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Concept Paper

Conceptualization of farmer as citizen scientists

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Introduction

Farmers are the end users of crop varieties. According to an estimate about one third of crop varieties released in India do not perform well in the seed chain. This is simply because of their non-alignment in the crop improvement process. Farmers can be engaged in the crop development programs through their close engagement in the process. This can be done through strengthening the participatory-varietal-testing programs or via involving them as citizen scientists. In participatory varietal breeding they can be closely engaged in evaluating varieties according to their felt needs/ preference (farmer traits). Usually the traits of market preferences are liked by farmers, which, may or may not be focused by breeders. I believe the coming era is of 'Breeding for value chain'. Secondly, through using crowdsourcing data approach large number of farmers can be approached and involving multiple stake-holders such as extension workers/NGOs/volunteers/Govt. agencies under-utilized crop varieties, landraces, traditional cultivars and modern varieties can be evaluated for their suitable environment/ climatic adaptation.

There is a long history of using participatory approaches in agricultural research and development projects, even though they are not always referred as crowdsourcing. These approaches aimed to facilitate interactions between farmers and researchers or simply collect agricultural data from the farmers (van Etten, 2011) [13]. The dissemination of agricultural research knowledge is usually organized by national or regional agricultural agencies, also known as extension services/ farm consultants belonging to private companies. These agencies have a common goal of transferring scientific knowledge and new technologies to farmers. It is important to note that, still there is a dis-connect/ information gap between scientists and farmers. Scientists might not comprehend or even be aware of what farmers require. In addition, even when research outputs are relevant, many project outcomes fall short of the needs or fields of the farmers. More recently, there was a decline in public support for agricultural extension services in several countries, and/or their missions had to be substantially recast, which delayed the dissemination and transfer of research and technology. Participatory learning, for example, has been effectively used in agricultural research and development programs to close the communication gap between scientists and farmers (Pretty, 1995). Crowdsourcing of farmer data has been recognised in past few years scientists (Beza *et al*. 2017) as an alternative approach to remote sensing and sensor networks for gathering field observations for yield gap analysis. Crowdsourcing applications in agriculture can help greatly in minimizing the information gap between researchers and their immediate clients i.e. farmers. Crowdsourcing further promotes farmer-to-farmer contacts in addition to providing inputs that satisfy the needs of agricultural researchers. The development of crowdsourcing applications for agriculture should offer substantial opportunities for scientists and professionals involved in the agricultural research and development processes.

Multi-stakeholders platforms in crop improvement

The multi-stakeholder platforms can help greatly the crop improvement programs. They can help in providing services such as 'on –farm evaluation of materials', they can guide effectively in defining the traits of market as well as farmers key interests and most importantly they can provide support as ground workers through providing seeds, informations and feedback as well.

Their personal contacts with the local farmers can be utilized efficiently. Further, they can provide assistance in trials, data gathering provide the farmers feedback observations. Through using this approach, crowd sourcing experiments can be conducted efficiently, thereby, with minimum investment sufficient amount of breeder's relevant information can be collected. Multi-stakeholder platform is very much helpful in the varietal release process and afterwards establishment of seed chain for impact delivery. Based on the reach in stakeholders and our specific needs different models can be developed to deploy and ensure impact.

Importance of the data science in agriculture

In the current era of Big data, most of R & D programs are equipped with it for enhancing their implementation efficiency. In agriculture extension, innovative approaches need to be worked out to amalgamate the crowdsourcing datasets, multi-location research data, high density genomics data etc. Algorithms can be created and tested as per need. Practically, research projects need to be linked to development programs during their implementation through utilizing the virtue of data science. For example conducting breeding/ molecular breeding experiment requires 'experimental field data', however, if on-farm data gathered by farmer is added to it with help of innovative crowdsourcing approach, outcome of research should have high impact. Experiments such as 'Integrated varietal selection programs can be implemented in which advancing generations can be pursued at farmer's field, while, selecting at experimental farm as well. This approach is unfavored by breeders due to several reasons that can be addressed through innovating in implementation strategy using Big Data approaches.

Crowdsourcing in crop diversity and climate adaptation

Genetic diversity of crops has tremendous potential to address challenges posed by the climate change. It is now well-established fact that monoculture in crop varieties is not very favorable situation for the current climate change era. Diversification in crop varieties as well as crops can effectively help in mitigating challenges posed by climate change. This can be done through innovating impact oriented participatory varietal testing approach and performing the crowdsourcing experiments. Through these approach traditional varieties, landraces and released but under-utilized varieties can be tested in diverse environments for their suitability. For example, rice landraces with the GI tag are still grown in their habitats and farmer receive good prices if they access to efficient marketing chain. Landraces and traditional varieties can be evaluated through conducting large-scale efforts with help of crowd sourcing and pursuing a multi-stakeholder platform. This approach has been proven successfully in Ethiopia in efforts conducted by Bioversity International. Large scale germplasm and information collection has enabled crop breeders to innovate new varieties. Traditional farmer varieties and landraces were originally adapted to specific environments, however, the on-farm diversity was reduced over time period due to change in demand pattern (growing population). Landraces and farmer varieties need to be maintained, thoroughly characterized and regularly utilized in the breeding programs through pre-breeding. A total of 8416 Mexican wheat landraces were characterized in field and genotyped with high density marker approach and the resultant 'big data' is being used in wheat breeding programs of different countries, ultimately delivering disease resistant genotypes (Vikram *et al*. 2016, Singh *et al*. 2018) [15, 11].

Applications of crowdsourcing in agriculture

Crowdsourcing is a tool that can be used to externalize complicated activities. This strategy is the foundation of many scientific efforts that use crowdsourcing, such as the classification of land cover based on readily available earth imagery (Fritz *et al*., 2012; See *et al*., 2015) [5, 10]. Agriculture-related studies aim to identify plant species through a combination of crowdsourced plant image gathering and computer-automated image analysis based on machine learning. The contributor takes a photo of a plant using a mobile application, then uses automatic image classification to try and identify the species. However, if the contributor can accurately classify the image using his or her own knowledge of the plant, the image will be fed into the image database, which will increase the effectiveness of the machine learning algorithm. A project about plant disease picture detection (Hughes and Salathé, 2015) [6], which aims to assist farmers in identifying pests and illnesses that impact their crops, is more specifically related to the agricultural industry.

The amount of time it takes to get from one location to another is a major problem for field officers who gather data or make observations. By crowdsourcing local residents' visual observations, a vast volume of data can be more easily gathered by numerous operators. The topic of biodiversity monitoring, which is also referred to as community-based environmental monitoring, has a great number of examples of crowdsourcing local visual observations in environmental sciences (Conrad and Hilchey, 2011) [4]. According to Roy *et al*. (2012) [9], visual observations are documented and disseminated through the use of brief notes and/or photos that are uploaded to a website. There are many mobile applications that are specifically designed to enable the monitoring of environmental observations (http://brunalab.org/apps). As an example case, a large-scale crowdsourcing approach for crop improvement was put into practice through pilot projects in Africa, India, and Central America (van Etten *et al*., 2016) [14]. Farmers were requested to assess and report crop growth performance for several crop varieties under farming settings in this method, which is referred to as participatory variety selection. Farmers have traditionally been required to submit small-scale observations to scientists and extension organisations, with or without financial incentive.

The idea of big data in agriculture was initially introduced when GPS-driven agricultural equipments, inexpensive environmental sensors together with mobile devices significantly expanded the amount of data for large-scale agricultural applications (Sonka, 2014) [12]. Applications based on the crowdsourcing of data that are more focused on the requirements of farmers exist, although being infrequently documented in the scientific literature. For instance, the UK's Potato Crop Management project's YieldCheck application (www.potatocropmanagement.com) combined a web platform and mobile application to enable potato growers to collect information about their crops (field location, crop variety, planting and emergence dates) using a mobile phone and then to provide them with yield forecasting information. Similarly, the Wageningen University, Netherlands' Akkerweb platform (www.akkerweb.nl) enabled the centralization of field information combined with satellite and soil data to give farmers with an integrated cropping plan.

Knowledge portals, Question & Answer (Q&A) forums, and wikis are examples of user-generated content web platforms that offer considerable potential for knowledge collection. These web platforms provide a variety of knowledge resource to users presents another application of crowdsourcing in agriculture. Croprotech (Bruce, 2016) [3], a recent platform in the agricultural sector, attempts to teach farmers in the UK about weeds, pests, and diseases while attempting to forge a two-way relationship between scientists (who built the platform) and farmers. As the foundation of a community of practise, Q&A forums can assist practitioners in gaining information, sharing new methods and technologies, and validating and legitimizing unofficial knowledge. There are a lot of blogs about agriculture that are frequently run by farmers who want to spread certain information to other farmers or make their work more well-known to the general public. These online platforms and knowledge hubs support the global dissemination of innovative agricultural techniques, such as the use of cutting-edge technology or different approaches to carrying out particular tasks, like organic farming.

Crowdsourcing data gathering in agriculture

Different types of data, information and knowledge inputs contribute toward crowdsourcing in agriculture. The geolocalized forms of the parcels and their land-use/land-cover properties serve as points or agricultural parcel limits that provide support for agricultural land-use data.

Applications of existing crowdsourcing projects that focus on soil data and stated soil attributes should be a big help in raising the accuracy and quality of soil maps (Rossiter *et al*. 2015) [8]. Regular soil analysis performed by extension services and private laboratories, which may share their soil survey results with a centralised web platform, could benefit crowdsourcing platforms for soil data. Databases for the phenology and crop calendar also heavily rely on crowdsourcing. Phenology is the study of seasonal life cycle events, which are influenced by the yearly changes in climate. The most advanced crowdsourcing initiatives worldwide involve gathering environmental phenology observations (e.g., National Phenology Network, US, Betancourt *et al*., 2007) [1].

Crowdsourcing data can assist in acquiring a significant amount of baseline information that is crucial for the integrated pest and disease management because weeds, pests, and diseases severely reduce crop yields. Croprotech, one of the crowdsourcing platforms, may be able to assist with logging weed, insect, and disease findings (Bruce, 2016) [3]. Crop pest and disease infections can be challenging to recognise and call for expert input. In the context of climate change and agricultural extension, there is a large demand for regional or worldwide observations of pests and diseases in cropping systems for crop disease modelling and forecasting. These details are crucial for agricultural extension services since they help to detect dangers and provide advice to farmers on how to prevent diseases and pests in return.

For farmers and marketers, prices of agricultural products are essential information. Through the exchange of price information, each manufacturing chain stakeholder can improve their commercial position. As an illustration, consider the Pommak project (www.pommak.be), which was recently created in Belgium by extension services of the potato industry to collect pricing data on potatoes with the goal of mutualizing access to free market prices.

In the current era of a globalised and information-techno society, general agricultural knowledge becomes highly crucial. Generally speaking, agriculture knowledge refers to topics like farming equipment, crop and animal production, pests and illnesses, trade and market, understanding of laws, etc. Many online knowledge portals collect general information and expertise about agricultural activities. On the basis of their personal experiences, farmers contribute the majority of this knowledge.

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