CHERUVU

Wege Prize: 2017 Final Phase

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Collaboration is the Key: Leveraging Transdisciplinary Makeup

Our solution to employ crop science and big data to improve yields of small farmers in India requires collaboration of knowledge across the traditional disciplines: Crop Science, Soil Chemistry, Computer Science Engineering, Geospatial Analysis, Survey Research, Public Policy, Decision Science, Local Agriculture Practices, and Community Outreach. Our transdisciplinary team comprises of graduate students and experienced mentors with domain expertise in above areas. By working together for the last 3 years, we have: established relationships across political and administrative functionaries in India, designed and conducted a survey of 1,100 small farmers to understand pain points, co-created survey to document agricultural practices of local farmers, developed a web application for data collection, hired field managers from local communities, established an ecosystem of partners for local outreach, collected 2,700 soil samples from farmers and conducted soil tests, designed an individualized farmer nutrient application guidance tool, tested and installed weather stations, created partnerships with local scientists and universities to collaborate on key research, conducted customer discovery interviews and developed a business model. Currently, we are validating our business model by selling our service to farmers and conducting crop experiments to further evaluate the efficacy of our service model.

Involvement of Mentors & Subject Matter Experts

The team has been collaborating with a broad spectrum of stakeholders and domain experts that encompass the knowledge areas required for the proposed product. By working with local soil scientist Dr. K. Srinivas in Telangana, India, we have realized that providing site-specific information can improve yields by up to 20%. After conducting interviews with small farmers in India, we have assessed that their willingness to pay for our service will make our enterprise economically viable. At the University of Michigan (U-M) Dr. Meha Jain, a professor of Agricultural Systems and Sustainability, is mentoring our team in designing crop experiments to validate our service. Dr. Joe Arvai, a professor of decision science and environmental risk, is guiding us to develop tools to nudge the behavior of small farmers to implement our nutrient advice. Dr. Peter Adriaens, a Cleantech expert at U-M, is helping the team explore value chain benefits from the data collected from small farmers. In addition, Peter M. Wege professor of Sustainable Systems and Industrial Ecology Dr. Gregory Keoleian has mentored us in evaluating the sustainability implications of our service for agricultural and nutrient circular economy in India.

Solution Summary

Cheruvu is a sustainable enterprise that employs crop science, machine learning, and crowd analytics to increase crop yields and improve the economic status of smallholding farmers, thereby reducing suicides among small-farmers. We mitigate risk for farmers in developing countries by increasing access to information for agricultural decisions. Our product is a site-specific precision agricultural tool that guides best nutrient practices while tracking farming operations such as tilling, sowing, weeding, fertilization, pesticide application, irrigation, and harvesting. Cheruvu plans to generate long-term value by integrating high-resolution data on farmer practices, soil nutrients, climate, and satellite imagery over multiple years.

~ 15,000
Suicides Per year

High Suicide Rate
From Failed Crops

97% of Farmers
Have Not Tested Soil

Inadequate Access
to Information

1/3 as Productive Per Acre
Compared to China

High Variation
Between Farmers

Scope of the Wicked Problem: Where, Who, How

India cultivated twelve million hectares for cotton production in 2015-2016, more than any other country. However, the average yield of cotton is around 200 kgs/acre which is one third of the average yield in China and about half the average yield of the United States. Every year, more than 15,000 farmers commit suicide and approximately a million farmers leave farming due to indebtedness and crop failure in India. Recently, the Supreme Court and the the central government of India have expressed the immediate need to design a comprehensive policy to prevent these social externalities in the agricultural sector. Changing climate, increased frequency of droughts, lack of access to irrigation resources, the popularity of cash-crops like cotton that are resource intensive, global market volatility, and uninformed decision making among farmers are all contributing factors to this epidemic.

Why Solve?

The epidemic of farm suicides and urban migration of rural farmers can lead to systemic collapse of small farms in the long run. Mitigating farm suicides and urban migration of farmers is imperative to retain the social and human circularity of Indian farming system. Given the enormous crop yield gaps in India (and other developing countries), there is huge potential to transform the socially extractive and linear agro-socio-economic model (in terms of farmers committing suicide and those leaving agriculture) to a sustainable and circular system. Developmental economics explains that yield gaps are caused by inability of farmers to access information and financial tools. While the government of India is addressing the financial barriers by promoting crop loans and insurance, improving access to farm-specific information has not been touched. We believe informing farm decisions can enhance agro-socio-economic circularity by increasing yields.

Previous Solutions & Shortcomings

A survey of 1100 farmers from 41 villages conducted by our team revealed that 97% of the farmers have never conducted a soil nutrient test for their farm. The Telangana government has recently begun to develop infrastructure required to provide soil testing support for farmers. However, recent experimental research by USAID did not find any impact of soil testing and fertilizer recommendations on actual fertilizer use of wheat farmers citing a lack of understanding, lack of confidence in the information's reliability, or the costs of the recommended fertilizers as the reasons. Specifically, our business model addresses the shortcomings of the governmental program by developing farmer friendly communication methods through co-creation and continuous feedback. We test soil, engage farmers and their communities, and build trust with locally influential farmers to engage a wider community. The result is action by the individual farmers who are participating in a comparative assessment of their yields, while providing and learning from local best practices. We plan on strengthening our delivery to farmers by providing weekly weather forecasts, continuous monitoring of practices, and employing crowd learning algorithms to predict best practices and solutions tailored to each farmer.

33-66%
Improved yields
w/ nutrient management

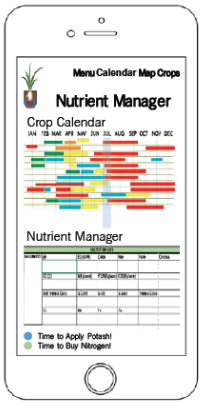
Research suggests
guidance works

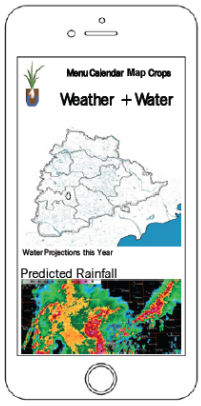
300
Data Points
per Farmer

Data Collected from
Agricultural Practices

3,600
Farmers
54 villages

Strong relationships
in region from pilot





Digital Platform –
Interactive Mapping, Calendars,
Nutrient Manager, Updated Weather

Detailed Summary

Our team is developing data-driven digital and analog frameworks to provide site-specific advice on nutrient application and climate for cotton farmers in India and other developing countries. By enabling small farmers to make smarter agricultural decisions, we plan to reduce input costs by optimizing the use of limited fertilizer nutrients - such as Nitrogen, Potassium, and Phosphorous - and increase crop yields. This will nurture the circularity of the agricultural ecosystem by improving profitability of small farmers, reducing farm suicides, creating rural employment opportunities, and mitigating urbanization.

Customer Validation

Currently, total addressable market includes 11 million cotton farmers in India, with a valuation of cotton value chain around 8 billion USD. As mentioned above, 97% of the farmers we interviewed in the region reported to have never conducted a soil test to inform their crop nutrient decisions. We also observed a crop productivity variation of up to 500% within and between villages, implying a huge potential to improve yields across villages. To further understand the need for site-specific nutrient and crop advice service, we conducted customer discovery interviews and willingness-to-pay experiments with more than 50 farmers from villages of two south Indian states - Maharashtra and Telangana. Farmers expressed interest by paying, on average, 40% more than our cost to provide the service. Now, we plan to further validate farmers' willingness-to-pay by marketing (peer yield comparison) and providing customized service (nutrient management advice) to more than 1500 farmers by June 2017.

Additionally, in regards to cotton market economics, given the total addressable market (TAM) of 11 million farmers and service addressable market (SAM) of 650,000 farmers, 30% yield improvement through our service for 650,000 farmers will result in an overall nationwide cotton productivity increase by less than 1%. We do not expect this to imbalance the existing supply demand dynamics of market for cotton in India.

Recently, between submission of Phase 2 of Wege Prize and today, our team designed the prototype of first paper based custom service and sold it to farmers in Goliwada village. This included designing two components for each farmer: first, the Peer Yield Comparison sheet (the nudge to act) and second, the soil test based Nutrient Recommendation sheet. 13 of the 14 farmers we reached out to expressed interest by paying 400 rupees, on average, for this service. This willingness to pay is 40% more than the cost we incurred to provide this service during this pilot. Currently we are improving the design and content of our prototype with feedback from farmers and field team. In addition, we also received soil test results of 2200 soil samples we collected from farmers across 54 villages. Our immediate goal is to deliver our service by June 2017 to all the farmers that plan to cultivate cotton during the 2017-18 crop season, and expand to more crops and services in the future.

Key Partners	Key Activities	Value Propositions	Customer Relationships	Customer Segments
Telangana Gov.	Develop Online Agriculture Platform	New data, new markets	Online Platform w/ personalized mapping	Farmers in Developing Countries
Farmers Organizations	Inform farmers on key agricultural decisions	Improved Agricultural Advice	Automated feedback, farmer socialnetwork	Telangana Gov.
Soil Testing Labs	**Key Resources**	Convenience and time for tests/ advice	**Channels**	CSR Groups
	Online Platform	Lower risk agriculture	Cheruvu.in	Agro-tech Businesses
	Testing Infrastructure	Optimize Fertilizer and Pesticide Inputs	Field Managers	Insurance Companies

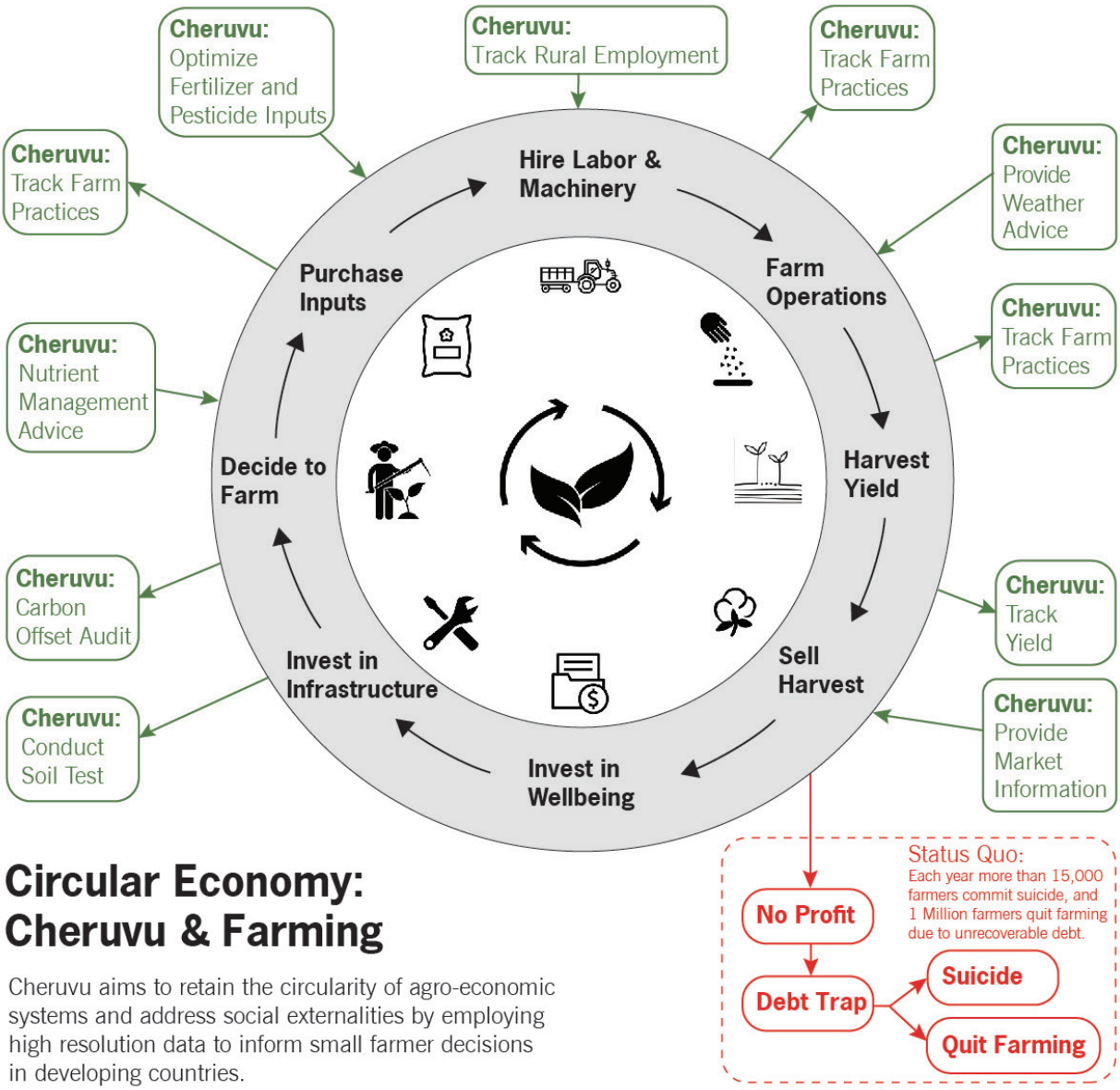
Cost Structure		Revenue Streams	
Soil Testing Operations	R&D For Agriculture side	Free Offering, Premium Subscription Program	Yield Predictions for Buyers + Banks
Field Managers		Ads for equipment	Anonymous Data for Indian Ag. Businesses

Incentive

Our key service includes two parts: first, providing comparative assessment of a subscribing farmer's previous year yield with peers in the village (the nudge to act); second, conducting soil nutrient assessment for the individual farmer's plot to provide a farmer friendly sheet on best nutrient practices - quantity, timing, and method of application - specific to the plot (site-specific actionable analytics). Here, given the wide variation in productivity (up to 500%) among farmers in most villages, the comparative assessment provides the nudge for the farmer to act by explicitly comparing his/her previous season's yield with other participating farmers in the village. The need to act created by this nudge is then fulfilled by the actionable analytics we provide upon payment for the ongoing crop season. Farmers' willingness to pay for this service corroborated their willingness to implement advice.

Creating Effective Flows

Our solution facilitates and leverages the flow of information between small farmers and our team to improve the quality of farming decisions in the region. Given the low penetration of smartphones in rural Indian villages, we are currently hiring and training local women field managers to deliver our service (soil nutrient and climate advice) and track farmer practices by calling farmers on a weekly basis. In effect, this service can help avoid the depletion of farmer stock by mitigating farm suicides and by reducing the flow of farmers from villages to cities.



Detailed Material Analysis

Over the first three years, we plan to employ crop science from peer reviewed research and local agricultural institutions to inform best nutrient practices for cotton farming in India. Subsequently, we will employ machine learning algorithms to learn from the data we collect to dynamically inform best farming practices, and move into other crop types.

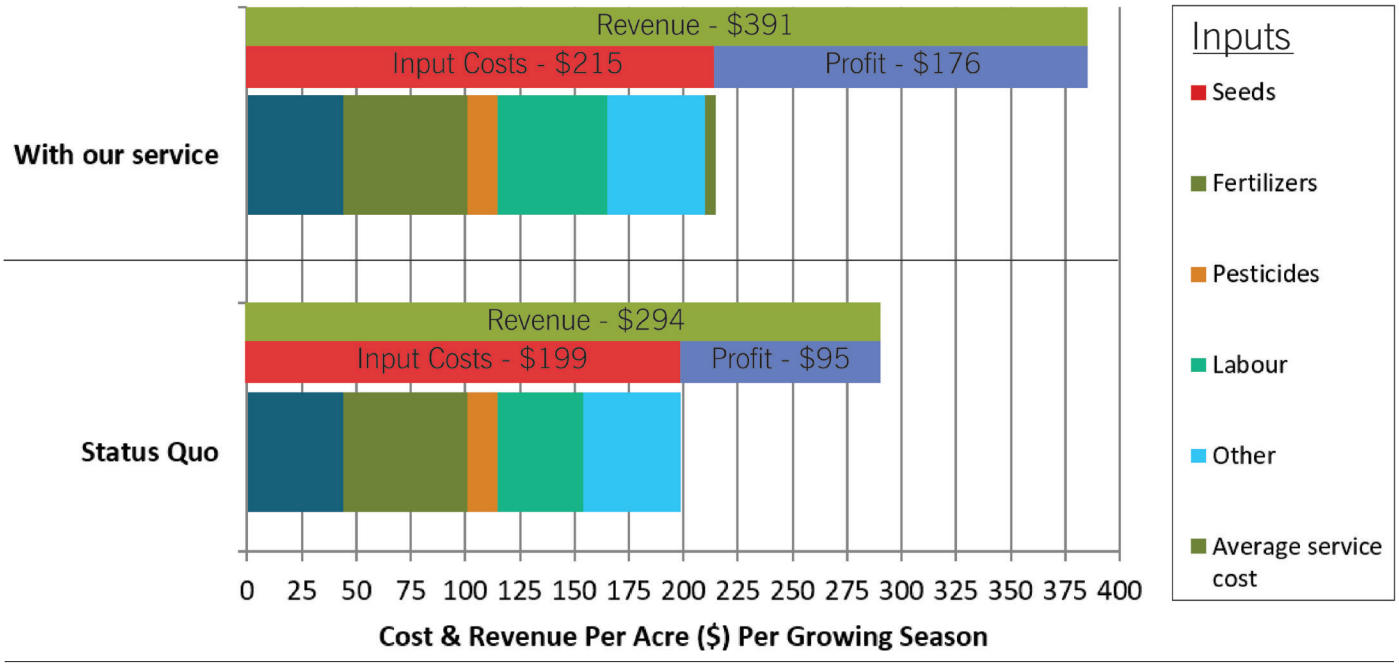
Why These Materials & Reuse of Materials

While the government of India is addressing financial barriers by promoting crop loans and insurance, improving access to farm-specific information has not been explored. We believe informing farm decisions by dynamically learning from the best farmers in the field can enhance agro-socio-economic circularity by increasing crop yields with a long term goal of reducing farmer sucides. New data collected each year will strengthen our ability to provide evolving best practices to improve sustainability of small farms.

Social Equity

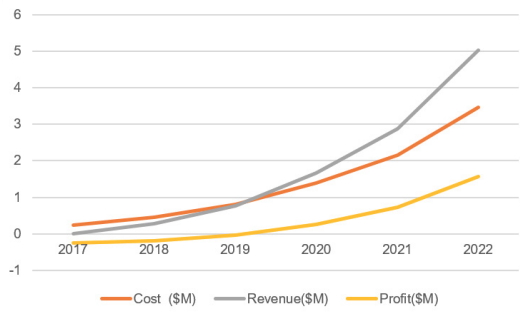
Small farmers (average landholding size: 3 acres) in India are the primary consumers of our service. To provide this service in the field (soil sampling, contour mapping, geo tagging, data collection, service delivery), we will empower and employ educated but previously unemployed women from the same farmer communities. This is a socially reinforcing model that benefits vulnerable populations in the service consumers and service delivery channels.

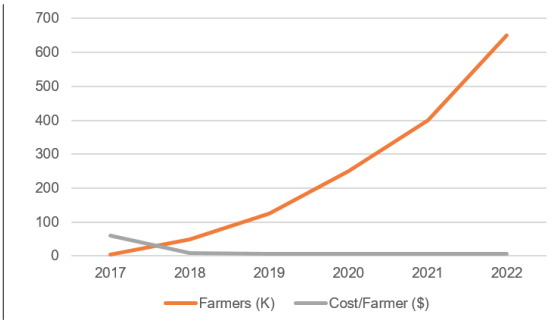
Farming Expenses Per Acre



Detailed Economic Analysis

According to Central Research Institute for Dryland Agriculture (CRIDA), 33 to 66% of yield gaps can be addressed by bridging non-monetary inputs, fertilizer management, and improved seed varieties. From our surveys and data collected so far in the region, 33 to 66% yield gap corresponds to 500kgs to 1000kgs of cotton per acre. As the Minimum Support Price (MSP) for cotton is at 3000 to 4000 rupees per 100 kgs, bridging even 15% (~200 kgs) of the existing yield gap through our service will have the potential to improve farmer yields by 6000 to 8000 rupees (80 to 110US$). From our recent willingness to pay experiments (between phase 2 submission and now), the operational cost of key service provision is around 250 rupees (~4US$) per farmer per season, which is about 5% of the additional benefit to farmers from using our service. For comparison, a farmer earns, on average, $450 from 3 acres of land by spending $450 to generate a revenue of $900. In our willingness to pay experiments, farmers demanded our service by paying, on average, 40% more than the cost of our service. Our business model is designed with three types of service (Basic, Advanced, Pro) to cater to the needs of all farmers.





TAM

11 million cotton farmers
$1.3B/ year
(India)

SAM

4.3 million farmers,
$0.52B/year
(40% participation from pilots)

SOM

650,000 farmers,
$78 M/ Year
(15% of SAM)

Basic (< 5 acres)	$2 / season	Soil Test + Comparative Assessment + Nutrient Advice
Advanced (> 5 acres)	$10 / season	Basic + Weekly Climate Forecast
Pro (open for all)	$5 / Acre	Advanced + Remote Sensing + Analytics on Demand

Barriers for Implementation

Lack of access to data and technology infrastructure including internet connectivity, low literacy rates, and technological awareness among farmers are challenges to our proposed solution. National statistics show that about 7% of rural India has access to internet and that less than 5% of the total rural population used a mobile device to access the Internet in 2014. Growing smart-phone use in rural India where access to mobile internet grew by 93% between 2014 and 2015 presents an opportunity to eventually employ mobile applications to improve access to informed decision-making for smallholding farmers in the region over the longer term. From our village surveys in 2015, less than 1% of surveyed farmers have access to internet and smartphones. However, from our most recent (March 2017) survey, more than 30% of farmers reported using a smartphone. We expect to see a continuation of this trend in smartphone usage by farmers as Reliance Jio, one of the biggest telecom service providers in India, started providing 4G internet service across Indian villages.

In the interim, we plan to provide service over paper based subscription model by printing hard copies of peer yield comparison and crop management advice. Our field managers are calling the farmers over the phone to collect farm practices data through the season. Concurrently we are designing a mobile application that will subsequently phase out the paper based service as farmers become familiar and comfortable with smartphones to access our service.

Issues Identified	Temporary Solution	Target Solution
Provision of timely advice requires fast soil testing; Government soil test labs do not have the capacity to test samples at the rate we would like to;	Relationship with government allows for priority & subsidized tests	Coordinate soil test services by private and government labs to test samples we collect or aggregate from farmers with due quality checks in place.
Identifying spatial trends to provide site-specific guidance requires accurate spatial data; Digitizing hardcopy maps and revenue parcel boundaries identified only 60% farmers;	Digitization of revenue maps and connection of data with revenue parcel	On-the-ground verification of field boundaries through field managers; Collection of farmer specific, high resolution, and cost-effective satellite imagery;
Instances of limited action from farmers after receiving recommendations in soil health card	Free or low cost service to promote initial adoption; Testing out a farmer-specific peer yield comparison nudge	Charge for services to ensure value addition; Document & demonstrate yield improvements through test plots and through farmers that implemented advice
Farmers are just beginning to use smartphones. Currently at 30% - recent trends show rapid penetration until saturation over next few years.	Deliver service through paper based model and data collection through phone calls and in-person visits	Design farmer-friendly mobile application to replace paper based service model as farmers get comfortable with smartphones

Resource List

1) “Area, production and productivity of cotton in India from 1947-48 onwards”. The Cotton Corporation of India Statistics. Web. Accessed on 30 June 2016. Accessed at http://cotcorp.gov.in/statistics.aspx.
2) “Cotton Yield by country”. Index mundi. Web. Accessed on 30 June 2015. Accessed at http://www.indexmundi.com/agriculture/?commodity=cotton&graph=yield.
3) Sainath, P. “Have India’s farm suicides really declined?”. BBC News. 14 July 2014. Accessed from http://www.bbc.com/news/world-asia-india-28205741.
4) Bruulsema, Tom, Jerry Lemunyon, and Bill Herz. “Know your fertilizer rights.” International Plant Nutrition Institute. Crops and Soils 42.2 (2009):
5) Tsosis, A. “Monsanto Buys Weather Big Data Company Climate Corporation For Around $1.1B”. Tech Crunch. 3 Oct 2013. Web. Accessed from https://techcrunch.com/2013/10/02/monsanto-acquires-weather-big-data-company-climate-corporation-for-930m/.
6) “Monsanto Acquires The Climate Corporation”. Monsanto Feature Stories. Web. Accessed on 30 June 2016. Accessed from http://www.monsanto.com/features/Pages/monsanto-acquires-the-climate-corporation.aspx.
7) Arora,K. “Only 9% of rural India has access to mobile internet: Report”. Times of India. Feb 3 2016. Web. Accessed on 29 June 2016. Accessed from http://timesofindia.indiatimes.com/tech/tech-news/Only-9-of-rural-India-has-access-to-mobile-internet-Report/articleshow/50840296.cms.
8) Global Climate Weather Data for SWAT. Web. Accessed from http://globalweather.tamu.edu/.
9) Telangana Agriculture Action Plan: 2015-16, Government of Telangana, Hyderabad, India
10) “Season and Crop Report 2013 - 2014”. Directorate of Economics & Statistics. Government of Telangana, Hyderabad, India. Web. Accessed on 29 June 2016/ Accessed from http://des-telengana.in/publications/scr2013-14.pdf.
11) Temperature and Precipitation Data. Indian Meteorological Department, Pune, India. Request at http://www.imdpune.gov.in/.
12) Over half of India’s workforce self-employed: NSSO. (2011, June 25). Retrieved June 30, 2016, from http://articles.economictimes.indiatimes.com/2011-06-25/news/29747818_1_rural-areas-casual-labourers-urban-areas
13) Neitsch, S. L., et al. “SWAT theoretical documentation version 2005.” Soil and Water Assessment Tool (2005).
14) Trevor Hastie, Robert Tibshirani, and Jerome Friedman. “Unsupervised learning.” The elements of statistical learning. Springer New York, 2009. 485-585.
15) Kevin P. Murphy. Machine learning: a probabilistic perspective. MIT press, 2012.
16) Dimitris Bertsimas, Angela King, and Rahul Mazumder. “Best subset selection via a modern optimization lens.” The Annals of Statistics 44.2 (2016): 813-852.
17) Aniket Deshmukh, Clayton Scott. “Kernel Approximation for Transfer Learning.” PhD Qualifier Report (2015).
18) Samuelson, William, and Richard Zeckhauser. “Status quo bias in decision making.” Journal of risk and uncertainty 1.1 (1988): 7-59.
19) C. S. Praharaj, K. K. B. and K. S. C. (1998). INTEGRATED NUTRIENT MANAGEMENT STRATEGIES FOR INCREASING COTTON PRODUCTIVITY, 158–170.
20) Kater Hake, K. C. and W. E. (1991). Cotton Nutrition - N, P and K. Cotton Physiology Today.
21) Kissel, D. (n.d.). Fertilizer Recommendations by Crops, Categorized.
22) “Area, production and productivity of cotton in India from 1947-48 onwards”. The Cotton Corporation of India Statistics. Web. Accessed on 30 June 2016. Accessed at http://cotcorp.gov.in/statistics.aspx.
23) Matuschke, I., & Qaim, M. (2009). The impact of social networks on hybrid seed adoption in India. Agricultural Economics, 40(5), 493-505.
24)KPR Vittal, TP Rajendran, G Ravindra Chary, GR Maruthi Sankar, T Srijaya, Y.S.Ramakrishna, JS Samra and Gurbachan Singh. Eds. (2004). Districtwise Promising Technologies for Rainfed Cotton based Production Systems in India. All India Co-ordinated Research Project for Dryland Agriculture, Central Research Institute for Dryland Agriculture, Indian Council of Agricultural Research
25)Agricultural Marketing Department, Government of Telangana. Web. Accessed on 4 July 2016. Accessed from <http://agrimarketing.telangana.gov.in/indexnew.js>
26)“CCI to procure cotton as prices below minimum support price in AP, Telangana & Maharashtra”. PTI. The Economic Times. 2 Dec 2014. Web. Accessed from <http://articles.economictimes.indiatimes.com/2014-12-02/news/56649178_1_domestic-cotton-prices-bales-cotton-corporation>
27)Dayashankar, K.M. “Record price for cotton at Jammikunta”. The Hindu. 23 June 2016. Web. Accessed from <http://www.thehindu.com/news/national/telangana/record-price-for-cotton-at-jammikunta/article8762541.ece>
28) Chandrashekar, B. “Mission Kakatiya already showing positive results”. The Hindu. 5 Jan 2016. Accessed on 29 June 2016. Accessed from http://www.thehindu.com/news/national/telangana/mission-kakatiya-already-showing-positive-results/article8066433.ece.

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