CROWDSOURCING AS A NOVEL STRATEGY FOR SEED DISTRIBUTION TO FARMERS: A CASE STUDY IN EAST AFRICA

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Introduction

The greatest majority of farmers in Africa continue to rely on their own crop varieties, with modern varieties covering only a small fraction of agricultural crops. Scaling up the delivery of modern varieties through formal seed systems not only requires a substantial investment in technological capacity but also the expansion of commercially-oriented agriculture. In Africa, the adoption of modern varieties of most crops remains limited, the major exception being maize production. Improved varieties cover about a third of the total surface planted to maize in Sub-Saharan Africa (Morris, 1998). For other crops, the numbers are far lower. In technological terms, formal seed systems may have relatively little to offer to improve production of low-input or subsistence crops.

If food security to the most vulnerable households is to be the main focus of seed-based innovation rather than achieving national production goals, seed system interventions will need to focus on the diverse crops and crop varieties that make up small scale agricultural production systems and diets (Van Etten, 2010). Having a wide range of crop species and varieties helps farmers cope with environmental challenges by matching varieties to diverse agro-ecosystems and diversifying their portfolio to minimize risks. Providing more crop diversity to resource-poor farmers can be expected to have a substantial positive effect on the food and nutritional security of their households. A study in the highlands of Ethiopia revealed that increasing varietal diversity increases crop production (Di Falco et al. (2010).

To improve crops in areas not reached by formal seed systems and to target the diverse environments, crops and varieties of African farmers, several participatory approaches to technology development and diffusion have been developed. Participatory plant breeding (PPB), participatory variety selection (PVS), community seed banks. crowdsourcing and seed fairs have been used to foster innovation and access to seeds and diversity in informal seed systems. Also, projects aiming at small-scale, organized seed production have been attempted in order to increase the availability of improved varieties. Essential lessons have been learned from these experiences over the last two decades. However, there has been no breakthrough in upscaling these projects to reach large numbers of farmers. In order to take informal seed-based innovation to the next level, interventions following a crowdsourcing approach, facilitated by new information technologies, might prove helpful.

Crowdsourcing as an innovative seed delivery mechanism

Crowdsourcing as a concept was first coined in 2006 and it is defined as the outsourcing of activities to ‘crowds’, large numbers of (generally unpaid) volunteers, who contribute with their skills and time to collective efforts (Silversmith and Tulchin, 2013). In crowdsourcing, information is sourced from a group of people in response to an open call, a request for specific information, or for an exchange, organized by a central organizer/ organizing body. Worldwide, it commonly refers to outsourcing a function done locally to a large, disconnected group of people. It broadly collectivizes a role otherwise done by an individual or small group by using ICT. The Internet has made it possible to mobilize volunteers without a high upfront investment in institutional organization. Citizen science
projects that make use of crowdsourcing illustrate the potential of mobilizing skilled volunteers. In these projects, volunteers have executed tasks such as simple environmental observations, visual recognition of objects, but also complex protein folding exercises that require advanced spatial reasoning (Hand, 2010). The level of enthusiasm as well as the quantity and quality of work done by online volunteers in these projects was far beyond initial expectations. Such approaches could inspire the rethinking of participatory approaches to crop production innovation in African seed systems since African farmers are gaining increased access to ICT day by day (Van Etten, 2011).

Crowdsourcing involves creating a mechanism to break a large task into “microtasks”, which are tasks that can be done by one individual in a short time span, and creating mechanisms to retrieve and combine the results to accomplish the original large task. The massive nature of the task makes it impossible to check every single contribution. Usually, crowdsourcing approaches have built-in redundancy, so that each or some tasks are executed more than once by several participants. Results from different participants are compared and filtered for quality by checking the consistency of answers. In this context, an important idea is the “wisdom of crowds” (Surowiecki 2005). The wisdom of crowds principle is that high quality information can be retrieved from noisy individual contributions as long as the contributions are independent, decentralized and diverse, and are aggregated with a robust mechanism. Citizen science often makes use of the crowdsourcing techniques and the “wisdom of crowds” principle. But at the same time many forms of citizen science give an active, engaged role to participants. The objective of citizen science often goes beyond data collection or the execution of simple tasks and also involves educational and awareness-raising objectives (Dickinson and Bonney 2012). This matches with the empowerment agenda behind the focus on participatory approaches in agricultural science.

Crowdsourcing in an agricultural development context is still fairly new in practice but it provides a potentially affordable tool for practitioners to conduct field research, gather data from remote areas, exchange information among key stakeholders, and other benefits. ICT-enabled efforts have the potential to leverage the accumulated knowledge of groups of people and expand access to information, funding and markets. Crowdsourcing in agricultural development can help with facilitating information gathering in different stages of the value chain. It allows practitioners to obtain a greater quantity and diversity of information and data inputs (Brabham, 2008; CTA, 2012).

There are some core differences though that distinguish the use of crowdsourcing in developing nations from their common application in developed economies. The first is the platform. Crowdsourcing in developed economies is primarily done via websites at computers accessed by internet, while in sub-Saharan Africa, mobile phones dominate the medium of information exchange. In addition, in sub-Saharan Africa crowdsourced participation in the agricultural context has generally been motivated by cash, cash-like payments such as airtime, or valued information with a direct link to securing or increasing income. When considering if crowdsourcing is applicable for potential new initiatives it is therefore necessary to ask the following fundamental questions: a) What is the fundamental role to be done or replaced by a group? b) Do target users have access to and literacy in using mobile phones? c) What is the incentive for people, aka ‘the crowd,’ to participate? In Africa, ICT-enabled crowdsourcing applications have been used within different agricultural development initiatives involving smallholder farmers. They include increasing farmer access to information, promoting market access and farmer collectivization, tracking pest outbreaks and sharing weather information (Silversmith and Tulchin, 2013).
Crowdsourcing seed innovation could be seen as an alternative to current major attempts to shift to more intense agricultural input use through subsidies and the provision of small-sized packages of inputs. Several seed companies and national agricultural programmes in SSA have adopted the distribution of small packages of seeds. The small package approach has also been adopted by the Alliance for a Green Revolution for Africa (AGRA), which will give the approach a further impetus.

The crowdsourcing approach to seed innovation aims to reach massive numbers of small-scale farmers. It specifically targets innovation around crop diversity for household food security, especially where market development is incomplete and commercial solutions can be expected to have less impact (Van Etten, 2011). A crowdsourcing approach has the potential to overcome some of the obstacles common to formal seed systems in Sub-Saharan Africa, to augment African farmers’ innovation skills, to have a direct positive impact on agricultural productivity and food security, and to lead to demand-driven (rather than supply-driven) seed market development. It builds on lessons learnt from participatory crop improvement over the last two decades, yet adds an important component to make it possible to upscale local efforts to a system that would have an impact on large populations.

In this research study, the objective was to use crowdsourcing as an innovative approach for increasing varietal portfolios to enable farmers to diversify their options for climate change adaptation. This was done through development and integration of scientific methodologies (on-station trials) with Participatory Varietal Selection approaches in three climatically vulnerable locations in Kenya and Tanzania. The methodological approach involved complementarity of socio-economic studies with on-station and on-farm participatory research that would provide insights on the potential of varietal diversification strategies to help farmers to adapt to climate change. The study was based on the assumption that increased diversity through introduction of germplasm from the National Gene Banks will reduce the vulnerability of farmers.

Methodology

The overall approach to crowd sourcing

A GIS based approach was used to select subsets of sorghum, cowpea and pigeon pea germplasm from the National Gene Banks. Case study sites in Kenya and Tanzania were selected as representatives of the arid and semi-arid agro-ecologies, which are vulnerable to climate change. Socio-economic studies were then conducted through household surveys and Focus Group in order to assess current vulnerability of farmers’ varieties and varietal portfolios and identify varietal diversification needs and opportunities in the benchmark sites. On-station trials were then conducted in Kenya and Tanzania. The 20 best performing varieties from the on-station trials were considered for crowd sourcing in each site. In each site a check comprising a popular improved variety was included to make the total number of crowd sourcing varieties 21. A total of 1300 farmers representing the three project sites participated in the crowdsourcing activity. Each farmer received a combination of 4 varieties. The combination was prepared randomly using Excel but the total number of occurrences of each variety was kept approximately same. Identification codes were generated to keep track of all the information such as the site, name of farmer and the combination of varieties received. Farmers were identified with the codes only. The gene bank accession numbers of the sorghum varieties were not disclosed to the farmers to allow a more unbiased opinion. 

A
questionnaire was developed and distributed to the farmers in each site. With the help of agricultural extension officers in each site, farmers scored for date sowing, days to 50% flowering, date of maturity and pest and diseases susceptibility. Farmers thereafter ranked the four varieties on a scale of 1 to 4, with 1 being the most preferred 4 as the least preferred. The other type of data that was collected included name of the farmer, village, age, gender, education level, household composition, date of sowing and mobile phone number.

Selection of gene bank accessions

The initial step was to use a GIS based approach to select subsets of sorghum, cowpea and pigeon pea germplasm from the National Gene Banks. A total of 19 bioclimatic variables were extracted using the BIOCLIM algorithm at 2.5 arc minutes\(^1\) resolution using the program DIVA-GIS. Most of these variables were associated with the different precipitation and temperature regimes characteristic of the different habitats of the three crops. Locality data from accession specimens were used to extract the variables. Agro-ecological variables at each locality were extracted using ArcGIS 10. R data analysis software was then used to implement a hierarchical clustering method based on the technique proposed by Grum and Atieno (2007) to group the gene bank accessions into different categories on the basis of the annual average temperature, annual precipitation and agro-ecological zone of each accession record. The outputs were dendrograms showing the approximate relationships among the set of accessions of each crop (Figure 1). Using the dendrograms, 191 accessions were randomly selected based on the cluster size in proportion to the number of accessions targeted for inclusion in the trials. A thorough analysis of selections and assessment of seed quantities available in the gene banks reduced this list to 114 sorghum, cowpea and pigeon pea accessions that were finally used in the on-station and on-farm trials.

\[^1\] An arc minute is a unit of angular measurement equal to one sixtieth (\(1/60\)) of one degree
Site selection

The selected case study sites needed to be representative of the arid and semi arid agro-ecologies, which are vulnerable to climate change. The project sites were therefore selected primarily because of the vulnerability of farmers to climate change and climate variability in those environments. The research was conducted in CCAFs benchmark sites and they were preferred because they fitted the set criteria and socio-economic data collected in previous studies was available. In Kenya, the project therefore used the CCAFs benchmark sites in Nyando and Makueni. In Tanzania, Hombolo in Dodoma was selected because the farmers are vulnerable to climate change and the case study crops are important in that region. On-station trials were conducted in Katumani in Kenya and Hombolo, Arusha and Morogoro in Tanzania. These sites were selected because they represent a transect of an environmental gradient in Kenya and Tanzania that was used to assess the effects of genotype x environment interaction of the selected germplasm. For crowsourcing, the selected sites were Nyando and Makueni in Kenya and Hombolo in Tanzania.

Three sites were selected for crowd sourcing:
- Makueni and in Nyando in Kenya
- Hombolo in Tanzania
Socio-economic studies

The socio-economic studies were conducted through household surveys and Focus Group Discussions in Makueni, Nyando and Hombolo to assess current vulnerability of farmers’ varieties and varietal portfolios and identify varietal diversification needs and opportunities in the benchmark sites. The study purposively sampled 120 farmers cultivating the focus crops from the 200 households. The objective of the study was to identify the extent to which the small scale focus crops cultivating households are vulnerable to prevailing climate variability and change conditions. The studies particularly focused on identifying local climate variability and change indicators that are affecting the focus crops small scale farmers; identification of the impacts of key climate variability and change indicators on livelihoods of the focus crops small scale farmers; characterization of the existing adaptation strategies among the focus crop small scale farmers against key calamities; determination of the vulnerability among the focus crop small scale farmers and determination of the socio-economic factors that influences the focus crops small scale farmers’ adaptation to climate change and variability in the study areas. The focus crops farmers were the entry point of this study since understanding climate based risks affecting these farmers is important for informing appropriate and transferable adaptive capacities. There is evidently little understanding of the vulnerability of such households. Accordingly, this research was critical for characterizing the nature of vulnerability of small scale farmers to inform on appropriate interventions for buffering against inherent and new combinations of climate extremes impacts.

On-station trials
In Kenya, the on-station trials were conducted at KARI Katumani and in Tanzania they were conducted at the Agricultural Research Institute in Hombolo, Selian Agricultural Research Centre in Arusha and Sokoine University, Morogoro. These trials were conducted at different times of the year since the growing seasons vary in the 3 sites. All experiments were laid out in Completely Randomized Block Design (CRDB) in order to eliminate any biases due to differences in field micro-environmental conditions. Soil samples and climatic data were collected in order to complement studies on genotype x environment interactions. Characterization for agronomic traits and morphological characteristics was conducted using the same protocols to allow for ease of comparison of data across the three research stations. The data was collected during the growing seasons using IPGRI descriptors for specific crops, but with some modifications. Preliminary analysis of the data has shown significant differences in plant height, days to maturity, colour and shape of head types and grains as well as overall yield potential across genotypes and research sites.

Figure 4: On-station trials for selection of best performing varieties

In each of the three sites, data analysis was conducted independently and comparisons carried out to determine the 20 best performing varieties to be used for crowdsourcing and on-farm trials. The traits used to identify the best performing accessions in each of the on-station trial site were the seed yield, days to 50% flowering, pest and diseases resistance/tolerance and plant height. Further analysis was conducted to select accessions which performed well in at least 2 sites. Analysis was not conducted for cowpea since the dataset contained only 20 accessions and therefore all the accessions were recommended for use in the on-farm trials.

**Collection of weather data**

Detailed daily weather data during the growing season was collected through the use of an iButton temperature/humidity logger (DS1923). This is a rugged, self-sufficient system that measures temperature and/or humidity and records the results in a protected memory. A total of 4, 3 and 2 iButtons were placed in Hombolo, Wote and Nyando on-farm trials sites respectively. There were no significant differences but variations were observed in both mean temperatures and the mean humidity in the four farms where the iButton was placed in Hombolo. However, mean temperature and humidity variations within and between sites where the iButtons were placed in Kenya (Nyando...
and Makueni) were higher. Generally, in both Kenyan sites, the mean temperature and mean humidity were lower than in Hombolo, Tanzania. Though there may not be statistically significant differences between and within sites the variations are a good indicator of micro-environmental differences which could have implications on the overall performance of the varieties.

Figure 5: Collection of weather data using iButtons

Selection and distribution of crowdsourcing farmers

Seeds were distributed through the local administration with the support from agricultural extension officers. Village offices served as distribution points for seed packages. Field officers were recruited in all sites to help in seed distribution. Distribution strategies included home to home, chiefs’ barazas, funerals and church gatherings.
Coding system (protocol)

Seeds used in the crowdsourcing activity were sourced from the national gene banks i.e. NGBK and NPGRC. They included seeds harvested during the on-station trials. We generated a randomized list with farmer code and unique combinations (500 in Hombolo and Wote, 300 in Nyando) of 4 varieties (including 1 check variety). The methodology was implemented in R and Excel software. A set of 1140 combinations of 20 items were generated using the R software. Due to a lack of seeds we are unable to implement crowdsourcing trials for cow pea and pigeon pea.

Packaging and seed distribution

Packaging of seeds was done on site. Varieties were first packaged in equal amounts of 75 packets per accession. The process included 6 people i.e. 4 people for picking the packets, 1 person for reading the combinations and 1 person for conducting checks of what has been picked.

Crowdsourcing data collection

Field officers visited the crowdsourcing farms three times during the cropping season i.e. At sowing, at 50% maturity and at harvest. Data collected during these visits included: Farmers’ name, variety codes, village, gender, education, household composition, age, coordinate information, phone

Figure 6: A crowdsourcing farmer in Hombolo

Figure 7: Packing of crowdsourcing seeds for distribution
number, date of sowing, date of 50% flowering, date of maturity, plant height, yield, ranking and diseases or pests. Although 1300 packets were distributed, data was collected from 1084 farmers only. Out of these only 924 (71%) had complete data i.e. Hombolo 354/500 (70%), Nyando 238/300 (79%) and Wote 332/500 (66%). Some of the reasons as to why some of the data was not collected from 376 (29%) farmers included: failure to plant, lack of rainfall and lack of cooperation by the farmers.

Table 1: Number of packets per accession

<table>
<thead>
<tr>
<th>Var</th>
<th>Total</th>
<th>Hombolo</th>
<th>Nyando</th>
<th>Wote</th>
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<tr>
<td>1</td>
<td>205</td>
<td>78</td>
<td>54</td>
<td>73</td>
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<td>2</td>
<td>88</td>
<td>76</td>
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<td>12</td>
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<td>3</td>
<td>205</td>
<td>76</td>
<td>54</td>
<td>75</td>
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<td>78</td>
<td>0</td>
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<td>20</td>
<td>142</td>
<td>77</td>
<td>0</td>
<td>65</td>
</tr>
<tr>
<td>21*</td>
<td>1178</td>
<td>503</td>
<td>247</td>
<td>431</td>
</tr>
</tbody>
</table>

* different check varieties: Macia (Hombolo), Seredo (Nyando) and Kateng ‘u (Wote).
Data entry and cleaning

Data was collected using paper forms and later entered into excel by the field staff involved in each location.

Table 2: Summary statistics of distributed seeds

<table>
<thead>
<tr>
<th>SUMMARY STATS</th>
<th>Hombolo</th>
<th>Nyando</th>
<th>Wote</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nr of packets distributed</td>
<td>503</td>
<td>247</td>
<td>431</td>
</tr>
<tr>
<td>Nr of names</td>
<td>407</td>
<td>247</td>
<td>431</td>
</tr>
<tr>
<td>Nr of ratings (full)</td>
<td>354</td>
<td>235</td>
<td>332</td>
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<tr>
<td>Percentage success</td>
<td>71%</td>
<td>78%</td>
<td>66%</td>
</tr>
<tr>
<td>Nr of ratings (partial)</td>
<td>2</td>
<td>3</td>
<td>55</td>
</tr>
<tr>
<td>No ratings</td>
<td>51</td>
<td>6</td>
<td>44</td>
</tr>
<tr>
<td>No variety codes</td>
<td>0</td>
<td>3</td>
<td>0</td>
</tr>
</tbody>
</table>

Data analysis

The crowdsourcing dataset is being analyzed using ClimMob, a software package to analyze data generated by citizen science or crowdsourcing. Additional analysis will be done using MS Excel, ArcMap and Google Earth for creating simple summary statistics and graphics.

Follow-up study on crowd sourcing farmers

A preliminary survey was carried out in Nyando and Wote to assess the effectiveness and diffusion of seeds into the communities following the distribution of seeds through the crowdsourcing approach. A random sample of 100 farmers was used (50 farmers in each of the two site) and a questionnaire was used to conduct interviews Appendix 1.

In Nyando, representative villages were Kodero, Kokwaro, Kamwana, Koloo and Katuk. In Wote, the representative sites were Kambi ya Mawe, Kathoka, Kavinguni, Muvau and Kiumani. An analysis of the gender representation reveals that overall there were more females than males that participated in the crowdsourcing activity in the two sites. In Wote the participation was 57.5% female and 42.5% male while in Nyando participation was 59% females and 41% male.

The survey revealed that in Nyando 42% of the farmers retained at least one variety of the seeds while in Makueni 38.5% of the farmers had retained at least one variety. The seed storage facilities and methods in the sites were varied. They included storage in airtight and moisture proof tins, polythene bags, gunny bags, gourds and traditional baskets. Some of the farmers reported treating the seeds with ash to prevent postharvest insect attacks.
The study further revealed that although many farmers still retained seeds, the majority didn’t plant the seeds due to various reasons which included preference for other crops, fear of losing the seeds due to drought, insufficient quantities and infestation by insects. In Nyando out of those who still retained seeds 22% had planted one variety, 12% had planted two varieties and 5% had planted three varieties. In Wote on the other hand, out of the farmers that still retained seeds, 28% had planted one variety, 10% had planted two varieties, 6% had planted three varieties and three had planted all the four varieties. Some farmers reported planting the seeds but they didn’t germinate due to dormancy while some germinated but didn’t do well due to drought. Figure 1 shows the percentages of the farmers that had planted different varieties in the two sites.

![Figure 1. Percentage of farmers that had planted at least two varieties in the two sites](image)

Crowdsourced seed innovation focused on providing crop and varietal diversity through small quantities of seeds, in sachets of 2.5g. The involvement of the local administration made it possible to initiate and monitor the process starting from seed distribution, to assessment of the performance through field visits and collection of minimal data. The initial target of 500 farmers per site was not achieved due to seepage and fall out. However, the participation of 1300 farmers provided enough data to allow for the assessment of crowdsourcing as an innovative approach to varietal diversification and broadening of the genetic base in small scale agricultural production systems. It also enabled the farmers to make varietal choices informed by their trait preferences.

As a follow-up activity, the promising varieties could be tested or distributed more widely, while invariably lowly ranked varieties could be discarded and included in ex situ seed collections if their diversity value warrants it. After the full analysis of data, it is envisaged that different clusters may emerge based on divergent preferences and they may be related to related to environmental or socioeconomic variables. It is also expected that the crowdsourced seed innovation will stimulate flows of information about collectively available varieties, as well as integration of the introduced
varieties into the local seed supply systems. Moreover, the full data analysis could be used to measure the potential demand for the preferred varieties across larger geographical or agro-ecological areas. This could help entrepreneurs to identify business opportunities in multiplication, distribution and marketing of seeds.

**Conclusion**

The collective farmer selection skills have been used as a main entry point in the development of alternative approaches to seed innovations and diversification of varietal portfolios to meet food security and nutritional needs. Thus, different forms of Participatory Variety Selection (PVS) can be used to increase farmer participation in innovation, in order to go beyond the transfer of technology (ToT) approach. Interventions using farmer-participatory approaches often target a limited number of farmers, who share their collective local wisdom, indigenous knowledge and time to produce new insights in crop diversity. Subsequently, varieties developed or identified through participatory variety selection methods then need to spread to other farmers through informal seed diffusion mechanisms. The methodology used in this project serves as a “proof-of-concept” that a combination of socio-economic studies, scientific methods and participatory varietal selection is needed for effective delivery of varietal portfolios for climate adaptation to farmers. The methodology can thus contribute to development interventions focused on agro-ecological resilience and varietal diversification by building on farmers’ perceptions of climate change and their local knowledge of agricultural practices and adaptation strategies. It takes a scientifically supported supported community-based approach that aims to identify how the use of local agro-biodiversity can be optimized through opportunities provided by outside interventions that are economically and culturally acceptable for small scale farmers while taking the local vulnerability context into account. However, for this methodology to be upscaled and replicated in other crops, countries and agro-ecological zones, it is imperative that all the data is fully analyzed and lessons fully documented.

In conclusion, it is quite clear that in the last few years, work on crowdsourcing approach has provided an interesting dimension to agricultural research and development, combining work on crop diversity, farm innovation, digital technology and social, institutional and behavioral aspects. This has opened the exploration of a myriad of interesting avenues that are relevant to a growing platform of collaborative experimentation. However, future research using crowdsourcing approached should answer the following questions:

- How can the crowdsourcing approach be applied to farm technologies beyond crop varieties, such as fertilizers, biofertilizers, soil amendments, crop protection products and any other related technologies? Can the crowdsourcing approach be applied to studies in postharvest management, consumption and nutrition?
- How can the crowdsourcing approach be built into sustainable institutional and business models? The crowdsourcing approach provides information that is useful to both farmers and seed and input suppliers. This is a so-called two-sided market (Eisenmann *et al*. 2006). More research is needed to develop the tricot approach into a platform that serves the two-sided market for agricultural technology targeting.
How can the best of bottom-up approaches and top-down approaches be combined to find a match between financial sustainability and empowerment of the user? The crowdsourcing approach needs to be evaluated from the lens of the recent critical literature on participation and technological citizenship (Cooke and Kothari 2001, Richards 2007).

References


