



Precision Agriculture for Development



2016 Annual Report

Letter from the Managing Director

2016 was PAD's first full year. We launched a product in India, piloted and evaluated a service in Kenya, gained the confidence and privilege of serving nearly 27,000 smallholder farmers, and turned a project with fiscal sponsorship into a fully independent organization, poised to rapidly expand and deepen our work as we roll out a new model for agricultural extension.

Our vision, aspirations, and early results have allowed us to attract top talent and funders who are ready to take a risk on a big idea. Just like us, they see the potential of bringing highly relevant and customized agricultural information into the hands of farmers, directly and at radically low cost. They also are aware of the challenges of a tech-based start-up, in particular one that works with low-income and semi-literate farmers, and we greatly value their trust and support.

We are pragmatic visionaries, an interdisciplinary and multinational team of agronomists and data scientists, field operators and action-oriented researchers. What energizes and aligns us is a shared vision and set of values. We envision smallholder farmers being successful agricultural entrepreneurs, able to profitably and sustainably produce food for themselves and others. Our values guide us as we plan and act on a daily basis.

1. Impact at scale. Impact at scale is our north star. Our decisions ultimately aim to serve this single purpose. Impact means environmentally-sound yield and income gains for smallholder farmers. Scale means serving millions of farming families. This requires a product that is in high demand, very low cost, and adaptable to

different contexts.

2. Data driven decision making and continuous learning. Programmatic and organizational decisions are founded in rigorous analysis. We study existing data and generate new data to inform operational decision-making and to assess impact. We trial, measure, and refine on an on-going basis.

3. Working with and through partners. As a new player, we aim to complement and leverage existing organizations. In India and Kenya, we already work with implementing and technology partners to deliver our own services, which serve as testing grounds for innovations in environments we control. But we also work with other groups to improve their existing services. We recognize that social change, especially at a systems level, is a team sport.

These values are shared by our partners and supporters. We greatly appreciate this alignment so we can focus our energies on empowering smallholder farmers to make smart input and other management decisions.

2017 and beyond will bring new challenges. But I believe there is reason to be optimistic. PAD is starting to become an effective force for change as we align energies around impact, accelerate learning in the field, and test different paths to scale.

Thank you for helping us move forward boldly and thoughtfully as we work to bring precision agriculture to South Asia and Sub-Saharan Africa. Thank you on behalf of the farmers we serve.

Heiner Baumann, *Managing Director*



Introducing Precision Agriculture for Development

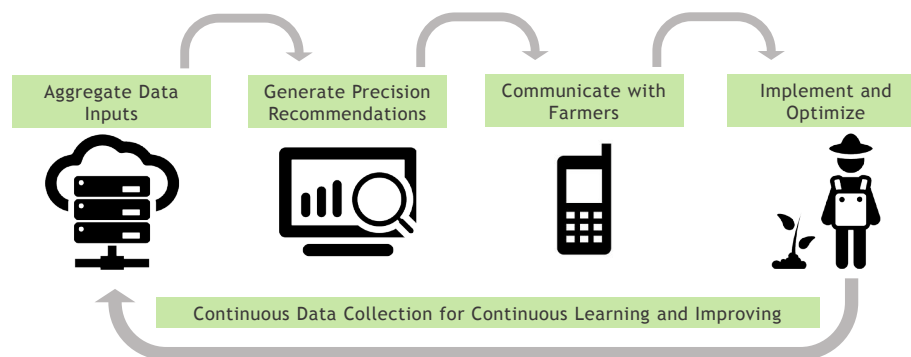
Precision Agriculture for Development, Inc. (PAD) is a new non-profit organization with a mission to support smallholder farmers in developing countries by providing customized information and services that increase productivity, profitability, and environmental sustainability.

PAD is working on a new model for agricultural extension: reaching farmers with personalized agricultural advice through their mobile phones. We implement this model in collaboration with partner organizations and gather evidence of its impact. We aim to eventually improve the lives of 100 million farmers in developing countries with our services.

We are developing location-specific intelligent platforms that provide farmers with context-relevant and personalized agricultural recommendations through their phones. These recommendations can be customized to optimize inputs and management practices, based on local agro-climatic and market conditions as well as farmers' demographic and risk tolerance profiles. Ultimately, the systems will include a two-way flow of information with farmers and will utilize machine learning techniques to continually refine our knowledge of best practices and prediction capabilities.

Simultaneously, we are supporting and improving systems that currently exist, particularly to help render these advisory services more customizable and intelligent with time. We approach working with new systems by rigorously evaluating their capabilities and impact, then help these service providers pilot and test new approaches to distributing more personalized information to farmers.

Direct model: Develop location-specific intelligent platforms that provide farmers with context-relevant and personalized agricultural recommendations through their mobile phones.



Indirect model: Support, evaluate, improve systems that currently exist, particularly to help render these advisory services more customizable and intelligent with time.



Why does PAD Exist?

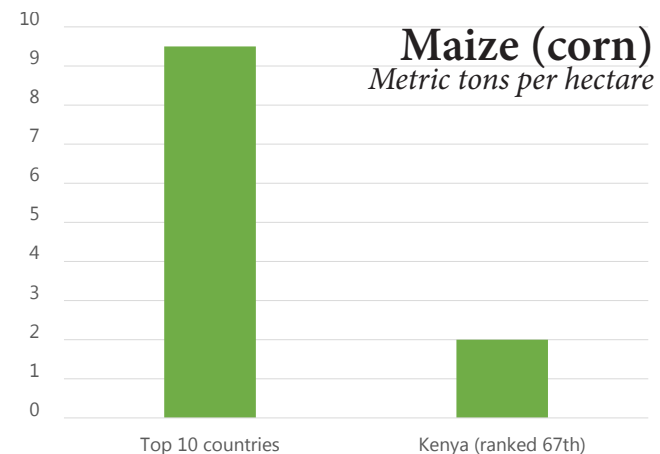
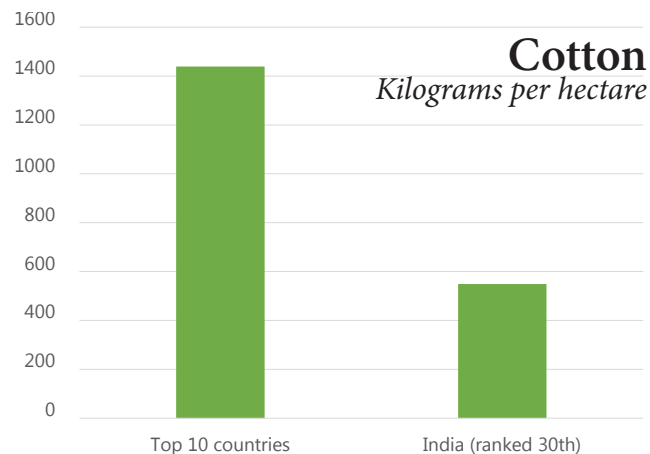
More than 2 billion people are supported by 450 million smallholder farms worldwide, and their annual production will need to increase substantially to meet growing demands for food and fiber in the coming decades. Studies in developing countries suggest that small changes in agricultural practices can substantially improve productivity and profitability. However, offering farmers standardized agricultural advice has limited effectiveness due to variation in conditions: for example, the profitability of seeds or fertilizers depends on pH levels or micronutrient content of the local soil. Traditional extension systems have been unable to incorporate and disseminate this information to farmers, in part due to the high costs of operating in rural areas.

In developed countries, precision agriculture technologies are transforming agricultural production by allowing farmers to better target inputs to local conditions, thus increasing yields and reducing environmental impacts from input overuse. Precision agriculture approaches in these settings include sensors, such as soil and yield monitors, and processing techniques for existing data: for example, new spectroscopy methods that measure growth stages and nutrient deficiency from satellite imagery.

In developing countries, such precision agriculture technologies are beyond the reach of most farmers. However, sever-

al technological innovations have created new opportunities to provide tailored information to farmers. First, new or improved measurement technologies enable better learning about local conditions. For instance, detailed weather forecasting data, soil type mapping, and remote sensing yield-monitoring devices allow more fine-tuned recommendations. Second, machine learning techniques make it possible to tailor expert knowledge at scale to conditions revealed in existing and new sources of data. These techniques can be further refined and improved using user feedback loops. Third, widespread adoption of mobile phones enables inexpensive information collection and delivery to farmers.

PAD harnesses these innovations to improve the lives of smallholder farmers in the developing world. Our approach is one of discovery, aiming to drive effective behavior change through repeated testing and model optimization using the best available techniques and technologies, as well as leveraging existing data sources. We are taking ideas from precision agriculture in developed countries and adapting them to the needs and constraints of farmers in developing countries. We believe that individual farmers should not need to invest in data collection and experimentation themselves. PAD brings this localized information to farmers' fingertips.



Data source for both figures: Index Mundi (www.indexmundi.com)

Our Inception Story and 2016 in Review

PAD is the brainchild of three professors from Harvard and Brown Universities working on agricultural projects in two disparate contexts: India and Kenya. In India, Professor Shawn Cole and PhD student Nilesh Fernando saw promising results in their rigorous impact evaluation of a two-way, customized mobile-phone based agricultural advisory service for a small set of cotton farmers in the state of Gujarat. In Kenya, Professor Michael Kremer, PhD student Raissa Fabregas, and others found evidence that smallholder maize farmers had an unmet demand for locally relevant agricultural information and advice.

In 2015, Michael Kremer, Shawn Cole, and Daniel Björkegren realized the major potential of starting an organization that would take similar products and services around the developing world. To further develop this ambitious idea, they wanted to couple their vision with expertise in social enterprise development, so they invited Heiner Baumann, formerly of Barr Foundation, to come on board. With four co-founders and two committed donors, PAD was born.

PAD started its fledgling operations under a full-service fiscal sponsor, Global Development Incubator (GDI), in mid-2015 and was incorporated in Massachusetts in December 2015. GDI expertly provided PAD with the legal structure, financial acumen, and strategic operations advice to ensure PAD was on a path to success. By October 2016, PAD was ready to stand on its own and transitioned to a fully independent organization.

2016 was a busy and exciting year for PAD. We describe some major milestones to the right and elaborate on our programmatic work in the pages that follow.



A worker at a ginnery in Gujarat, India beside fully cleaned local cotton. *Photo by Heiner Baumann.*



A farmer in Western Kenya shelling dry maize. *Photo by Megan Sheahan.*

January

Translated research and explorations of 2015 into specific implementation plan.

February

Received major funding commitment from Unorthodox Philanthropy

April

Launched our “Krishi Tarang” service with 200 cotton farmers in India

July

Received 501c3 status. Hired Managing Director and India Country Director.

August

Launched pilot service with 1,900 maize farmers in Kenya.

October

Graduated from GDI and became independent organization.

November

Hosted first planning retreat with team members from India and Kenya.

December

India service operational for 25,000 farmers. Pilot season ended for 1,900 farmers in Kenya.

Growing a rigorously evaluated service in India

A study by members of our team found that the introduction of a low-cost, mobile phone-based agricultural extension system among 1,200 farmers in the state of Gujarat had positive effects on yields and efficient input use in cotton cultivation (Cole and Fernando 2016). They estimated that yields rose by 8.6% for cotton and 28% for cumin while profits for farmers increased by \$100/season, with a return of more than \$10 per dollar invested in the system.

Building on these successes, we—alongside our technology partner, Awaaz.de, and implementing and evaluation partner, J-PAL South Asia—rolled out our initial service with only 200 farmers in April. The service, called Krishi Tarang—which means “agriculture wave” or “vibe” in Gujarati and Hindi—grew to over 25,000 farmers by December.

Krishi Tarang provides farmers with free, customized information in two ways: via weekly voice messages sent to a farmer’s mobile phone and a direct response to any agricultural question that a farmer logs. Through a hotline-like feature, farmers can record a question in the system and receive a customized answer within 48 hours from an agricultural scientist in our call center in Ahmedabad. Weekly recommendations are generated based on farmer profile data, such as which crops they grow and whether they use irrigation, as well as weather conditions in the farmer’s specific region. We seek to make

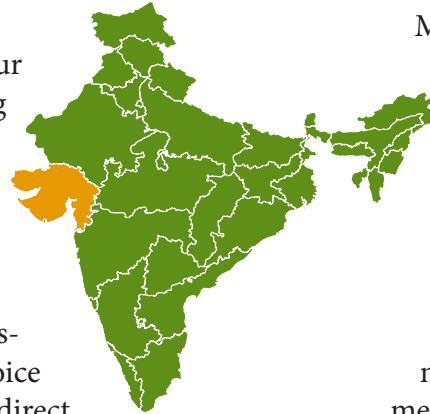
the content as relevant as possible by randomly calling 50 farmers each week to get their input on the most pressing issues in the field

We used several methods of acquiring new beneficiaries. The richest source has been the deep farmer networks of partners—Aga Khan Rural Support Programme (AKRSP) and Sajjata Sangh—which provided lists of over 16,000 farmer contacts that our team called to offer the service for free.

Moreover, PAD implemented a farmer referral feature through the mobile system, allowing the service to organically grow. Over the year, 6,245 subscribers referred over 15,000 peers.

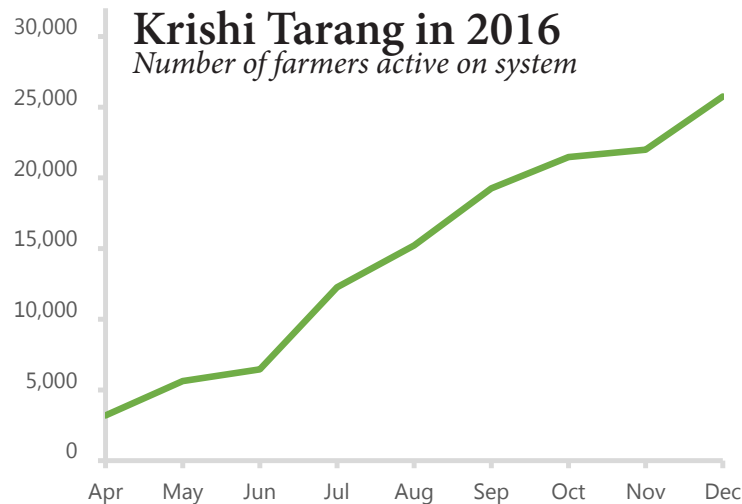
We also experimented with different types of marketing strategies, including through brochures, posters, seeking targeted referrals from high system users, agrodealer outreach, and newspapers. Marketing through agro-dealers and newspapers were found to be the most cost-effective methods of outreach. We plan to test other marketing strategies in 2017 and to scale them as appropriate.

PAD operationalized several other new features in the phone-based system over the year, including a subjective rating feature (allowing farmers to provide feedback on the usefulness of the information), an automated user survey (allowing us to collect farmer profile information easily), and a content forwarding option (allowing farmers to share information with peers).



As part of our constant evaluation and improvement, we piloted several approaches to training farmers on the use of the technology to assess their relative effectiveness and costs: one-on-one training, remote training via phones, group training, and training via community mobilizers (tech savvy and educated farmers recruited from the local population). We tested these training methods with over 4,000 farmers, by randomly assigning each farmer a type of training and analyzing their subsequent engagement with the Krishi Tarang system. We found that while in-person training was the most engaging, remote training had the greatest user engagement per dollar. We decided to scale-up remote training and attempted to mimic aspects of in-person training by offering new training types, such as training by post.

Another method of evaluation PAD has continually used to refine and improve the service is A/B testing. One example is testing which voice is most effective at delivering content. As part of this A/B test, 2,800 farmers were randomly assigned to receive weekly push calls in one of four voices: female professional, male professional, farmer, and agronomist. We found that farmers did not express a clear preference for voice type. In another example, we tested whether including a jingle in the beginning of the call increased duration of listening time. We found that the sub-set of farmers who listen to more than 30 seconds of a call are much more likely to listen to the entire call when there is no jingle at the start of the call. PAD uses small experiments like these to constantly upgrade the farmer user experience.



2016 in numbers

- 250,000+ push calls sent
- 11,500+ questions logged
- 43,091 unique calls
- 13,520 unique callers
- 7,530 repeat callers
- 82% average pick-up rate
- 62% average listening duration

In 2017, we plan to explore reliable sources of weather and price information to incorporate into our system. We are designing a randomized control trial around the delivery of soil fertility information, and aim to measure the impacts of providing customized fertilizer recommendations. We will also explore low-cost ways of generating customized soil fertility information by validating publicly available soil data. We also plan to test third party mobile applications, by tracking usage and determining their relevance for farmers.



A team member training a PAD farmer.
Photo by Tarun Pokiya.



A PAD farmer in his cotton field.
Photo by Heiner Baumann.



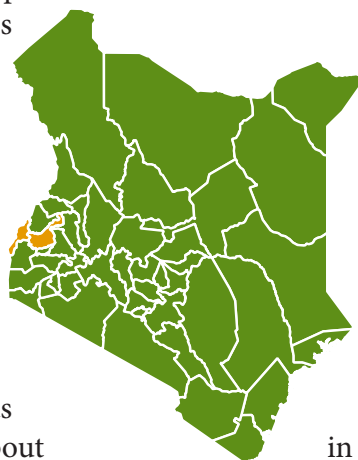
Call center team in Ahmedabad.
Photo by Heiner Baumann.

Piloting a service for evaluation in Kenya

Getting to impact at scale first requires substantial investment in product development, testing, and evaluation. In Kenya, we started from scratch, armed with initial ideas about what services smallholder farmers need in a geography entirely dissimilar from India.

Evidence from related work by our team members and others suggests that farmers have an unmet demand for local agricultural information and advice on input use (Fabregas et al. 2015) and that there is potential for using simple systems to successfully deliver extension services through mobile phones to farmers in Western Kenya (Casaburi et al. 2014).

Guided by this research and by the experiences from India, in 2016 we—alongside our technology partner, Echo Mobile, and implementation and evaluation partner, Innovations for Poverty Action—developed and piloted an SMS-based advisory service among 1,900 smallholder maize farmers in Western Kenya to gather evidence of demand and impact. This service was specifically tailored to dispensing information about how to increase yields using agricultural inputs appropriate to local soil conditions. In Kenya, as in many parts of Africa, smallholder crop yields have remained very low partly due to soil degradation: small land holdings are continuously cultivated without adequate nutrient replenishment, soil acidity is prevalent,



and the adoption of productivity-enhancing inputs is low.

For our pilot, the content of the system was developed by agricultural experts. A soil scientist guided the creation of customized fertilizer and agricultural lime application recommendations using previously collected soil data from the area. We consulted with the Kenya Agricultural and Livestock Research Organization (KALRO) throughout this process. Farmers were recruited through two existing databases, including one from Mumias Sugar Company, that contained farmer contact information. We called farmers to offer them access to the system and assessed their demand for it via several methods: willingness to pay, responses to a follow-up SMS poll, and referrals of other farmers in their villages. We used this information to randomly assign each farmer into one of three groups: a control group, or one of two treatment groups – one offering generic agricultural advice and the other offering locally-specific advice.

One measure of behavior change impact of interest in this experiment is the rate of redemption of electronic coupons distributed to farmers via SMS. Farmers were provided with coupons that offered discounts on various types of agricultural inputs and household items. We evaluated whether the farmers' choices aligned with the fertilizer and lime recommendations promoted through the SMS system. Our preliminary results show

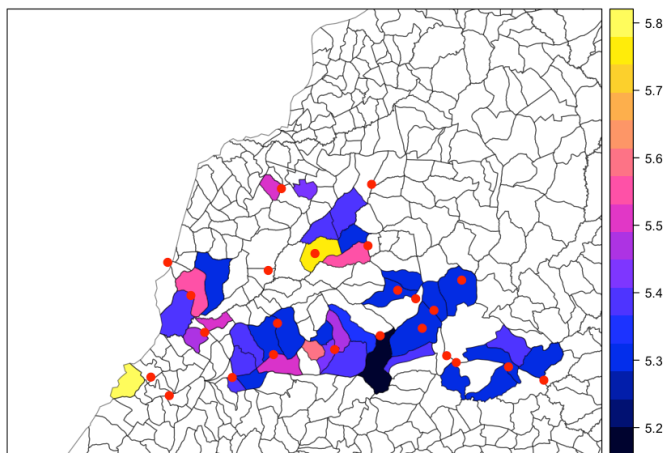


that farmers receiving locally-specific input recommendations were no more likely to purchase the inputs we promoted. This leads us to believe that this set of farmers received *too much* information, which ultimately resulted in them not recognizing the electronic coupon when it arrived. In early 2017, we will follow up with farmers again to assess impact more fully by collecting other outcome measures.

We also sought to add to the existing research base and to lend credibility to our advice by testing the fertilizer and lime recommendations on experimental farmer plots. On 59 farms across the region, we worked with farm owners to establish 9 test plots on their land, on which we applied randomly assigned combinations of different types and amounts of fertilizer and lime. Our field team visited these farmers regularly to ensure compliance with recommendations and sound management practices. At the end of the season we helped the farmers harvest and meticulously measure yields. We are now using this data to calculate rates of return and learn more about the conditions under which our recommendations are most beneficial.

To improve targeting in the next agricultural season, we conducted several farmer recruitment pilots to determine how to offer the system to farmers who would benefit the most. We sent letters through schools and churches, and stationed our field team in market centers and agrodealer shops to sign up farmers in person. Ultimately, we expect that the farmers most likely to use the advice currently offered by our system are those who already buy improved inputs (e.g., fertilizer and modern seed varieties), as they would benefit from more targeted advice on fertilizer types and amounts, and information on other complementary inputs. Therefore, we will use a network of agrodealers to recruit farmers in the next agricultural season.

In 2016 we also learned that farmers preferred a system that enabled two-way communication.



Map of soil pH levels by sublocation and market locations (red dots) across area of work in Western Kenya.
Map by Giulia Zane.

Drawing on this and other lessons learned in the pilot, in 2017 we aim to offer an upgraded service and a new approach, which will include an updated method of farmer recruitment, expanded content, and different message framing. We plan to add voiced-based features to the existing SMS platform, to allow farmers to call in and ask questions about the content of the SMS messages. We will also work with experts in behavioral science to craft messages that will be more appealing to farmers. We plan to rigorously evaluate this improved service during the main long rains season with a sample of around 6,000 maize farmers.



Farmer preparing test plot for planting.
Photo by Lillian Alexander.



Piloting messages with a focus group of farmers. Photo by Lillian Alexander.



Working with farmers to measure recommendations. Photo by Lillian Alexander.

PAD farmer profiles

PAD chose to focus the first several years of product testing and expansion in India and Kenya because these countries represented environments where the team has existing contacts and institutional knowledge, and because their different farmer populations would enable a more nuanced understanding of the impact of and demand for context-specific, mobile phone-based agricultural advisory services. Below, we describe the characteristics of the typical farmer working with PAD in each geography, and which motivate the content of the information provided to farmers through the PAD systems.



India

- Farming operations are small to medium scale (6 acres on average), and all farmers grow a major cash crop — cotton — alongside traditional Indian staple crops.
- Farmer profits are around \$650/season, with two main growing seasons.
- These farmers have high input costs for their cotton production (seeds, fertilizer, pesticide, and hired labor), plus operational and rental costs (irrigation, tractors). The PAD system in India encourages farmers to reduce their consumption of certain inputs to more optimal levels that will increase yields and revenue while reducing costs.



Kenya

- Farming operations are very small scale (1–2 acres), often subsistence level, where staple crops are key. All farmers we work with currently grow maize.
- Farmers are generally far poorer than PAD farmers in India. Household incomes are around \$225/year, and only 1/3 derive any income from maize sales, most keeping what they produce to meet home consumption needs.
- Over 70% of farmers are using fertilizer, but often suboptimal types and in limited quantities. The PAD system in Kenya encourages farmers to use locally-appropriate inputs that are affordable and should increase yields and incomes.

Indirect service model

In addition to direct services that we provide to farmers in India and Kenya, PAD also works through partners to indirectly support farmers through the evaluation and upgrade of existing services. In 2016, PAD fostered two important partnerships with organizations interested in providing locally specific agricultural advice through mobile phones: One Acre Fund (in Kenya) and IFFCO Kisan (in India). PAD will continue to work with both in 2017 to analyze existing data and conduct joint experiments on upgrades to existing services.

One Acre Fund

One Acre Fund (OAF), a non-profit organization working with over 400,000 farmers throughout East Africa, has a history of using experiments to improve its field operations. Our team has partnered with OAF to conduct rigorous analysis using data from several of these experimental trials to shed light on farmer behavior change challenges starting in 2017. The analysis includes data from agricultural advisory activities offering customized and locally specific recommendations to farmers, both in-person and via mobile phones. Originally OAF focused exclusively on in-person extension and only recently began exploring how to leverage ICT to communicate with farmers directly. This partnership is poised to add value to the operations of both OAF and PAD as well as the larger international development community, with the end goal of informing the creation of better targeted and more customized agricultural advisory messages to farmers. PAD is also partnering with OAF to share high quality soil data from the region.

IFFCO Kisan

IFFCO Kisan Sanchar Limited, a subsidiary of IFFCO (a fertilizer cooperative federation owned by over 35,000 cooperatives in India), runs a mobile phone advisory service in partnership with a Telco which now reaches more than 3.5 million farmers across 19 states and offers information customized by agro-climatic zone. To improve the effectiveness and relevance of its services, IFFCO Kisan measures various user engagement statistics and has undertaken a range of upgrade initiatives. In late 2016, IFFCO Kisan shared its data from two districts with PAD, through which we analyzed pick-up rates, listening duration, and churn. After presenting our preliminary results to IFFCO Kisan, we decided to work towards a pilot in Gujarat wherein PAD would use data analytics and new profiling techniques to improve the product and engagement with farmers by leveraging PAD's core competency, coupled with experiences from operating our own service in Gujarat. This partnership has the potential for expansion across India.



Our financials and funders

We estimate that developing and rigorously testing our services over the first three years will require approximately \$10 million in funding. Assuming we are able to demonstrate farmer acceptance, impact, and scalability, PAD will continue to explore several options for financial self-sufficiency at the country level.

To date, PAD received a total of \$3.39 million in unrestricted funds from philanthropic investors as well as grants for specific research endeavors. While earned income from monetizing our services will become an important part of PAD's revenue sources in the future, all services are currently provided free of charge to farmers. PAD has spent \$1.17 million by the end of 2016.

Our initial funders have been essential to our ability to operate and grow without major constraints. We are grateful for the support, encouragement, advice, and confidence of the following four important funders and partners.

Funders

- **Anonymous (2)**
- **J-PAL and CEGA's Agricultural Technology Adoption Initiative (ATAI)**
- **Unorthodox Philanthropy**



Cotton bolls opening at 18-20 weeks.
Photo by Heiner Baumann.



Maize at market in Western Kenya.
Photo by Megan Sheahan.

Our partners

Our partnerships are central to our ability to achieve our mission. With appreciation, we present the stellar cast of organizations that has supported and enabled PAD across various capacities in 2016.

India Partners

- **The Abdul Latif Jameel Poverty Action Lab - South Asia (J-PAL SA):** Our implementation and evaluation partner (www.povertyactionlab.org/south-asia).
- **Awaaz.de:** Our technology partner (www.awaaz.de).
- **Aga Khan Rural Support Programme (AKRSP):** A Gujarat-based NGO that has provided us with access to farmer contacts (www.akdn.org).
- **Sajjata Sangh:** A Gujarat-based NGO that has provided us with access to farmer contacts (www.sajjatasangh.org).

Kenya Partners

- **Innovations for Poverty Action (IPA):** Our implementing and evaluation partner (www.poverty-action.org).
- **Echo Mobile:** Our technology partner (www.echomobile.org).

Global Partners

- **Global Development Incubator:** Provided us with full service incubation and fiscal sponsorship in our inception months (www.globaldevincubator.org).
- **Insource Services:** Our Boston-based back office support, helping with human resources, finance, and information technology services (www.insourceservices.com).
- **Debevoise and Plimpton:** Our pro-bono lawyers who have helped with a range of legal services (www.debevoise.com).

Board

Shawn Cole, *President*
Heiner Baumann, *Secretary and Treasurer*
Daniel Björkegren, *Director*
Michael Kremer, *Director*

Kenya Team

Michael Kremer, *Program Lead*
Carolina Corral, *Country Director*
Carolyn Nekesa, *Associate Director*
Lillian Alexander, *Implementation Associate*
Raissa Fabregas, *Research Advisor*
Giulia Zane, *Research Advisor*
Violet Omenyo, *Lead Soil Scientist*
Robert On, *Advisor*

India Team

Shawn Cole, *Program Lead*
Madhur Jain, *Country Director*
Niriksha Shetty, *Research Associate*
Garima Sharma, *Research Associate*
Veethi Vyas, *Research Associate*
Nilesh Fernando, *Research Advisor*
Tarun Pokiya, *Lead Agronomist*
Ofir Reich, *Data Scientist*
Fatima Wagdy, *Intern*

Global Team

Heiner Baumann, *Managing Director*
Megan Sheahan, *Director of Operations*
Olga Rostapshova, *Development Advisor*

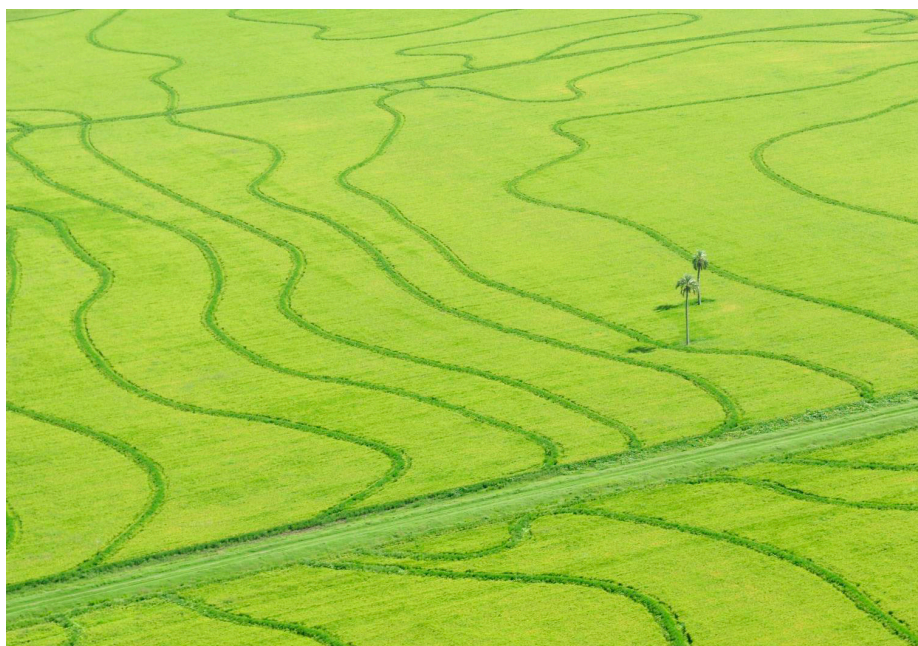
Other Supporters and Volunteers

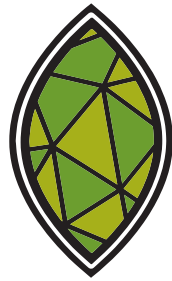
Getu Shikur, *Advisor on Ethiopia*
Javier Castellanos, *Advisor on Soil*
Sam Whittemore, *Advisor*
Elizabeth Spink, *Intern*

Our team

The dedicated PAD team that has made this work possible and enjoyable in 2016 spans affiliations and institutions. What we sometimes refer to loosely as “PAD staff” are often individuals employed directly by our partners — including J-PAL South Asia and IPA-Kenya — who dedicate their time to PAD activities, research, and implementation. Beyond affiliated staff members, PAD also benefits enormously from the contributions of volunteers who devote their time to co-directing research efforts and advising on strategy and content delivery. Moreover, the team members listed here are supported by a vast network of field officers and call center employees who do most of the farmer-facing work. They are the ones that nurture our beneficiaries and maintain the PAD brand name on a daily basis. We extend our deep appreciation to the countless hours that have been involved in taking PAD from the idea stage to a fully-independent organization with an ever-growing vision.

Guiding our staff deployment is the acknowledgment that resources are most effectively utilized as close to the farmers as possible. We strive to maintain lean US-based operations with the goal of serving and supporting our work in developing countries.





Precision
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