What is your idea? We will radically transform pest and disease monitoring by using artificial intelligence, advanced sensor technology and crowdsourcing capable of connecting the global Ag community to help smallholder farmers. We aim to increase the effectiveness of farm-level advice by leveraging three critical advances that allow for a major transformation in how knowledge is communicated to the farm level: 1) The democratization of Artificial Intelligence (AI) via open access platforms like Google's TensorFlow, 2) The miniaturization of technology allowing affordable deployment and 3) The development of massive communication and money exchange platforms like M-Pesa that allow rural extension to scale as a viable economic model enabling last mile delivery in local languages.

Why is the idea an unconventional or creative approach to the problem outlined in the topic? Pests and diseases hobble smallholder farmers, yet technology for rapid, in-field diagnostics already exists! Smartphones, satellites, drones, miniaturized devices and cloud computing are daily features of life in the developed world. What is unconventional is integrating these technologies and providing them open sourced/open code/open access for smallholder farmers and the public and private extension agents that serve them. Furthermore, the ability to deliver regional alerts to millions of farmers across the last mile in local languages also exists. For this project we will leverage our partnership with Vodafone/Safaricom who transformed mobile banking. Together we will to deliver via SMS locally relevant alerts on crop diseases and pests to 350,000 Kenyan farmers by July 2018.

Describe the hypothesis for the proposal and why it is expected to succeed. Our hypothesis is that existing technology can diagnose pests and diseases and can provide diagnostics in real-time to someone with minimal training, in the field. We also anticipate that advice from such rapid diagnostics can be delivered to large numbers of smallholder farmers via SMS. We fully expect the proposed work to succeed. The first steps of this work have already been completed over the last 18 months through field work using cameras, spectrophotometers and drones at RTB cassava field sites in coastal Tanzania and on farms in western Kenya. We have taken >200,000 images of diseased crops to train AI algorithms. Hughes, Legg and collaborators recently developed an AI algorithm with TensorFlow that can automatically classify 5 cassava diseases (submitted to *Frontiers in Plant Science*) building on published work that did this for 26 diseases in 12 crops. Through a collaboration with Google, a TensorFlow smartphone app has been developed that is currently being field-tested in Tanzania by IITA (https://www.youtube.com/watch?v=479p-PEubZk&feature=youtu.be). The M-Pesa mobile money transfer revolution has demonstrated how new phone technology can benefit millions of rural people in Africa. We have already developed the linkages with the Vodafone ag SMS platform (called DigiFarm) which positions us strategically to link digital diagnostics to large-scale rural text messaging services.

How will you pilot it? We aim to extend this highly promising proof-of-concept work to other key experimental sites where RTB scientists are working with national partners. These will include cassava/banana in Uganda (IITA/Bioversity International), potato in Kenya (CIP) and cassava/plantain in Nigeria (IITA). Key disease targets during this stage will be: cassava mosaic and cassava brown streak viruses for cassava; banana fungal and bacterial diseases and banana bunchy top virus for banana/plantain; and late blight for potato. For some important diseases the infected plants may be asymptomatic making detection reliant on lab facilities that are often not available. Cassava brown streak viruses are a notable example and the inadvertent human spread of infected but asymptomatic material threatens to spread the disease to West Africa which would be an economic and humanitarian disaster. Penn State developed a mobile spectrophotometer and early results (at IITA in TZ) suggest it can accurately diagnose different viral diseases and, critically, can do so even if the plant looks healthy. It does this in seconds in the field in the hands of the field worker with zero training. In addition, we recently deployed drones in Tanzania and Kenya for CMD and Fall Army Worm (both of which we can rapidly diagnose). We will test what other diseases can be accurately diagnosed from cameras on drones. We use both standard 4k RGB (red, green, blue) cameras and multi-spectral cameras that take images in 5 bands at once (RGB, infra-red, red edge allowing for vegetation indices data collection like NDVI). Although all drone/camera agricultural software is proprietary we are developing open access platforms in R to democratize this technology. Since we expect our work to have major impact, we will test how rapid disease diagnosis increases yield in cassava value chains in Kenya involving 28,000 farmers. Finally, through an existing platform (www.PlantVillage.org) we will enable real time discussions of disease and pest diagnoses across the CG community and with other experts to enhance SMS alerts from the DigiFarm platform. After piloting the technology in Africa, we plan to extend the approach for application to the whole range of major crop pest/disease constraints that are being addressed by the CGIAR.

Describe the implementation plan, including any new technologies or tools that will be developed. The component technologies have already been developed, and we have experience using AI, mobile spectrophotometers, drones and crowdsourcing in East Africa. We will work with RTB experts at multiple sites in Africa to refine the approach and extend to other crops/diseases. Importantly we will leverage Big Data from the RTB science community to achieve network effects.

Explain how the work will be performed within the budget (USD$100,000) and time (12 months) allowed? Our prior experience working together in the field (as recently as June 2017) means we can hit the ground running with minimal costs for setup. We will work at each site (Kenya, Nigeria, Tanzania, Uganda) collecting data with phones, drones, spectrophotometers and performing same-day analysis using our existing TensorFlow platform. This allows RTB experts who effectively diagnose pests and diseases to determine the accuracy of the machines. Our expenses are travel and support of local staff (for standard field and lab-based diagnosis) with substantial subsidization by Penn State (which will pay for the computer scientist, hardware, drones, cloud storage and platform cost) and TensorFlow mobile support by Pete Warden at Google. SMS costs are borne by Vodafone/Safaricom.

What essential data will be generated during this pilot? We will generate: 1/2 million images of crop diseases from cameras/phones and resultant algorithms developed using transfer deep learning (V3 inception model with TensorFlow); aerial data from drones for farm-level diagnostics (crop density and disease/pest status); data from mobile spectrophotometers on symptomatic and asymptomatic crops referenced to qPCR results or other standard laboratory diagnostics.

If the pilot is successful, what are the next steps? If Africa-based piloting is successful, we plan to extend the approach to the entire CGIAR, and since this is cutting-edge technology development, we also anticipate that there will be major applications for developed world agriculture too. M-Pesa represents a shining example of a technological application from the developing world that was truly world leading, outpacing mobile money in the developed world. We think that our digital diagnostics platform could be similarly ground-breaking, showing how farmer-centric crop health assessments with affordable technology and open access data and code can become a global reality.