection and publication ranges from 24 to 72 hours.

Type of data and location: Nkalo collects the prices of 15 commodity items of a range of types, including wholesale price, price at the farm gate, retail price at the market and export prices such as Incoterms (International Contract Terms). Food prices are collected across the country (national), and at sub-regional and international level (Côte d'Ivoire, Burkina Faso, Gambia, Mali, Senegal). Nkalo's dataset includes commodity–location pairs.

Cost drivers: The cost of personnel is the biggest cost driver in the data collection process. The budget for a local analyst is €10 000–15 000 per year. The SMS service costs around €1.5–2 per user annually; it is included as an added value service in a mobile network operator service and it is free of charge. Marketing the service is the biggest financial expense for Nkalo. This includes, for example, designing offers, increasing visibility in rural areas and implementing communication campaigns.

Access: Users need to register for the food price information service.

Funding: Rongéad is a non-profit organisation and is funded by international donors such as the EU, WFP, CTA, ECOWAS, OIF, AFD.

Pros of the service

- The management of the service is easy as the local analyst collects data through a trusted network using phone, SMS or email channels.
- The personal exchange between the local analyst and the network adds value, as, in addition to the quantitative data, qualitative data about the market situation are shared.
- As external data collectors are not used, there are no training requirements.
- The organisation structure requires fewer personnel.

Cons of the service

- Data collection is more complex; with no standardised method of data collection in place the local analyst needs to work with different information channels to gather the data.

Challenges: Rongéad considers the 'human factor' to be critical to the collection of food price data; therefore, retention of staff is a critical challenge. The local analyst must build a solid and trusted network with various members of the value chain. Development of skills in market analysis requires training and capacity development. Well-qualified staff can be attracted to work for other organisations; loss of staff to competitors is a great loss of human capital. Further challenges to be overcome in service implementation were sourcing and maintaining an IT service provider, setting up a subscription system and obtaining a short number and authorisations for server installation. The subscription system went down and the service lost more than 80% of its users; getting users back was not easy. Time constraints and funding issues have had an impact on the progress of the system development. Marketing campaigns for informing potential users about the advantages of the service are costly and cannot be covered by the subscription fees alone. In addition, the willingness to pay for such a service is low as communities are accustomed to obtaining agricultural and market information free of charge from development projects.

Rongéad's crowdsourcing model for data collection

Among the food price data collection initiatives examined, the unique approach used by Rongéad stood out. Rongéad experimented with a smartphone app for food price data collection in 2010. After a trial run, the organisation decided against this technology; providing each data collector with a smartphone and appropriate training was considered too costly and customising the app according to new observation trends in the markets was also considered to be expensive and time-consuming. Rongéad decided to use an alternative crowdsourcing model. Trusted partners within the value chain share food price information with Rongéad based on a collaboration agreement; partners agree to share information on the basis of exchange of services between the national analyst of Rongéad and its trusted network. Data collectors receive no payment direct from Rongéad. There is no standardised method for the sending of food price data; the national analyst calls people over the phone and receives SMS and email updates. In this way, the information provider can also share qualitative information about the market situation. On average, it takes half a day to gather food prices from the whole country. The regular networking creates a trusting relationship between the national analyst and the data collectors. The human factor is critical for gathering food price data using this approach; the motivation of contributing persons is driven by their professional and networking interests. From a financial point of view, this data collection method is more cost-efficient than the implementation of a system of paid field agents.

4.1.7 Farmerline, Ghana

Institutional set-up: Farmerline was founded in 2012 and is located in Accra, Ghana. It provides mobile services that improve the livelihoods of farmers through communicating timely and relevant agricultural information such as weather alerts, best farming practices, financial tips and market prices through voice and SMS messages directly to their mobile phones.

Method of data collection: Farmerline uses modern food price data collection technology. In areas with good internet connection, paid agents use the smartphone Android app *Mergdata* to collect food price data. In areas where the internet connectivity is poor, information is sent via SMS through short codes for each agricultural commodity. Experiments with USSD are also ongoing.

Method of data dissemination: Farmerline disseminates price information by SMS and by phone.

Data validation: Farmerline cooperates with sellers to confirm prices or obtain information about prices, apart from its own food price data collectors. The organisation's marketing information platform has validation features that allow the administrator to approve or reject the prices sent by the enumerators via SMS. When an agent uses the app and a price figure goes beyond a certain threshold, the system flags this. If there is a valid reason, a comment can be inserted. Officers also call agents for confirmation if the information is outside a normal range. Data integrity is strengthened through frequent cross-checking: outside contractors are sometimes commissioned to collect prices and sometimes Farmerline sends its own staff to collect reference data.

Date, frequency, time gap: Farmerline started food price data collection in 2015 and, as of October 2016, it is still ongoing. Food price data are collected weekly and the time between collection and publication is less than one week.

Type of data and location: Farmerline collects a range of food price types including wholesale price, retail price and price at farm gate. Farmerline gathers the price of eight commodity items. Food prices are collected across the country in 17 markets (national). Farmerline's dataset includes commodity–location pairs.

Cost drivers: During the data collection process, the payment of allowances to data collectors and the costs for sending the price data are significant. Data dissemination activities also incur significant expenses, including the cost of personnel, the cost of translation of content and the cost of sending the data to subscribers.

Access: Users need to register and pay a subscription fee to access the food price information service.

Funding: Farmerline is a private company that is funded privately.

Pros of the service

- The app and SMS methods enable market prices to be available within a day.
- The SMS method is not dependent on internet connectivity.
- The transfer of SMS data to the platform is cheaper than traditional data collection methods.
- The availability of two technologies, app and SMS, provides a level of flexibility for the data collection process.

Cons of the service

- Utilisation of the app requires internet access but this can often be unreliable, particularly in rural areas.
- The SMS method has a character limit.

Challenges: Farmerline faces challenges in the data collection process because of interruptions in the internet access and electricity supply. Agents may delay the sending of data when they cannot charge their mobile phones. Where the app is used for sending the data, collection can be done offline, but data transfer depends on internet access. When there are internet connectivity issues for long periods of time, price data cannot be sent to the platform on time. Sometimes agents cannot be present in their communities on specific market days. If Farmerline had more staff members it could reach a greater number of potential clients. Therefore, they plan to set up an agent network system, operating on commission, to sell services. Food price data collection is still an evolving service for the organisation and cost recovery has not yet been achieved. As such, the price information service is integrated in a bundle of other services, providing information about weather and farming advice.

4.1.8 Société nationale de gestion des stocks de sécurité alimentaire du Burkina Faso (Sonagess), Burkina Faso

Institutional set-up: Sonagess was founded 1994 and is based in Ouagadougou, Burkina Faso. This public body manages the food security stocks in the country. Sonagess started collecting and disseminating food price information in 2009 to support better decision-making, to ensuring food security and to support marketing of agricultural products.

Method of data collection: Sonagess uses a modern method of food price data collection based on a smartphone app. Previously, Sonagess used both SMS technology and paper-based food price records, which were sent by mail to the organisation. The current method enables the system to receive data within a day. Each agent is assigned to at least one market. Data are collected in the market once a week through the mobile app. When the smartphone is connected to the internet, the data are automatically sent to the system. The internet access is organised through a virtual private network accessible only by the collectors' smartphones. It is a paid service, preventing the need to pay individual internet fees for each agent. The software is proprietary and not available to the public.

Data dissemination: Sonagess disseminates price data through emails and SMS, and over the radio. Radio programmes transmit the food price data in 16 local languages. Institutions and stakeholders of value chains receive information via email for easier archiving and re-usability. Customers of the mobile network operator *Airtel* receive food price information as a value added service. In the future, it will be necessary to develop subscription services in order to generate funds rather than providing the information free of charge. The willingness to pay for this service is low and to increase subscription uptake, awareness campaigns will be required.

Data validation: Sonagess has built a validation grid by taking the average maximum and minimum prices for the last four weeks for each commodity. Data out of this range are rejected. The corrected data are approved by an analyst before they are uploaded to the system.

Date, frequency, time gap: Sonagess started collecting food price data in 1994 and, as of October 2016, it is still ongoing. Food price data are collected weekly and the time between price data collection and publication is less than a week.

Type of data and location: Sonagess collects a range of food price types including wholesale price, retail price, price at the farm gate and retail price at the market. Sonagess collects the price of 12 commodity items. Food prices are collected across the country (national). The organisation's dataset includes commodity–location pairs. Sonagess did not provide any information about the locations of the markets.

Cost drivers: Sonagess shared detailed information about cost drivers (see Table 6).

Table 6: Cost drivers as seen by Sonagess

Cost data collection	Cost data dissemination
• collectors: each of the 64 collectors receives €8 per week (€32 per month) to cover a market • mobile services: around €6 000 for all collectors per year	• 5 radio programmes in rural areas cost about €800 annually • 1 national radio programme costs €1 440 annually

Owing to the high annual costs of TV broadcasting (€16 800), this dissemination channel was discontinued.

Access: Users must register for the food price information service.

Funding: Sonagess is a public body, funded by the national government of Burkina Faso and international donors such as AFD, FAO, ECOWAS, CILSS, Trade Hub and the WFP.

Pros of the service

- The app enables market prices to be made available within a day.
- The SMS method does not require internet connectivity.

Cons of the service

- Use of the app is frequently prevented by lack of the unavailability of an access point to networks.
- The app collects quantitative data but not qualitative data, which are still provided by paper-based methods.
- The SMS technology is human resource intensive as data entry to the database is done manually.
- The SMS method has a higher risk of error than the app.

Challenges: Sonagess faced a mix of challenges when setting up the service. The system development was a bureaucratic and time-consuming process and the procurement and budget release procedures of the government were complex. Developing effective and efficient cooperation with private mobile network operators and software companies was also very complicated.

Operating the service requires sustainable finance from government. Incentives for the price collectors need to be secured and appropriate training provided. Training is usually not covered by public funding. Technical constraints were experienced while using Microsoft® Office Access software to manage the large volume of data, a problem that was later solved by using a Microsoft SQL server.

4.1.9 Esoko, Ghana

Institutional set-up: Esoko was established under the name TradeNet in 2005 in Kumasi, Ghana, to collect and share market food prices via SMS. In 2009 it was renamed Esoko (from the Swahili word 'Soko', meaning market, and 'e' representing electronic). The designed platform enables multiple stakeholders in the value chain to provide critical information, such as market prices and agronomic and training tips, to smallholder farmers, while also providing the ability to survey the farmers.

Method of data collection: Esoko uses modern methods of food price data collection. Enumerators use an Android app to collect and send food price data. Data are received in real time once uploaded and the app is quick and easy to use. When internet access is not available, data are transferred via SM; the enumerators use short codes for each commodity.

Method of data dissemination: Esoko uses various methods to disseminate food price information to users. The SMS market price data service has 40 000 subscribers. In addition to dissemination via SMS, a call centre provides price information to users. Call centre staff speak the local language and can provide explanations of the SMS content, if necessary. The cost of the call is paid for by the recipient of the message at a standard rate of 8 Pesewas. The SMS service for farmers is usually paid for by third parties, e.g. a NGO supporting the farmers. Through its website, Esoko also provides food price data to its subscribers. Traditional dissemination channels, such as radio, print and TV, are also used.

Data validation: Esoko has a comprehensive validation process. When data are submitted to the platform, they are cross-referenced with the previous data to determine the price change and the system flags issues based on set percentage changes; this process takes a few hours. Food price data collectors are included in the validation process via phone calls to ensure consistency. In addition, an independent person is called from each market to cross-check some prices. Esoko collaborates with the Ministry of Agriculture to confirm price trends in some markets. After validation, data are approved for public dissemination. An enumerators' conference is held annually to enable data collectors refresh their skills on data collection. Enumeration managers visit the markets twice per year to re-weigh some of the commodities and monitor the market situation.

Date, frequency, time gap: Esoko started food price data collection in 2006 and, as of October 2016, it is still ongoing. Food price data are collected in some markets daily and in some markets weekly. The time gap between data collection and publication is 24 hours.

Type of data and location: Esoko collects the wholesale food price and retail food price of 22 commodity items. Food prices are collected across the country (national) in 35 markets. Esoko's dataset includes commodity–location pairs.

Cost drivers: Infrastructure costs involved in setting up the service and making it operational were significant. The biggest cost driver of running costs of the service are the monthly allowance and the annual training costs of the food price data collectors. The cost of connectivity and sending data is a major cost driver of food price dissemination.

Access: Users need to register for the food price information service.

Funding: Esoko is a privately owned and funded company. Esoko benefits indirectly from international donors when development programmes include price data services.

USAID, IFPRI and the New York University Centre of Technology have provided indirect funding through development programmes.

Pros of the service

- The app is user-friendly and data accuracy is high.
- The app makes the food price collection process faster.
- Esoko uses SMS technology as a back-up method where internet connectivity is problematic.

Cons of the service

- The biggest challenge is interruption of internet connectivity at some markets.
- The SMS method has only limited characters available, which limits the sending of price data from the field.
- Memorising the codes for all commodity prices has been an issue for enumerators.

Challenges: Esoko considers technical, financial and operational challenges to be major challenges to its service. Internet interruption is the major technical issue that can impair the utilisation of the app for data collection; in this case, Esoko uses SMS for data transfer. The running of an enumerator programme is expensive. Agents receive training, phones and tablets, phone credit and a monthly allowance as incentives. The willingness to pay for a food price data service alone is low. A combined service including other features, e.g. weather information or extension service information, increases the willingness to pay. The data validation process can be delayed when it is difficult to contact enumerators by phone to confirm the data sent. Another external factor creating challenges for Esoko is the lack of regulations that enforce the use of standardised measures and weights in Ghana; this can create confusion when collecting price data.

4.2 Innovative food price data collection initiatives through crowdsourcing

This section, based on a literature review, provides information of key aspects of various innovative food price data collection initiatives that used crowdsourcing.

4.2.1 Food price data collection with smartphones in eight countries

The World Bank carried out a pilot study for crowdsourced price data collection through mobile phones. The study was a response to the need for high-frequency data to analyse food price trends. The pilot study was carried out by a private company JANA (www.jana.com). Data were collected in eight countries in South-East Asia, South Asia, East Africa and Latin America (Hamadeh et al., 2013 — see Figure 5).

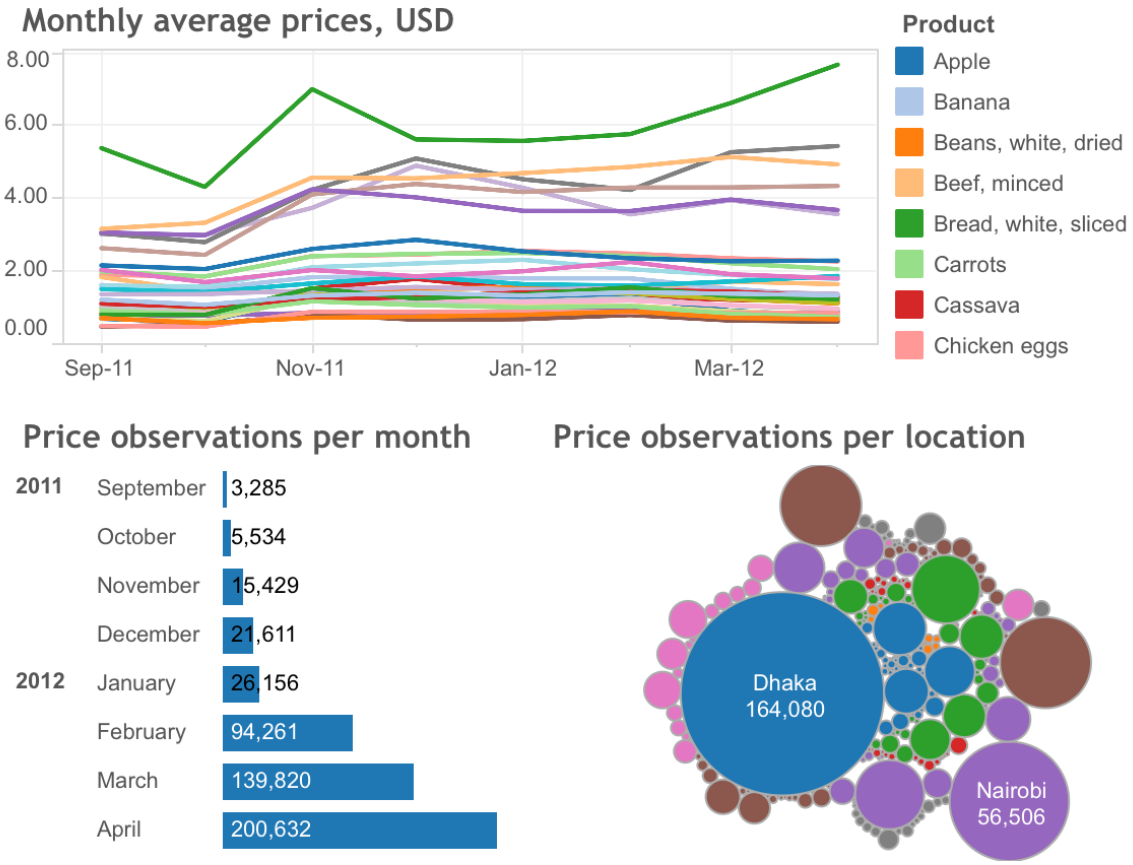


Figure 5: Crowdsourced food price data in New Delhi (World Bank Data Blog, 2013).

⇨ **Food price context:** The objective of the study was to investigate the feasibility of crowdsourced price data collection. In the pilot phase, price data were collected for 30 specified food commodity items in about 3 000 supermarkets in 500 survey locations across Brazil, Bangladesh, India, Indonesia, Kenya, Nigeria, Pakistan and the Philippines. The basic set of information collected covered the price of the item identified; the weight or volume of the item; additional comments (e.g. whether the item is in season or not); and a photograph of the item. Data were captured on a monthly basis for a period of approximately six months.

Crowd: In this pilot project non-professional price data collectors represented the 'crowd'. The data collectors were recruited using various social media channels, such as Facebook and Twitter. Further, a website for recruitment was programmed in English, Portuguese and Indonesian, corresponding to the focus countries.

Motivation and behaviour: The crowd behaviour differed between the pilot countries. In Indonesia and Brazil price collectors were generally less active than in other countries being investigated. Therefore, the monetary incentives offered in these locations were increased to US$7.00 in Indonesia and US$15.00 for Brazil for each batch of food prices submitted.

Implementation and governance: Legal, cultural and language challenges arose during the project and had to be addressed. Designing the level of incentive was a complex task for the different countries and influenced the retention of the crowd. Managing and analysing a huge number of data sets required appropriate database and validation systems.

Quality control: The submitted data were verified in a semi-automated process, involving analysis and manual inspection. Each price collector was scored based on various behaviours and the quality of the item batches that were submitted. Data submitted by high-scoring contributors were automatically verified, data from negatively scoring participants were blacklisted and data from those rated in the middle were manually verified. During the project, weekly payments were limited to US$20.00 per participant to limit excessive payments and to avoid fraudulent behaviour. Statistical measures were used to flag potential food price data outliers.

Incentives: Participants received airtime rewards after data verification and validation. The original value structure of airtime minutes paid was US$1.00 as an initial bonus for providing supermarket information; US$0.50 for each supermarket identified up to a limit of three supermarkets; and US$5.00 for each verified batch submission, consisting of price observations for each available item, up to a maximum of 30 price observations. Subsequently, a referral bonus of US$1.00 was granted to existing contributors for every new referral that enlisted as a contributor and submitted price data.

Technology: Data collection was handled using personal computers and mobile phones as modern ICT tools. A multilingual website was specifically designed for the project to facilitate the survey.

Conclusion: The project highlighted the potential to use alternative methods to sample and collect food price data across countries. The platform developed proved that once efficient verification and validation mechanisms are in place, data users across the globe could have access to the price data within days of data collection. The data recorded show that crowdsourcing is an innovative and feasible method to collect food price data.

More information about the project can be found at http://blogs.worldbank.org/opendata/can-our-parents-collect-reliable-and-timely-price-data

4.2.2 Africa Food Prices Collection project

The JRC of the EC launched the Africa Food Prices Collection project in April 2013. The project aimed to explore the possible uses of, and challenges to, accessible, timely, accurate and high-frequency food prices data collection in Africa. After completion of the pilot phase, the JRC concluded a contract with Knoema for collecting data every week from August 2014 to June 2015 in 21 countries in Africa. After the end of the project a similar approach was implemented in additional African countries and the collection is ongoing supported by funding provided by the AfDB. Weekly price data are collected on selected agricultural commodities in almost all African countries. In each country, data are collected from the largest urban commodity marketplaces and, typically, one rural commodity market (see Figure 6). Data collectors are hired and compensated financially for their work. Crowdsourcing as an alternative way of food prices data collection was explored in three countries: Kenya, Uganda and Sierra Leone.

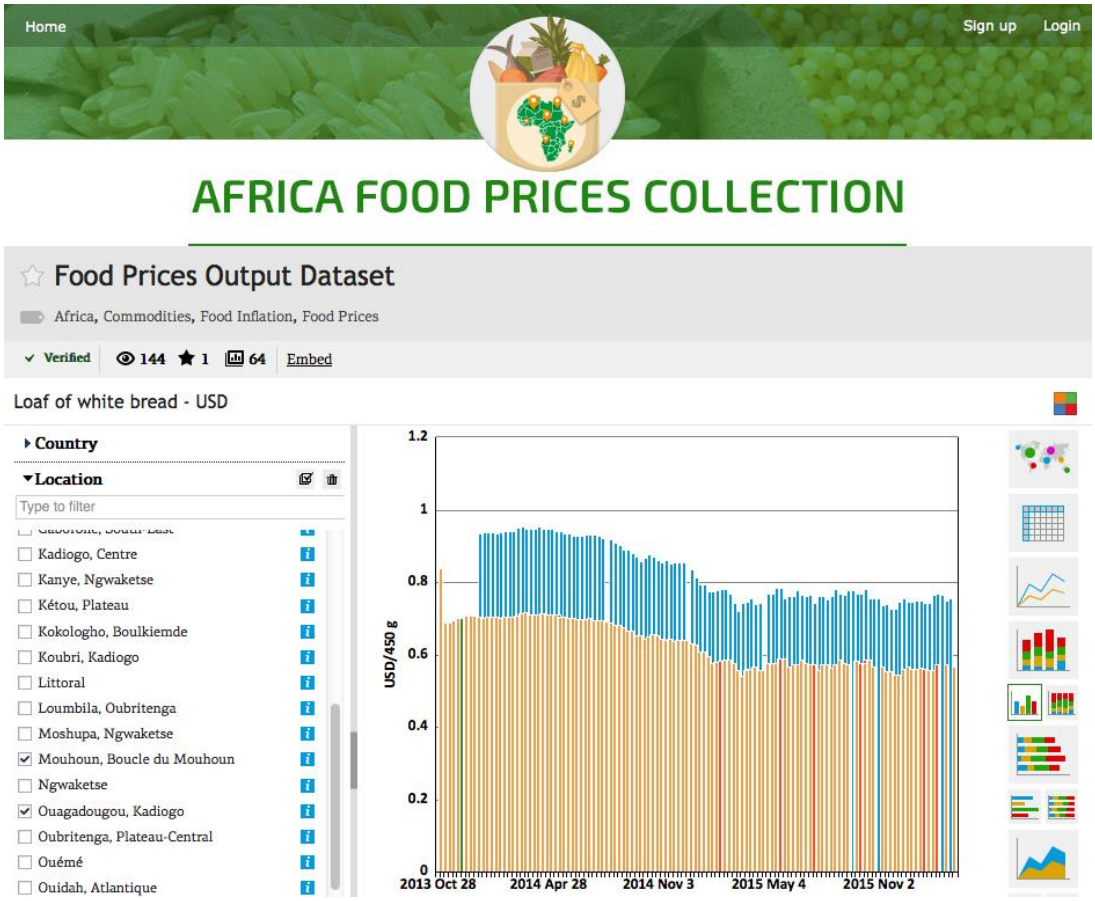


Figure 6: Visualisation of the open food price data collected as part of the Africa Food Prices Collection project (http://africafoodprices.io/)..

- **Food price context:** The objective of the project is to investigate the feasibility of high-frequency data collection in Africa by engaging professional data collectors. A network of data collectors on the ground visit market locations and collected agricultural commodity prices on a weekly basis in almost all African countries. The data are reviewed and submitted to a centralised data repository using a web-based data platform. A weekly food price database was built and made available to researchers and policymakers.

Crowd: The crowd is a group of individual volunteers. The project sought to engage at least one data collector for an urban location and one data collector for a rural location for each country. In some countries, more data collectors could be engaged, leading to a larger geographical coverage within that country. For certain locations data are collected from only one market (Donmez et al., in preparation).

To expand the data collectors' network, different approaches to establish new contacts were investigated: international non-profit organisations were contacted directly by email and encouraged to contribute to the data collectors' network; an incentive scheme was used to encourage existing data collectors to invite friends and colleagues to contribute to the project, e.g. a bonus scheme, with collectors being paid US$50 for each referral (up to a certain limit) that resulted in a new collector who submitted data regularly for at least four weeks; and social media websites such as Facebook, Google+ and LinkedIn were used to advertise the project.

Data collector details were verified by checking their address details, contact number, photograph or social media profiles.

Motivation and behaviour: The motivation of the crowd to contribute to the project is most probably related to the financial compensation for regular data collection.

Implementation and governance: Vague definitions of food items and the different varieties, types, sizes and quality of the same commodities led to very different prices being reported, even within a single market. Therefore, more precise definitions of food items for the data collection project are needed. Moreover, consistency checks are needed to verify if data submissions are based on falsified prices. Infrastructure challenges were experienced during the course of the project, such as lack of internet connection or interruption to power supply. Intermittent submissions were received for various reasons; in such locations a second collector was sought to enable consistent data collection.

As the study covered different countries, language challenges arose during the project. This was addressed by implementing multilingual support to the system, available in nine languages. Political uncertainty was also a challenge in several countries.

Quality control: Two measures were introduced to increase the data quality. First, automatic checks carried out during the data entry aimed to identify if a data collector entered wrong or inconsistent data. This was achieved through a comparison with previous data entries. If the difference in price between the current and previous entry was more than 50%, the submission was blocked. The data collector could correct the data or submit them together with an explanation. Moreover, outliers were detected automatically by the system. As a second check a moderator reviewed each submission manually and could reject it if necessary.

Incentives: Collectors were paid according to the number of submissions they made per month. After an initial manual approach, the process of tracking the compensation was replaced by an automated online tracking and payment recording system. Establishing this system presented challenges as there is no single payment solution available across the various countries and collectors wanted to get paid by different payment methods. Some of the collectors did not have a bank account and asked for payment to be transmitted to a friend's or family member's account.

Technology: The project used a web-based and a mobile-based platform for crowdsourced data collection that belongs to the contracted company Knoema. After initial training, data collectors visited markets on a weekly basis. Afterwards, the gathered food prices were inserted on the online price sheet and submitted. A moderator reviewed each submission and either approved or rejected it. The data were input to a database, from which they could be downloaded and reused. The software supported submission of food price data in local currencies and automatically converted it to US dollars based on exchange rates available at the time of submission.

Conclusion: The project demonstrated a successful crowdsourcing approach to the timely collection of food price information in Africa. Several challenges were identified and had to be overcome, e.g. establishing a relationship with the data collectors was an important task.

The outputs of this data collection project are available at http://africafoodprices.io

4.2.3 Crowdsourcing food price data in Nigeria

The Standard Chartered Bank, in cooperation with the ICT start-up Premise[22], launched a consumer price tracker in key Nigerian cities (Standard Chartered Bank, 2014). The collection process is described in Figure 7.

Figure 7: Food price capturing by a crowd worker (Maritz, 2014).

⇨ **Food price context:** This innovate data collection project benefited from the knowledge of the crowd. It was a very fast way of capturing volatile food prices. Crowd workers captured price information on their smartphones, taking photographs of food staples and their price tags and uploading them to a central database. Each week, price information on 21 000 food data items was recorded in this way. This allowed the analysis of price trends in different geographic regions.

[22] http://www.premise.com

Crowd: More than 350 persons collected real-time food prices.

Motivation and behaviour: This aspect could not be investigated as the Standard Chartered Bank did not provide any feedback.

Implementation and governance: This aspect could not be investigated as the Standard Chartered Bank did not provide any feedback.

Quality control: Managing data outliers was necessary to explain extreme price rises relative to the macro price trend. Food items were packaged in variable ways and sold in local markets; locally appropriate units of measure were adopted to address this challenge.

Incentives: Participants were paid through top-up mobile phone credits.

Technology: Crowd workers used an app on their smartphones to take pictures and geo-track location and price of food items. These data were uploaded to a data portal for processing, analysis and visualisation.

Conclusion: The speed of this innovative data collection initiative is greater than any other method. The collected information could be used to detect food price pressures earlier in different geographical regions. Price trends could also be linked to farming disruption due to a worsening security situation or rising transport costs.

More information about the project can be found at https://www.sc.com/en/news-and-media/news/global/2014-10-07-weve-launched-real-time-price-information-for-nigeria.html

4.2.4 Crowdsourcing food price data in refugee camps in Kenya

The mVAM project of the WFP collects food security data through phone surveys, using SMS, live telephone interviews or IVR. The crowdsourcing tool is at present used in 11 countries and the WFP wants to increase this number to 30. In Kenya, the WFP currently provides food assistance to 148 000 refugees or 33 000 households, where 60% of households have a phone number. The mVAM tool is used in this country to sense food prices in the markets located near the refugee camps (Bauer, 2014; WFP, 2015; WFP, 2016a). Figure 8 describes the process of food price data collection by the mVAM tool.

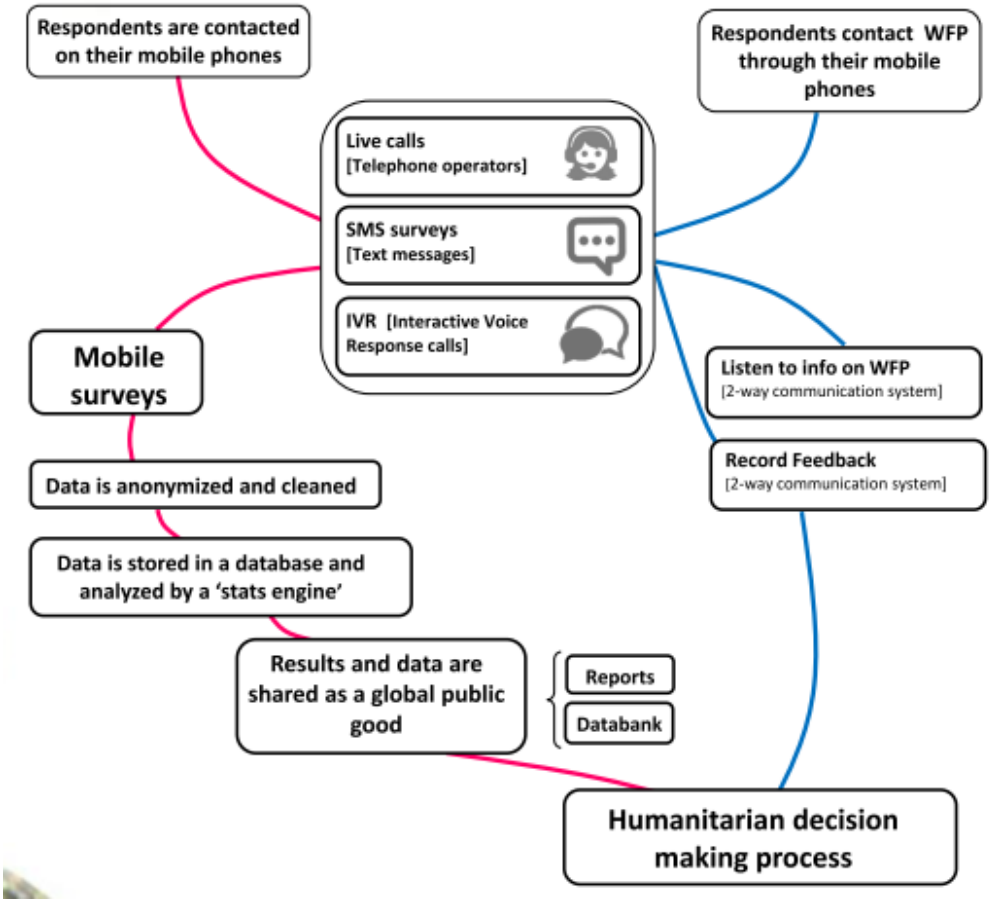


Figure 8: Food price capturing process in crowdsourcing (WFP, 2016b).

> ⇨ **The food price context:** In cooperation with a mobile survey company, around 1 600–1 700 text messages are sent out to random numbers in the Kakuma refugee camp each week. Refugees receive an SMS asking them to text back to 'opt in' to take the survey. If they send back '1' for 'yes,' WFP texts them questions about seven food items. The refugees text back the food prices and are not charged for the messages.

Crowd: Operators hired by the WFP call people who have agreed to take part in a phone survey on their mobile phones, and ask about their needs, i.e. food. The data generated provide humanitarian aid managers with information about the status of people's food security.

Motivation and behaviour: The WFP reports a response rate of 6%. It acknowledges that this appears to be low but claims that monitoring food prices does not require an exhaustive sample of respondents. The WFP also mentioned a group of very motivated respondents who volunteered to participate in the weekly poll even though they had not been invited to do so; the WFP does not survey the same participants every week.

Implementation and governance: The performance of the survey is monitored on a monthly basis. User-friendliness is captured by indicators such as response rates and call duration. A free-of-charge beneficiary helpline was installed to receive feedback about the survey.

Quality control: During implementation, the survey questions were reviewed to increase data quality. For instance, refugees were initially asked about the price of fresh

milk, but this was subsequently changed to the price of powdered milk, which is more common in the market. In addition, 'don't know' and 'skip' options were introduced so that participants can skip certain commodities if they do not know the price, avoiding guessing.

Incentives: The WFP provides the crowd airtime credit of 10 free SMS messages as an incentive for participation in the survey. Respondents welcome the incentive.

Technology: The mVAM tool uses three methods to gather data: interactive voice response calls, live calls through phone operators and SMS surveys. In the case of Kenya, the SMS survey technology is in place. The mVAM tool uses an automated statistics engine that processes and analyses all data that are produced. The data collected in all countries will be published on a web portal in the future; however, as of October 2016, country data for Kenya are not yet available online.

Conclusion: The mVAM tool benefits from the increasing mobile phone ownership seen even among low-income communities. It provides the opportunity to capture food security information in remote and insecure areas real time. While the mVAM tool will not replace traditional food security surveys, the technology complements the traditional means of data collection.

More information about the project can be found at http://mvam.org/2015/11/16/crowdsourcing-food-prices-in-kakuma-kenya/

4.2.5 Food price reporting over mobile phones in Indonesia

This pilot project used crowdsourcing to track commodity prices in near-real time in areas of Indonesia where the availability of other data sources is limited (see Figure 9). In these regions traditional data collection methods are difficult or costly to maintain because many areas are remote and are susceptible to food insecurity and high food price volatility. The project had a pro-poor focus, targeting vulnerable consumer groups. This project was conducted in collaboration with the FAO, the WFP and Premise.

Figure 9: Screenshot of the Premise dashboard showing the locations of the 15 000 most recent reports on Lombok Island, Nusa Tenggara Barat Province (UN Global Pulse, 2015).

⇨ **The food price context:** A basket of commodities to be monitored was selected through a series of consultations with partners, which was informed by a review of national and provincial priorities on food security. The final list included staple foods, such as tofu, tempeh, chillies, mackerel and eggs, as well as liquefied

petroleum gas. To produce high-quality price statistics, the network needed to generate a minimum of 30 price reports per commodity per week from each geographic area.

Crowd: The crowd workers in this project were recruited through social media advertisements. This approach created a viral effect within the local networks of students. More than 200 users across the Nusa Tenggara Barat province were recruited, each of whom contributed more than one report per month.

Motivation and behaviour: This project recruited a trusted network of local citizen reporters to submit food price reports.

Implementation and governance: The project had to deal with recruitment challenges. Initially Facebook advertisements were used, but this approach proved unsuccessful as respondents could provide false contact information and could not receive information about the project. The BlackBerry Messenger app was known to be used locally, so advertisements for the project were disseminated through the app's popular job boards. A common mistake discovered during the initial period of data capture was confusion between different agricultural commodities among the data collectors. This problem was solved by sending photos to explain the difference between onion and garlic, sweet potato and cassava, fresh and flavoured milk, and green beans and green lentils.

Quality control: For quality control purposes, participants exhibiting fraudulent activities were identified by a mixture of automatic and manual approaches and had their accounts deactivated. Profile fraud was also an issue; some participants tried using multiple phones to create the illusion that observations came from different users. Additionally, some users travelled to the same markets together and submitted food price data for the same items, giving the false impression of a broad sampling base.

Incentives: Data collectors were rewarded with mobile phone credit or mobile money based on their contributions.

Technology: This initiative made use of a customised mobile phone app. The technology company Premise evaluated the efficacy of a distributed monitoring infrastructure.

Conclusion: The approach is analogous to computer-assisted personal interview applications, already widely used by national statistical offices for data collection. The crowdsourcing approach offers added value by creating networks of collectors through social mobilisation and enables them to respond rapidly to data needs when required. The value of the data source is limited as the data are not yet subject to government auditing and quality assurance.

More information about the project can be found at http://www.unglobalpulse.org/blog/engaging-citizens-collect-daily-food-prices-rural-indonesia-%E2%80%93-proof-concept-project

4.3 Crowdsourcing examples from other sectors and countries

This section presents two innovative data collection initiatives from other sectors. The focus is on the critical aspects of the use of crowdsourcing from the perspectives of the initiating organisation, the participants involved and the ICT tools used. The initiatives were examined through both desk research and personal interviews.

4.3.1 Crowdsourcing an urban transportation map

In Dhaka, the capital of Bangladesh, there were no publicly available bus route maps. A student from the Massachusetts Institute of Technology initiated a crowdsourcing project that used the smartphones of citizens travelling on public transport to gather data on the urban bus routes of Dhaka. Data collectors used their smartphones during bus trips through the city to capture data about the vehicle location, travel time, stops, traffic jams and bus user satisfaction. This crowdsourcing approach provided a solution to the lack of accountability for bus service and performance in the city (Ching, 2012). Figure 10 shows the different views of the Share My Bus crowdsourcing app.

Figure 10: The app Share My Bus, Dhaka (Ching, 2012).

Crowd: This project used a guided crowd of eight persons, a process called 'flocksourcing', to carry out data collection. After only a few hours of training, the group recorded 270 one-way bus rides in just one week.

Motivation and behaviour: The data collectors were highly motivated to take part in the project; all participants worked for the same NGO, Kewdradong, which promotes environmental protection in Bangladesh. They were aware of the absence of a bus map for Dhaka and had an interest in solving the issue to improve their daily commute.

Implementation and governance: Before starting the project a successful test run was carried out. The monitoring of the real-time data collection activity was done through online dashboards. The organiser of the project, based in the USA, was even able to observe the ongoing collection efforts in real time. Through regular communication with the local partner organisation adjustments were possible during the data collection process.

Quality control: The accuracy of bus location measurements was tested and was within ± 25 m.

Incentives: The unpaid data collectors were driven by an intrinsic motivation, to work towards a common goal and contribute to making Dhaka's bus routes visible.

Technology: A bus data collection app was developed that could collect (1) bus positions (spatial and temporal), (2) bus crowding (passengers' conditions) and (3) user demographics and satisfaction of the bus riding experience (perception). A cloud-based

back-end technology was used to monitor the data that were collected in real time. The participants used Samsung Galaxy Y smartphones equipped with the app.

Conclusion: This project showed that smartphone sensing could be successfully used to collect urban transport data using a small number of participants, over a short period of time. The initiative led to the generation of a bus transport map for Dhaka, information that was not previously available.

More information about the project can be found at https://oatd.org/oatd/record?record=handle\%3A1721.1\%2F77836

4.3.2 SLB (Service Level Benchmarks) Connect — rating ICT-based service delivery

In India, SLB Connect is an extension of the Service Level Benchmarks Programme of the Ministry of Urban Development (MoUD). It uses a citizen feedback mechanism to monitor the delivery of essential services. Data collectors interview citizens by mobile phone to elicit their views on critical aspects of water supply and sanitation service delivery. The subjects covered include access, adequacy, continuity, quality, customer satisfaction and the ease of bill payment. Sanitation service performance is measured based on indicators such as toilet access, toilet usage, access to the sewage network and alternative disposal. The project is part of the Indian urban reform agenda, which has been implemented by various centrally funded schemes such as the Jawaharlal Nehru National Urban Renewal Mission (WSP, 2015). The map in Figure 11 shows the crowdsourced maintenance requirements for water supply infrastructure in the city of Jabalpur, India.

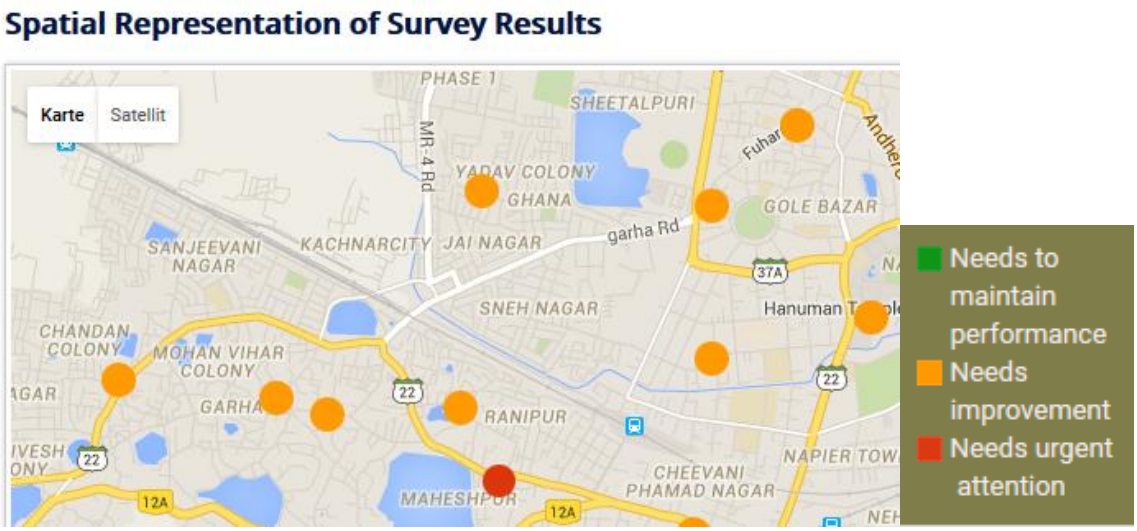


Figure 11: Water supply infrastructure in Jabalpur, the third largest urban agglomeration of Madhya Pradesh, which mobile phone-based citizen reporting suggests is in need of service delivery improvement (WSP, 2015).

Crowd: The crowd was citizens who were interviewed by professional data collectors from the Society for Participatory Research in Asia in partnership with NGOs in various cities. Students from local colleges and universities were trained to conduct the household survey in all the cities and were paid for doing so. Participants provided information voluntarily and gave their views on the adequacy of water supply and sanitation services, their satisfaction with the service, potential improvements to the service, their willingness to repeat the survey and provided a contact number.

Motivation and behaviour: The students were motivated to learn through the interview work. The assignment was commissioned by the Society for Participatory Research in Asia.

Implementation and governance: The ward-level information along with online maps produced by the survey was used to identify and prioritise localities that were deficient in service delivery. The SLB Connect dashboard was also linked to the websites of municipalities for wider dissemination of the findings.

Quality control: A web-based survey management module enabled survey managers/sector experts to design a survey task and track the progress of the survey in real time using remote monitoring.

Incentives: Data collectors were paid cash on a per day rate, assuming a target number of households were covered over a defined period of time.

Technology: An Android-based mobile app was used to obtain citizens' feedback on various service aspects. A spatial tracking system in the mobile phones provides the location of data collection. An online dashboard enables analysis of data on the various service indicators and addresses the information needs of various stakeholder groups, e.g. city managers, administrators, political representatives, researchers, civil society organisations. The results of the survey were presented through graphs, tables and maps. Simple traffic-signal colour codes were used to facilitate easy inferences on performance levels.

Conclusion: SLB Connect maps service performance and fosters transparency. The survey findings provided concrete and relevant data on the status of water and sanitation services, which have been used by the city authorities in the preparation of proposals under the various national urban programs. Mobile phone-based household surveys were utilised to develop an efficient, flexible and scalable tool for citizen engagement in innovative data collection.

More information about the project can be found at http://www.slbconnect.in/web/cfs/home

5 Main findings from research in innovative food price collection methods

This section summarises the key findings with respect to the different innovative price data collection initiatives studied. The presented findings come from initiatives involving both professional, i.e. trained and paid, and non-professional, i.e. crowdsourced, collectors.

5.1 Technology

5.1.1 Smartphone app versus SMS technology

Four of the organisations studied apply an approach that makes use of multiple mobile ICTs. Smartphone apps are used for routine food price data collection, but if internet access is not available SMS is the preferred tool. Only one organisation uses only a smartphone app. Among the interviewed organisations are four that use only SMS for data collection. Four of the crowdsourcing initiatives used smartphone apps combined, when necessary, with PC-based tools.

The pros and cons of both technologies were compared and the following aspects were identified (a summary is presented in Figure 3 and Figure 4).

Apps are generally regarded as being more user-friendly than SMS for collecting and sending data. Apps can guide the user through the data collection process, whereas SMS methods rely on a simple text interface and do not provide the user with any prompts to send the data. Data entry using an app is structured, and therefore not only is less time-consuming but could lead to higher overall data accuracy.

Almost all organisations mentioned issues with the SMS limit of 160 characters and the time-consuming data entry method as disadvantages. All organisations that use a SMS method use some type of short code for each agricultural commodity to circumvent the limited number of characters available. Some interviewees mentioned that data collectors have difficulty remembering these short codes. Furthermore, the SMS method also often suffers from syntax errors. Both of these issues can adversely affect the accuracy of the data received. The use of an app can resolve such issues. Some apps flag potential errors when an unexpected price is entered, and one service provider has incorporated a comment menu to alert users to unexpected price information. The biggest disadvantages of using an app are its dependence on reliable internet access and the higher costs of devices. All of the experts interviewed raised reliability of internet access as the biggest obstacle for the efficient use of smartphone apps in food price data collection. This is especially important when considering data collection in rural areas, where the availability of reliable internet networks is low. This can lead to delays in the sending of information. The SMS approach has a major advantage in this regard because, compared with the internet network, the mobile phone network is much more extensive and stable. None of the interviewed organisations flagged the mobile phone network as being a barrier to data collection. The pros and cons of the two systems are summarised in Table 7.

Table 7: Pros and cons of technologies for food price data collection

	SMS	Smartphone app
Advantages	+ requires no internet connectivity + relies on an existing, extensive and stable mobile network	+ more user-friendly + higher data accuracy + less time-consuming
Disadvantages	– character limitation – time-consuming – more complex for users to handle	– internet connection necessary – cost of devices and of connectivity

5.1.2 SMS technology versus paper-based methods

Four of the organisations studied use SMS technology to collect food price data. All of them reported that the SMS solution is better than the traditional paper-based method. According to the experts interviewed, the introduction of SMS-based collection procedures reduced the time needed for data collection. When collected data were recorded on paper, the forms were sent by mail, which took more time, and frequently the data were out of date by the time they arrived. The SIMA company, based in Niger, mentioned that the delay between data collection and receipt was 10 days before the introduction of SMS methods.

Another advantage of SMS technology over paper is that the technical platform receiving the information by SMS checks the data accuracy of the SMS automatically. In contrast, data sent by mail need to be checked for plausibility by the managing administrator. Using pen and paper methods created substantial workloads to keep the documentation in order and sending data by mail was costly; sending data via SMS is significantly cheaper.

5.2 Actors

5.2.1 Type of organisations

Food price information services applying modern methods are led by entities from different sectors. Of the organisations interviewed, four organisations were registered as private companies, two organisations identified themselves as being non-profit and three organisations were public sector bodies. Four of the actors that were operating using smartphone apps were private companies; they used SMS technology as a backup solution in regions with poor internet access. One public sector organisation also used a smartphone app. Three out of the four organisations utilising SMS technology for data collection were from the public sector; the other was a non-profit organisation. One of the organisations differs from the others as it used an app during a pilot phase, which it abandoned, and now uses a mixed approach of traditional paper-based methods and SMS partnering with unpaid volunteering partner organisations.

Four out of the five crowdsourcing activities were initiated by public organisations — the JRC, the AfDB, the World Bank, the FAO and the WFP — independently or in collaboration with other organisations from the public or private sector. Four of these five initiatives use smartphone apps independently or in combination with web-based

tools accessible with a PC or laptop. The refugee camp initiative in Kenya, which uses the mVAM tool, is the only initiative that uses SMS technology.

5.2.2 Information users in the value chain

The interviews revealed that different organisations focus on different user profiles. Three organisations, Farmerline, Rongéad and CPC, target farmers as the main users of their services. Novus Agro and ACE, both private entities, focus more on traders, sellers and exporters. Esoko, a privately owned business, offers a wide range of services across all players within the agricultural value chain. ODR, SIMA and Sonagess, all public bodies, and the crowdsourcing initiatives focus on a variety of users, including farmers, researchers, government agencies, traders, sellers and exporters. Crowdsourcers aim to make available, for their own use and for the benefit of all types of potential users, near-real-time food prices. Such prices shall allow for monitoring food price trends in different geographic regions and for early detection of food price pressures in remote areas and areas susceptible to food insecurity, where availability of data from other sources is limited. Their focus is mainly pro-poor, targeting vulnerable consumer groups.

5.3 Operational

5.3.1 Crowdsourcing model

Only two organisations out of the nine service providers interviewed used volunteers to collect food price data: CPC and Rongéad. CPC works with a network of farm cooperatives whose members collect the data. Incentives include an allowance, transport costs and a mobile phone and airtime credit for communication. Rongéad uses a very different crowdsourcing approach for data collection that is not based on financial incentives. Rongéad relies on a 'trusted network' of price information providers that is built and maintained by the national market analysts in each country. The partners in the network (farmers, sellers, processors, exporters and government officers) have a cooperation agreement with Rongéad to share data or other services they develop.

Other crowdsourcing approaches recruited data collectors (the crowd) mainly through social media advertisements, e.g. on Facebook, Google+, LinkedIn and/or Twitter. In some cases, international non-profit organisations were contacted and encouraged to contribute to the data collectors' network, and incentives to recruit friends were sometimes also provided. One of the initiatives planned a website for recruitment in several languages. In some initiatives, the data collectors' profiles underwent a verification process or participants were interviewed during the recruitment process. During the collection process some initiatives established a system to score the quality of the data delivered.

Understanding how to motivate the crowd is one of the most important factors to consider in developing and sustaining a productive crowdsourcing platform. The crowds in the five crowdsourcing food price collection initiatives researched in this study seem to be driven by extrinsic motivation, i.e. the crowdsourcers typically pay the crowd to carry out the tasks. Two of the organisations provide monetary payments, while the other three offer mobile phone airtime. In one of the crowdsourcing initiatives in a non-food sector, students were recruited to conduct interviews. Although their principal motive was to learn from the interviewing process, they were also paid cash.

In another initiative, which had clear short-term goals and a time limit for the task, the unpaid data collectors (all workers for the same NGO) were driven by intrinsic motivation: to work towards the common goal of making a bus map for Dhaka.

The examined organisations consider crowdsourcing a successful method to capture food security information in real time, including in remote areas, using a mobile phone-based approach. This technique offers added value by creating networks of data collectors that

can respond rapidly to food price data needs by taking advantage of the trend of increasing mobile phone ownership. Challenges relate mainly to ensuring data quality, recruiting the crowd, building a relationship with participants and having the right incentives in place.

Collaborating with volunteers could help determine the right incentives. The majority of service providers use paid price collectors or their own staff to collect food price data. With the exception of Rongéad, initiatives that work with volunteer data collectors provide some sort of financial reward; thus, the relative cost-efficiency of crowdsourcing rather than using professional data collectors is to some extent reduced.

5.3.2 Personnel

Recruiting qualified personnel is essential for any data collection initiative. Staff training and capacity building are also important elements of data collection campaigns. Finding the right incentives and retaining personnel is not easy. Rongéad reported investing in personnel who are later poached by other organisations or the private sector.

Our reviewed initiatives also cited training in the task and the availability of appropriate tools as important factors in a successful crowdsourcing initiative. All organisations also considered communication with the crowd to be very important to an initiative's success.

5.3.3 Data validation

The absence of a system of standardised weights and measures for use in African markets is an external factor that can have a significant impact on data accuracy. Errors can arise from the use of a wrong unit or incorrect conversion of a measure. Data validation is critical if high-value information is to be generated. The private sector organisations interviewed appear to have very rigorous validation procedures in place to ensure this. In most cases, the platforms receiving the data use built-in features to flag erroneous inputs. This validation is combined with statistical analysis, qualitative information on historical price trends or other indicators that can be used as a benchmark for data quality. Manual reviews are also carried out in some organisations by administrators or analysts during a second round of data validation. As some organisations did not disclose details of their validation process and do not use automated data validation features with their data receiving platform, it is difficult to judge the data quality based on the interviews alone.

The crowdsourcing initiatives reviewed in this report use a mixture of automatic and manual approaches to data validation. Automatic detection of outliers and the ability to detect potentially fraudulent data were considered as an important issue and, therefore, techniques to address these issues where implemented during data validation. The Work Bank scores its data collectors on their behaviour and quality. Data from high-scoring collectors are automatically verified, data from negatively scoring collectors are blacklisted and the remaining data are manually verified. In Indonesia, the FAO-WFP initiative deactivated the accounts of crowdsourcing participants who exhibited fraudulent behaviour. In order to increase data quality, some initiatives improved different aspects of the process; for example, the mVAM project improved its survey questions during implementation, while in Nigeria it was found that adopting locally appropriate units was important, and in Indonesia sending photos of food products was found to avoid confusion between commodities. This initiative found that, to produce high-quality price statistics, the network needs to generate a minimum of 30 price reports per commodity per week from each geographic area, which provides an intrinsic measure of quality. Finally, most initiatives incorporate a manual data validation process, usually taking the form of a second check by a moderator, who reviews each submission manually and can reject it if necessary.

5.4 Institutional and political

The food price information service providers have developed strategic partnerships with donors, mobile network operators, internet service providers and the private and public sectors. A unique example of cooperation is mentioned by ODR under its corporate social responsibility programme, the mobile network operator offers phone contracts at a lower cost. Mobile network operators can also bundle food price data to other content already supplied to mobile phone service users.

NGOs and private sector companies cooperate with government organisations to cross-check price trends or use historical information as a benchmark for their data analyses. Several of the organisations interviewed mentioned that there is a lack of awareness among politicians of the advantages of food price information systems for market observation and analysis with respect to food security. They suggested creating greater awareness among politicians of these advantages.

5.5 Financial

5.5.1 Cost drivers in data collection and dissemination

All organisations providing food price information obtained from professional collectors highlighted the high cost of data collection. The major cost driver is the coordination of a network of permanent paid data collectors. ODR in Madagascar employs 22 agents in 199 districts, CPC in Togo works with 48 collectors and Sonagess in Burkina Faso works with 64 data collectors.

Once established, crowdsourcing still requires a baseline level of financing to maintain it. The research on motivation of individuals to participate in crowdsourcing initiatives for food price data collection found that participants were mainly driven by financial compensation, either cash or mobile phone airtime. Therefore, the cost-effectiveness or advantage of crowdsourcing compared with professional food price data collection will depend on the level of financial incentives needed to keep the crowd motivated and the number of price collectors required for each location. Crowdsourcing requires several data points for each location; to ensure the quality of the data, researchers must find the minimum number of contributions required per location (intrinsic measure of quality of crowdsourced datasets) (Haklay et al., 2010). Table 8 provides an overview of the main costs involved with food price data collection in the organisations interviewed or reviewed for this project.

Table 8: Overview of data collection costs

Organisation and country	Type of collectors	Number of collectors	Commodity coverage	Frequency and time to publication	Tech used	Funding	Collection costs
ODR Madagascar	Professional/ hired	22 agents in 199 districts	7	Weekly/less than a week	SMS	Public entity funded by donors (AfDB, EU, World Bank)	US$ 25 000 per year
CPC Togo	Producers and members of the organisation	48 collectors and 5 regional agents	5	Weekly/1 week	SMS	Private org. funded by government and donors (FAO, USAID)	Phone: Less than €50 per collector and agent Communication cost: €3 per collector Financial compensation: €15 per month per collector

Organisation and country	Type of collectors	Number of collectors	Commodity coverage	Frequency and time to publication	Tech used	Funding	Collection costs
SIMA Niger	Professional/ hired	66 collectors	21	Weekly/1 week	SMS	Public entity funded by government and donors (EU, Mercy Corps, Catholic Relief Services, Oxfam and Save the Children)	Phone: €80 per phone Mobile services: around €410 per year per collector Collectors bonus: €11 per week per collector
Rongéad Côte d'Ivoire	Cooperation agreement/ not paid	–	15	Weekly/1–3 days	SMS	Non-profit org funded by donors (EU, WFP, CTA, ECOWAS, OIF, AFD)	Local analyst: €10000–15000 per year
Sonagess Burkina Faso	Paid agents	–	12	Weekly/less than a week	app	Public entity funded by government and donors (AFD, FAO, ECOWAS, CILSS, Trade Hub and the WFP)	Mobile services: €6000 for all collectors per year Financial compensation: €8 per week per collector
World Bank (in cooperation with JANA) Kenya, Nigeria and others	Non-professional/ crowd	500 locations	30		app	World Bank	Financial compensation: €5 per submission
AFPC (JRC and AfDB in cooperation with Knoema) Kenya, Uganda and Sierra Leone	Professional/ hired and crowd	53 countries (1 to 2 markets per country)	22	Weekly/one week	Websit e/app	EU-JRC, AfDB	Financial compensation: First, €15 per month per collector, then payment by data submission
SCB (in cooperation with Premise) Nigeria	Crowd	More than 350	21 000 food items/month	Weekly/one week	app	SCB	Mobile phone airtime
mVAM (WFP) Kenya	Crowd			Weekly/one week	SMS	WFP	Mobile phone airtime
FAO, WFP (in cooperation with Premise) Indonesia	Crowd	More than 200	5	Weekly/one week	app	FAO	Mobile phone airtime

Note: Based on available information

The cost of disseminating food price data varies. Some organisations disclose the information free of charge while others offer paid subscription models for regular information services. Most of the services disseminate information through paid or unpaid SMS. Rongéad publishes some information free of charge on its website and sends newsletters about the development of food price trends of certain agricultural commodities. Other, more comprehensive data are available only on subscription. Many organisations still use traditional means of information dissemination, such as in newspapers or through local radio in rural areas. SIMA (Niger) spends about €4 600 per year on the dissemination of food price information by radio. These methods increase the time between collection and dissemination as radio programmes are usually recorded and sent out with a delay of at least one day. Newspapers require time to be printed and distributed to the various outlets, also resulting in a delay between data collection and

dissemination; nevertheless, many users, particularly farmers in rural areas, depend on these channels. Sonagess experimented with broadcasting food price data on television, but decided that this method was unsustainable because of the high annual cost (€16 800).

5.5.2 Financial sustainability of services

Financial challenges appear to be the highest barrier to setting up and operating a food price information service. All organisations interviewed agreed on this (Table 9). Currently, none of the organisations is able to cover all the costs of the service. Government bodies and NGOs usually rely on donor money. Even the organisations based on paid subscription models do not recover their costs through user payments. Several interviewees mentioned that they do not believe that a food price information service alone is financially sustainable. Only when such information is included in a service bundle do they expect to make a profit. So far no food price information service has been found to be financially viable without external financial assistance.

Table 9: Issues related to financial sustainability of food price information services

Organisation	Financial challenges
ACE	Service is not profitable as the subscription revenues do not cover all expenses
Farmerline	Cost recovery has not yet been achieved Service is integrated in a bundle of other services
Novus Agro	Service revenue does not cover the costs Donor support Diversified business model generating income from other services, such as weather information and farm extension information
ODR	No government budget for maintenance and salary costs Operation of the service relies on monetary donations
Sonagess	Operation of service requires sustainable financing through the government Training of enumerators is not covered by public funding

5.5.3 Lack of willingness to pay

A major issue highlighted by the majority of organisations is the unwillingness of actors at the start of the value chain to pay for food price information services. This is especially true of farmers, who are accustomed to receiving useful services, such as food price information, free of charge through development programmes. They are also unaware of the advantages of having up-to-date food price information, which could help them make better-informed decisions about when and where to sell their produce. A

combined service that includes dissemination of food price data along with other information, such as weather information or extension service information, may be more attractive. In contrast, private sector users are aware of the advantages of having up-to-date food price data and are willing and able to pay for it. In general, there is a need to raise awareness, particularly within rural farming communities, about the potential of timely food price data to assist in better farm management. Innovation adoption theory should be integrated into any projects planning to offer food price data services, to better understand how potential service users behave (Rogers, 2003).

6 Key elements/dimensions of successful food price crowdsourcing

Using the findings from the literature review and insights from current and previous experiences of innovative data collection activities that apply mobile-based technologies and recruit professional and/or crowd workers, a set of recommendations has been drafted. They are designed to guide researchers and practitioners in developing crowdsourced-based food price collection approaches by highlighting factors associated with successful approaches.

In general, effective implementation of crowdsourcing requires detailed consideration of the following elements of the crowdsourcing process: definition of the task and suitability for crowdsourcing; recruiting and communicating with the crowd; selecting the technology; selecting the right mix of incentives; establishing the process of data collection; management of contributions, i.e. validation and aggregation; and producing a high-quality and useful output. Additionally, country-specific aspects and regional differences must be considered when designing the crowdsourcing process, such as available technology and participant skills, locally used units of measurement and types of packaging of food items.

The current study and the results presented in the literature, reveal five areas of primary influence that drive a successful food price data collection and information service: data collection, data dissemination, management of the service, the financial model and the enabling environment (see Figure 12).

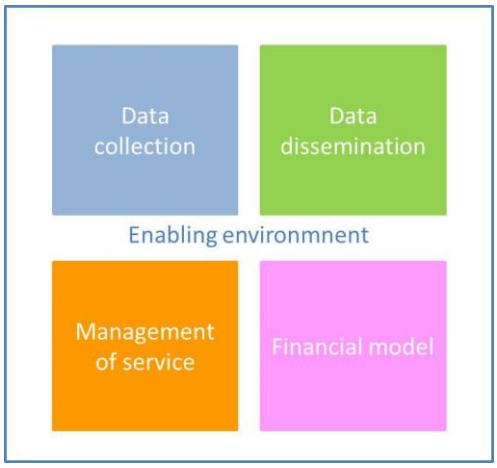


Figure 12: Critical aspects to successfully operate a food price information service.

Furthermore, the literature identifies three critical perspectives that must be considered to implement successful crowdsourcing projects: the participant (motivation of the crowd), the organisation (crowd and process management) and the system (incentives, technical tools). Our set of recommendations combines these three perspectives with the main factors in each area of influence driving the creation of a successful price information collection system.

A basic overview of a suggested workflow is presented in Figure 13. The system is made up of four parts: the data store, the processing facility, communication and dissemination.

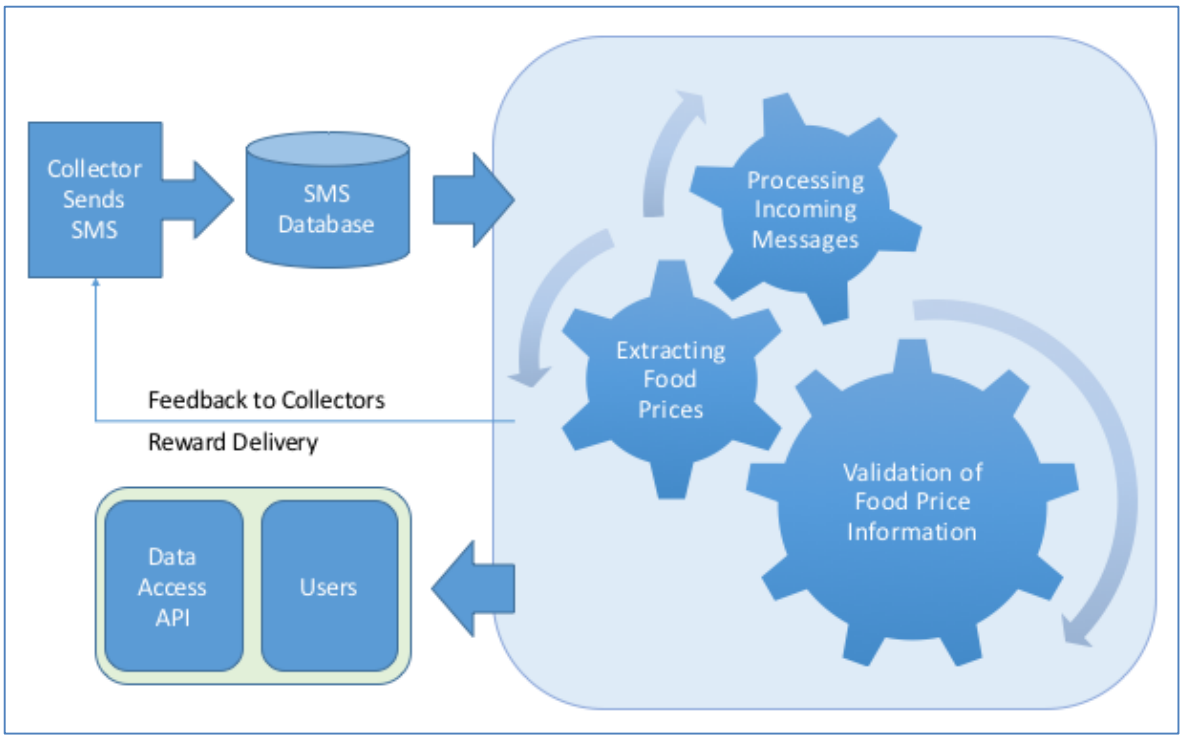


Figure 13 A suggested workflow for a crowdsourced food price data collection system based on the use of SMS technology.

6.1 Data collection

One of the primary requirements of food price data collection is timeliness. The ideal frequency of data collection is daily, although weekly updates are acceptable. However, the techniques identified in use today are unable to deliver daily data updates as there are a limited number of data collectors. The limited number of collectors also limits their geographic reach, which is not extensive, with major markets in urban centres usually the only ones accessed. Crowdsourcing has the potential to increase not only the frequency of data collection, but also the geographic coverage and the speed of data availability. However, the final output from the crowdsourced data must be accurate for it to be useable. The following key recommendations are made for implementing a crowdsourcing programme.

Participants' perspective

- Understanding the motivation of the crowd is one of the most important factors for developing and sustaining a productive crowd.
- The crowds in food price collection initiative appear to be driven by financial compensation (extrinsic motivation). Although payments can be low, unpaid voluntary work is not the rule.
- Increasing awareness of the importance and advantages of food price information systems for market observation and analysis regarding food security could increase intrinsic motivations for participation.

Organisation's perspective

For the proposed methodology to work, the number of collectors must be sufficiently large to produce robust data. Based on 'big data' analysis techniques, for the

crowdsourcing methodology to work, daily collectors must number at least in the hundreds of collectors, although thousands would be preferable. This is one to two orders of magnitude higher than any of the current food price collection systems; in paid crowdsourcing this could lead to financial issues. However, the WFP mVAM study demonstrated that monitoring food prices does not require an exhaustive sample of respondents. The crowdsourcing experience in Indonesia (FAO-WFP) found that, to produce high-quality price statistics, the network needed to generate a minimum of 30 price reports per commodity per week within each geographic area. Similarly, the analysis of the VGI (Haklay et al., 2010) concluded that there is a non-linear relationship between the number of contributors and the quality of data and that, with more than 15 contributors, accuracy becomes very good. Further research should investigate the required number of contributors per market location to ensure the quality of price information.

Key areas of consideration for organisers of crowdsourcing initiatives include:

- Strategy for recruiting crowd members — social media tools such as Facebook, Google+, LinkedIn and Twitter have been shown to be good advertising channels, while local advertisements, e.g. in newspapers, and direct SMS can be used in areas where internet access is lacking.

- Involving local organisations and international non-profit organisations and providing incentives to encourage the friends of crowd members to participate will further develop the crowd network.

- The expected task to be completed must be clear and well defined. Use locally appropriate units of measurement and precise definitions of food items (include pictures where possible).

- Task training and access to the necessary tools are important.

- Quality process — A key quality indicator of a food price information system is data accuracy. This requires a systematic data validation process integrating statistical analysis, a comprehensive review and an information verification mechanism.

System's perspective

Price data need to be provided in a timely manner. Outdated information is of no value to the user of a food price information service. Therefore, the time gap between market visit, receiving the data, validation and dissemination should be minimised. The collected data must be accurate; there is no value in inaccurate price data.

- Find the right mix of incentives (money, airtime, commodities) to attract qualified people to master the technology and collect reliable prices. It is recommended that a survey be carry out among potential crowd members to identify the most attractive incentives.

- Data collection should be simple so that anyone can provide the data whenever possible. However, the final result must be accurate in order for it to be useable.

- The technology for data collection and sending should be easy to use for the collector to avoid data entry errors.

- The data entry process should be presented in a structured manner, e.g. short codes for SMS or standardised forms for apps, to reduce the time to complete the task. Smartphone apps offer the advantage of the guided data entry, but

infrastructure challenges, e.g. lack of internet, make SMS methods more suitable in some areas.

6.2 Service management

A fully automated service is required to minimise operational and consultant costs. To implement the proposed crowdsourcing methodology, some initial ICT development is necessary. Once the pieces are assembled the cost can be controlled and overall maintenance costs are low. At this time, for reliability reasons, such a service would need to be deployed in Europe, possibly as a cloud service; the required infrastructure is not yet available in sub-Saharan Africa.

- Both the crowd and the service learn by doing. Therefore, the service management should be willing to adapt the service and/or reward structure based on the evolving crowd.

- Good crowd communication increases the success rate. Crowd moderation and sharing best practices are key aspects.

- The implementing organisation must place a high value on a strong work ethic.

- Setting up, managing and maintaining the technical infrastructure is very important for the sustainability of the service. Continuous technical support is required for data collection, processing and dissemination. Use of existing platforms for incoming–outgoing information (SMS, app) is recommended.

- Food price data collection requires personnel with experience in collecting prices, an understanding of units and measures used and the capacity to use the necessary technology (SMS, app) for data transmission. Attracting the right personnel is also dependent on using the right mix of incentives.

6.3 Data dissemination

The goal is to disseminate food price information as open data. Therefore, it require the data to be distributed regularly through a variety of social media outlets to which users can subscribe and/or via an application programming interface (API) so that downstream organisations can develop services around them.

- The open data model or the linked open data model provides a variety of ways to deliver food price data quickly. Consequently, downstream users can decide on the most appropriate form of dissemination.

- An information service should provide valuable information to the user. Food price information alone does not seem to be sufficient to attract paying users. Food price information can be bundled with other agricultural information services requested by users. In particular, smallholders benefit more from food price information when it is bundled with other services, such as weather alerts, insurance, micro credit, warehouse information, farm advice service training, etc.

- A price information service should disseminate information regularly. Current social media outlets, such as Twitter, can be used to disseminate food prices regularly to followers.

- The dissemination channel should fit the preferred method of its users. Owing to issues with internet access SMS is currently the preferred method.

6.4 Financial model

There are different financial models currently in use that can sustain crowdsourcing initiatives. The research carried out with respect to the collection of food prices in Africa did not find any service that achieves cost recovery, i.e. no food price collection service is profitable. Public price information providers rely on donations, which can be sporadic, or inflexible government budgets. Private price information providers either work with paid subscription models or integrate price information into service bundles together with other paid agricultural services. The willingness to pay for a food price information service is still low.

- The data collection process is the greatest cost driver for a food price data service. Therefore, it is important to investigate how the data collection process could be made more cost-efficient.

- Crowdsourcing incurs both monetary and resource costs that need to be covered throughout the lifetime of the project, therefore realistic budget is needed.

- There is a need to research viable financial models that can sustain a food price crowdsourcing service. Key aspects influencing financial issues are the level and type of financial incentives that attract sufficient and accurate contributions; securing participation of sufficient contributors at each location to ensure the quality and representativeness of aggregated contributions while preserving the potential cost advantage of crowdsourcing; and interaction with other motivational factors such as social rewards, the acquisition of skills, personal interest or altruism.

6.5 Enabling environment

- The most accessible technologies should be used in order to reach the maximum number of citizens who can provide input. In Africa, the mobile network is the most stable ICT infrastructure and SMS is the cheapest means of communication.

- Simple tasks can be accomplished more easily. With only 160 characters available, a maximum of three pieces of data can be sent: food description, price, and location. Any combination of these three pieces of information that can fit within the SMS message limit can also be used.

- From a technical point of view, reliable internet access and mobile phone networks are essential for the collection and dissemination of data and will be facilitated by rapid technological development, increased mobile phone uptake and a growing number of network access points. The anticipated expansion of mobile broadband and smartphone adoption will enable the use of apps in the future.

- From a political point of view, there is a need to increase awareness among political leaders on the usefulness of food price information for improved market transparency and better anticipation and decision making in the area of food security. This would entail adjusting budgets accordingly in order to set-up and operate public food price information services, while supporting technological innovation, increased access to technology and development of digital skills.

7 Conclusions and recommendations

Food prices are a key indicator for measuring changes in food supply and demand as they signal the availability and affordability of food, and they are, therefore, key determinants of households' access to food. The food crises in the last decade revealed the need for timely and geographically specific food price information for the monitoring and intervention in food security issues, in particular in developing countries and remote areas susceptible to food insecurity, where availability of near-real-time data of other sources is limited.

In this context, the present report addresses the potential of innovative food price collection methods, in particular crowdsourcing using various ICT methods, for capturing timely and more frequent food price information and reaching a wider geographic area in a cost-efficient manner. The study focused on developing countries and particularly on Africa.

The research reveals that with the increasing availability of mobile phones and the improving mobile networks and broadband coverage, even in low-income countries, there is great potential to implement crowdsourcing initiatives through ICTs. This prospective crowdsourcing network would allow access to a large number of volunteers with specific geographic expertise. Various initiatives consider crowdsourcing to be a promising approach to capture food security information in real time, including in remote and food-insecure areas. Moreover, it offers added value by creating networks of data collectors that can rapidly respond to requests for data. Challenges relating to crowdsourcing of data collection relate mainly to ensuring crowd participation and the costs (incentives) linked to it, data quality, as well as maintaining communication with the crowd and building confidence.

Crowdsourcing cannot yet be considered a replacement for traditional methods of collecting food price data. Instead, it can be used to enhance the available sets of food security information by potentially increasing the frequency and geographic coverage of data collection.

Many factors must be considered when initiating and sustaining a productive and useful mobile-based food price crowdsourcing project or platform in developing countries. While financial rewards might be comparatively low, unpaid voluntary work is not common in crowdsourcing initiatives, thus decreasing to some extent the potential cost advantage of crowdsourcing.

Previous collection studies point to the lack of crowd participation (i.e. failure to understand crowd motivation and incentive alignment, lack of awareness and skills, lack of bank accounts), management of contributions and quality assurance, access to technology (i.e. affordability, network and mobile broadband coverage) and financial issues (i.e. cost-efficiency, long-term sustainability) as the main challenges to be addressed by successful crowdsourcing. Other issues related to cheap labour without regulation, labour rights and standards or minimum wages must be considered by organisations. Finally, country-specific and regional disparities, in particular urban–rural disparities, need to be considered when designing crowdsourcing initiatives.

Figure 14 summarises the main results from the literature review, the survey and interviews conducted and the investigation of initiatives of ICT-based food price crowdsourcing in developing countries. It provides a set of key elements and recommendations for implementing and sustaining a crowdsourcing food price collection programme.

Enabling environment

- In Africa the mobile network is currently the most stable ICT infrastructure and SMS the cheapest mean of communication. The expected mobile-broadband expansion and smartphone adoption will facilitate the use of apps
- Increasing awareness and promoting public food price information systems (release of budgets) while supporting technological innovation, technology access and development of digital skills can catalyse the process

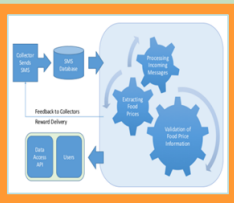
	 **Data collection**	 **Management of service**	 **Dissemination**	 **Financial model**
Participants/Users	• Understand the motivation of the potential crowd (extrinsic/intrinsic) & alignment of incentives • Although payment can be low, unpaid voluntary work is not common practice. Minimal financial compensation (monetary, airtime, commodity) is expected	• Both the crowd and the service learn by doing. The service management needs to be willing to adapt the service and/or reward structure based on the evolving crowd • Effective crowd moderation/communication and sharing best practices	• Added value to other agricultural information services in demand by users (weather alert, insurance, microcredit, etc.) • The dissemination channel according to user preferences (mostly SMS, when no internet available)	
Organisation	• For the methodology to work the number of collectors must be large enough ('crowd wisdom') • Recruit through locally used social media tools while using local advertisement and direct SMS to address lack of internet/media launch event • Partner local and international non-profit organisations (building trust) • Clear and well-defined tasks. Use locally appropriate units and precise definitions of food items (include pictures) • Task training and access to necessary tools is important	• Implementing organisation must place a high value on a strong work ethic • Quality process: a mixed approach of automatic and interactive data validation methods is recommended (Automatic filtering and flagging potential errors, manual inspection through moderator, use of control data, peer review of review through third parties) • Self-correcting mechanism through majority agreement ('crowd wisdom'). Discover minimal required number of contributors per location for the methodology to work • Checking profiles and ranking participants according to the number and quality of contributions to avoid fraud and improve quality		• While public price information systems rely on volatile donor money or inflexible government budgets and private service providers work with either paid subscription models or integrated price information in a bundle of other paid agri-services, there is still a need to research viable financial models that can create a sustainable food price crowdsourcing service. • Data collection is the biggest cost driver, crowdsourcing has the potential of being more cost-efficient, nevertheless it does incur costs, both monetary and resources. • A realistic budget aligned to the quantity of work and quality of the end product is necessary in crowdsourcing
System	• Find right incentive mix to attract qualified people to master technology and collect reliable prices. A survey is recommended • Easy to use technology and structured data entry process: short codes (SMS) or standardised forms (smartphone app) • Smartphone apps offer the advantage of the guided entry of information, but infrastructure challenges (e.g. lack of internet) make SMS more suitable in some areas	• A fully automated service is required to minimise costs • A robust back-end infrastructure is required for data collection, processing and dissemination. It is recommended the use of existing platforms for incoming-outgoing (SMS, app) price info	•Open data model or linked open data model provides a variety of techniques to deliver food price data quickly. Downstream users can decide the most adequate form of dissemination • Price information service needs to be regular. Current social media outlets such as Twitter can be used to disseminate food prices regularly	• More research recommended regarding the adequate level of financial incentives, the number of contributors required per location and the interaction with other motivations such as social rewards, acquiring and showing skills, personal interests, altruism

Figure 14: Recommendations for implementing and sustaining a crowdsourcing platform for food price data.

The limitations of this study, and its exploratory nature, can be attributed to the innovative subject matter, namely the use of 'crowdsourcing' and technology for food price data collection in Africa. So far there has been very little research on this topic, and evaluations of the use of crowdsourcing in food price data collection are rare. This is

reflected in the methodological approach of the current study. We used a 'mixed methods' approach. First, we reviewed the literature for reports of past and previous experiences of price collection in Africa and, in particular, on crowdsourced data collection.

The literature review identified the relevant stakeholders in the research field. The largest group of stakeholders (from the public sector) was approached through an online survey. Furthermore, a number of stakeholders from the private, public and non-profit sector were contacted and interviewed directly to map experiences of price data collection in Africa. The results were combined with the findings of the literature review on critical aspects of crowdsourced data collection.

As time and resources were finite, the number of interviews conducted and online questionnaires processed was relatively low. This could be one reason why the geographical coverage of initiatives results was limited. The crowdsourcing cases identified and analysed represent some key initiatives of food price data collection from the private, public and non-profit sectors in Africa, which have been operational for several years.

To successfully implement crowdsourcing, the target crowd must be identified; the technology choice must be in line with local availability (e.g. network coverage and devices); recruitment tools used must match community uses; the right mix of incentives must be in place and adjusted if needed; the task must be well defined (including correct local units of measurement and food packaging types); communication and training are needed; and a mix of automatic and manual checks must be implemented to ensure data accuracy and prevent fraud. Partnering with local and/or well-known organisations can build trust within the community. A robust infrastructure for incoming, outgoing and processing information is needed; using existing platforms is recommended. Finally, a realistic budget must be provided.

While many of these success factors (e.g. technology choice or communication and training) apply to any initiative that utilises mobile-based technologies to gather price data, the main difference between crowdsourcing and the use of professional enumerators is the potential *cost efficiency* of crowdsourcing.

Ensuring participation of a sizeable crowd, with sufficient high-quality contributions while preserving the cost advantage becomes an important challenge. At present, collection costs are the main cost driver of any food price data collection activity. The crowdsourcing initiatives we analysed rewarded participants for their contributions in the form of monetary payments or mobile airtime. Achieving an adequate number of contributors and acceptable quality appears to be linked to the right level and type of financial incentives.

Further methodological research work is required to develop a robust, crowd trusting or quality assurance methodology, that addresses among others the minimum number of crowd participants needed to ensure accuracy and reliability of prices and representativeness, while preserving the cost-advantage. Future crowdsourced price collection initiatives could also assess the impact of different type of compensation and how these interact with intrinsic motivational factors. Crowdsourcing through ICTs as a means to promote development and generate additional income for poor households could be further investigated.

The provision of timely and high-frequency food price data should increase market transparency, allowing market participants to trade more effectively. At the same time, these data provide valuable information for researchers, policy makers and humanitarian organisations in the context of food security monitoring and economic analysis. Further research could address the potential use of crowdsourced food prices to contribute to

food security early warning analysis in combination with other early-warning indicators and to allow for ex ante and ex post economic impact analysis and domestic policy support.

The present study provides a better understanding of innovative food price data collection methods by combining the results of an extensive literature review on the topic with the main findings from food price collection initiatives. The potential advantages and challenges identified are translated into a set of key elements and recommendations for future endeavours.

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List of abbreviations and definitions

ACE	Agricultural Commodity Exchange
AFD	Agence Française de Développement
AfDB	African Development Bank
AGRA	Alliance for a Green Revolution in Africa
AI	Artificial Intelligence
API	Application Programming Interface
CILSS	Comité permanent Inter-Etats de Lutte contre la Sécheresse dans le Sahel
CPC	Centrale des Producteurs de Céréales, Togo
CTA	Centre Technique de coopération Agricole et rurale
EC	European Commission
ECOWAS	Economic Community Of West African States
EU	European Union
EMM	Europe Media Monitor
FAO	Food and Agricultural Organization
GSMA	Groupe Spéciale Mobile Association
ICT	Information and Communication Technology
IFPRI	International Food Policy Research Institute
IT	Information Technology
ITU	International Telecommunication Union
IVR	Interactive Voice Response System
JRC	Joint Research Centre
MoUD	Ministry of Urban Development
MTurk	Mechanical Turk
mVAM	Mobile Vulnerability Analysis and Mapping
NASFAM	National Smallholder Farmers' Association of Malawi
NGO	Non-Governmental Organisation
ODR	Observatoire du Riz, Madagascar

OIF	Organisation Internationale de la Francophonie
SIMA	Système d'Information sur les Marchés Agricoles, Niger
SLB	Service Level Benchmarking
SMS	Short Message Service
Sonagess	Société nationale de gestion des stocks
UN	United Nations
USAID	United States Agency for International Development
VGI	Volunteer Geographic Information
WFP	World Food Program

List of figures

List of tables

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