NATIONAL SECURITY

A VIF Publication

[Instructions for authors]

Decision Intelligence for the Indian Agriculture Sector

Roger Moser

Moser, Roger. "Decision Intelligence for the Indian Agriculture Sector". National Security, Vivekananda International Foundation Vol.II (2) (2019) ISSN 2581-9658 pp. 191– 204.

https://www.vifindia.org/sites/default/files/national-security-vol-2-issue-2-rmoser

Article

Decision Intelligence for the Indian Agriculture Sector

Roger Moser

Abstract

The Government of India has taken on a mission to support the growth of the farm sector in the country and has laid out a strategy to double farmers' income in the years to come. This requires a leapfrogging approach in a community where approximately 2/3 of the more than 190 million hectares cropped area in the country is held by marginal farmers with holdings below one hectare. Adopting modern technologies to deliver decision intelligence across the agriculture value chain is one of the means by which such growth can be realized. The adoption of satellite big data analytics represents an advanced technology solution which can resolve prominent and persistent bottlenecks in India's agricultural sector and support decision making among several stakeholders along the agriculture value chain. The article addresses several potential avenues where democratised data from satellites and other allied sensors can be tailored to support productivity increase, resource efficiency and improvement in terms of trade for farmers in the country. Leapfrogging farm income entails strategising the adoption of advanced technologies such as satellite big data analytics to deliver decision intelligence on every element along the agriculture value chain, which will subsequently enable the fruits of agronomy to trickle down to the farmer without any friction.

Agriculture is one of the key pillars of employment and sustenance in large parts of the Indian subcontinent. It is estimated that 60% of India's 1.25 billion population directly depends on agriculture for a means of living[1] and contributes around 18 percent to the country's gross domestic product (GDP)[2]. Some 80% of India's farms are

Prof. Dr. Roger Moser is an Assistant Professor with the University of St Gallen, Switzerland.He currently also serves as Adjunct & Visiting Faculty at the Indian Institute of Management in Udaipur & Bangalore. Dr Moser is also the Chairman of the Supervisory Board of the international consultancy, SatSURE

dependent on monsoon rains for crop production whose uncertainty affects over 100 million families.[3] Taking measures to reduce agrarian distress and bringing parity between income of farmers and those working in non-agricultural professions are central pieces to promote farmers' welfare and to catalyze the growth of this sector. Recognizing these demands within the agricultural sector of the country, Prime Minister Narendra Modi has put forth a vision to double farmers' income by 2022-2.[4]

Experts within the NITI Aayog (National Institution for Transforming India) have studied the sector and have indicated that the underlying growth output needs to be accelerated by 33 per cent to meet the goal. Thus, they have suggested the use of advanced technologies as one of the key strategies in the mission to double farmers' income.[5] In the present paper, we shall specifically explore how Decision Intelligence based on satellite big data analytics can help to address some of the immediate and imminent needs within the agricultural sector of India.

Satellite Big Data Analytics

Satellite remote sensing provides a basis for the assessment of crop health, yield estimates and forecasting of crop development. The holy grail for the proliferation of the usage of the satellite data has been the cost to acquire the data alongside its availability and coverage over areas of interest.[6] The ability to leverage satellite remote sensing data has been improved by leaps and bounds owing to the increased number of Earth Observation (EO) satellites and their capacity to provide almost daily and global coverage.[7] Today, satellite-derived data has several of the characteristics of big data including volume, velocity, veracity and variety of sensors alongside the slash in prices.[8] For example, the European Commission's Copernicus programme which uses the Sentinel satellites produces approximately 10 TB of EO data per day.[9] Several complimentary technologies such as cloud-based processing and software deployment, weather and allied sensor/geolocation data streamed through Application Programming Interfaces (APIs) have also come of age and allow to be fused with satellite big data to generate decision intelligence.[10] Social scientists have highlighted the use of big data analytics algorithms using satellite data, deployed on cloud to be able to generate meaningful insights for socio-economic applications.[11] Through this paper, we intend to identify some of the key areas within the Indian agriculture context which can leverage the benefits of satellite big data analytics to support the goal of doubling farmers' income.

Decision Intelligence for the Agricultural Sector

The fundamental value of decision intelligence in the agriculture context is its ability to simplify the complex decision-making challenges related to crops themselves. Figure 1 provides an example of how satellite big data and other allied sources of information can be ingested within the process of decision making. It is important to note that insights drawn on the basis of individual sources of data will always remain rudimentary when compared to insights drawn as a combination of multiple sources which can corroborate the ground truth more holistically.

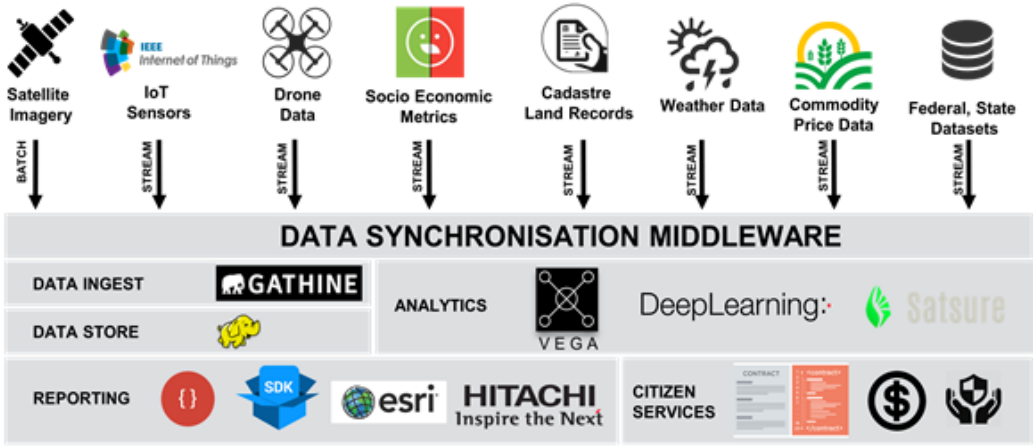

Figure 1 - Decision Intelligence from SatSure Ltd. for the Agricultural Sector

Decision Intelligence can support various aspects in the effective management of agricultural value chains such as deriving yield risk ratings, providing predictive crop modelling, provisioning water-use efficiency, supporting data-driven precision farming, enabling agri-financial services (e.g. farm credit access, farm insurance. commodity trading) and enabling evidence-backed agriculture policy making. We would like to discuss three main areas (Figure 2) within the Indian agrarian context to elaborate the utility of Decision Intelligence based on satellite big data analytics. Directly engaging with the farmers, provisioning support to stakeholders supporting small and marginal farmers such as agri-financial service providers and utilizing the insights to support sustainable development within the agri-supply chain can address various impending bottlenecks within the agriculture value chain. We shall discuss each of these identified areas individually to provide a perspective on plausible large-scale adoption of satellite big data analytics in India.

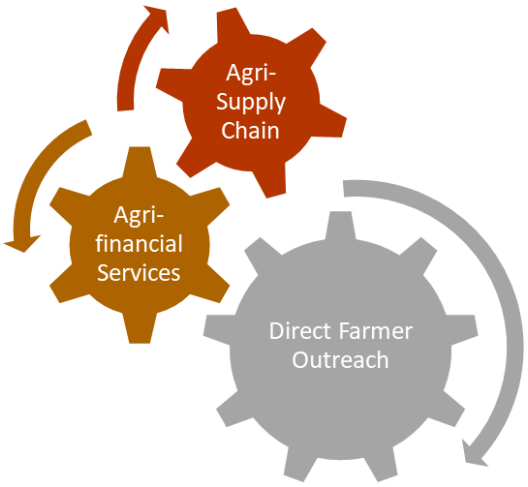

Figure 2 - Avenues for application of Decision Intelligence using satellite big data analytics

Direct Farmer Outreach

Direct outreach to the community of small and marginal farmers is a bottom-up approach. The potential of direct farmer outreach comes with the ability to tailor advisories to enhance agricultural productivity directly at the farmer's level and thereby enable farmers to increase their productivity and income. Positive externalities such as the penetration of mobile phones in rural India has created a platform on the basis of which grassroots level change can be inculcated. However, such bottom-up models are also challenging in execution. For example, previous efforts based on delivering market and weather information directly to farmers to support obtaining higher market prices for their agricultural output have been assessed to have limited success.[12] The service was found to have reasonable up-take by farmers in creating market awareness but failed in terms of farmers gaining in terms of reducing transaction costs or increasing revenues.

The use of Decision Intelligence based on satellite big data analytics within the context of direct farmer outreach advisory mainly comprises of comparative analyses of past years' data and latest data to provide pre-sowing advisory, end of crop season and post-harvest analytics. A notable independent effort in such a direction is the Agri-GIS service by the Centre for Spatial Analytics and Advanced GIS with support from TATA Trusts which aims to deploy satellite data-based farmer's advisory in 532 villages of Odisha covering about 20,000 farmers and almost 80,000 cadasters.[13] Tailored direct-outreach can also help integrate other satellite-derived insights including suitability of beneficiary land for various crops, assessment of water availability and provide the ability to integrate the results into local and regional policymaking. The policymakers in the Government of India can take note of such efforts and integrate such services into their

own efforts, which at the present moment seem to be restricted to farmers getting information only related to crop insurance and prices of agri-commodities in different mandis across the country.[14]

The near future may see several new generation technologies such as Artificial Intelligence (AI) being deployed on the insights that are derived from satellite big data and other alternate spatial data sources. Such pilots are being explored recently in India by corporations such as Microsoft collaborating with International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) to develop applications which sends sowing advisories to participating farmers on the optimal date to sow without the farmers needing to incur any capital expenditure for install any sensors in their fields.[15] More recently, Niti Aayog has also partnered with a technology firm to explore providing such real-time advice to farmers.[16] Given the diversity of both the land and the farmers themselves, sustainable direct farmer outreach may heavily depend on the maturity of connectivity to individual small and marginal famers in rural India. To this end, a Boston Consulting Group (BCG) study predicts that by 2020, about 315 million Indians living in rural areas will be connected to the Internet as compared to 120 million at present.[17] The adoption of direct engagement models may witness significantly greater traction owing to such developments. As an interim step, there is scope to study mixed models of delivery such insights that encompasses engagement at different layers (e.g gram panchayat vs direct farmer level) to help stakeholders make informed decisions on scaling up their outreach.

Agri-financial Services

Financial inclusion of small and marginal farmers through institutional agri-financial services is widely accepted as both a social responsibility and a business opportunity.[18] The Government of India has created several schemes such as the Kisan Credit Card (KCC) and the Pradhan Mantri Fasal Bima Yojana (PMFBY) to support small and marginal farmers with agri-financial services. There is no doubt that such schemes can catalyse the growth in the sector. However, such efforts need to be complemented with the greater participation by the commercial agri-financial services sector in the country to achieve the goal of doubling farmers' income. Therefore, financial institutions such as commercial banks and insurance companies are key to supporting growth of small and marginal farmers and help securing the timely access to agricultural inputs as well as crop risk coverage. According to recent reports by National Bank for Agriculture and Rural Development (NABARD), approximately 30% of agricultural households still borrow from only informal sources[19] and only 29% of the 120 million farmers in the

country have crop insurance cover at present.[20] The problem is two-sided where the need for greater awareness among farmers represents one side and the need to catalyse the role of agri-financial institutions the other.[21]

Some of the impediments in increasing the penetration of institutional credit to small and marginal farmers are identified to be lengthy processes for the sanction of loans, demand for collateral security, and the nature of loans being short-term.[22] The barriers to expansion of institutional lending is aggravated due to the relatively small size farming operations, the capacity to furnish collateral to the formal lenders, the lack of information on creditworthiness on the basis of historic performance and weather/ market related risks.[23] Research indicates that the persistence of informal credit in India is due to the proximity that informal lenders enjoy backed by the economies of scope[24], which in-turn enables them to use social collateral to replace the formal processes used in establishing creditworthiness.[25] Similar bottlenecks are also being witnessed in risk coverage via crop insurance. Crop insurance claim settlements in India have been suffering delays owing to the inertia in data collection, which is used as the basis for underwriting.[26] According to the a recent task force constituted by the Government of India[27], the process to settle crop indemnity claims has embraced timelines of 6 to 12 months. These are corroborated also by media reports of summer monsoon of 2016 which indicated that insurers have processed 83% of the claims until March 2017.[28] The lack of trust in the underlying data in the underwriting process[29] adds to the delay in indemnity calculations and payments. These in-turn affect the planning of subsequent crop cycles.[30] Researchers have identified some of the key challenges for stakeholders supporting the agriculture value chain in India through financial services to be the absence of agro-meteorological data[31], lack of digitized farm records[32], and lack of data on historical performance of farms[33]. These challenges are creating inertia and affecting the operations of both institutional credit and crop insurance providers.

Decision Intelligence driven by a combination of satellite big data analytics and allied complementary sensors have the potential to leapfrog the operational landscape of agri-financial services in India....

Decision Intelligence driven by a combination of satellite big data analytics and allied complementary sensors have the potential to leapfrog the operational landscape of agri-financial services in India by establishing previously unavailable information on individual farm-level agricultural productivity. From the vantage point of institutional lending, satellite-derived crop risk indices can increase transparency between the

stakeholders by provisioning creditworthiness using historical satellite imagery, facilitate digitization of borrower onboarding processes using geotagging and substantially cut costs in supervision of the underlying asset. Therefore, the adoption of satellite big data analytics can substantially reduce the transaction costs between the formal lending institutions and small and marginal farmers. Similarly, the use of legacy techniques such as Crop Cutting Experiments (CCEs) to settle crop indemnity claims are found to have loopholes in implementation which includes being prone to political intervention, treating the conduction of CCEs as paper formalities, lack of sufficient professionals to conduct CCEs as well as wrongful estimation of average crop losses due to insufficient CCEs.[34,35] Within the use of CCEs, satellite big data analytics alongside satellite positioning can improve the administration of crop insurance in India by improving the sampling design using yield proxy information. Moreover, estimation methods based on simulation models or empirical models on the basis of satellite big data analytics can help to generate scalable crop yield maps. Ultimately, such steps hold potential as alternate options to CCE processes for crop yield estimation.

The adoption of Decision Intelligence from satellite big data analytics can specifically target goals such as end hunger, achieve food security and improved nutrition and promote sustainable agriculture..

Sustainable Agri-Supply Chains

From a supply chain perspective, food security, economic development and environmental sustainability across agricultural landscapes are some of the main issues in maintaining the long-term sustainability of human and natural systems.[36] It is no surprise that agriculture emerges as one of the key areas of interest within international frameworks of the Sustainable Development Goals (SDGs) laid down by the United Nations General Assembly. For several years, researchers have indicated the need to integrate Information and Communication Technology (ICT) innovation in agri-food supply chains for safety and sustainability reasons.[37] The adoption of Decision Intelligence from satellite big data analytics can specifically target goals such as e*nd hunger, achieve food security and improved nutrition and promote sustainable agriculture*. Services based on EO data is recognized to provide the ability to monitor, measure, and report on progress in meeting *Target 2.c adopt measures to ensure the proper functioning of food commodity markets and their derivatives, and facilitate timely access to*

market information, including on food reserves, in order to help limit extreme food price volatility, which is one of the main targets within the SDG framework to bring in sustainability in agriculture supply chains.[38]

Historically, India's agriculture supply chain strategy has mostly focused on attaining food grain self-sufficiency and not necessarily on development of sustainability in agriculture.[39] There is scope to utilize satellite big data and other allied geospatial technologies to implement the transparency and accountability objectives of the National Food Security Act 2013.[40] Policymakers in India need to go a step further in considering the use of decision support systems to aid the optimization of natural resource usage subsequently leading to improved efficiency within the food–energy–water nexus.[41] Decision Intelligence based on satellite big data analytics can also contribute to addressing several adjacent issues to the crop production and distribution such as management of irrigation sources[42] and health of soil.[43]

Incubating Decision Intelligence derived from satellite big data analytics across the agriculture value chain can be done by instituting their utility as a part of new business models as well as the creation of ecosystem linkages between stakeholders to achieve positive agronomic, ethical and socioeconomic externalities that shall benefit small and marginal farmers. As an example, policymakers in India can derive inspiration from some of their peers in other governments who are implementing the use of satellite big data analytics for the automated assessment of crops as a part of their agricultural subsidy control.[44] Such measures can enhance the spatial resolution to move from a community or village level to individual level and strengthen supply chain governance by creating technology-aided fair accountability systems.

Conclusion

The adoption of advanced technologies such as satellite big data analytics at scale is still at its primacy in developing countries. India should take advantage of the convergence of open satellite data, machine learning & artificial intelligence, cloud computing, and the proliferation of mobile phones to explore data products which can help support increasing the productivity of its small and marginal farmers. Decision Intelligence based on satellite big data analytics has immense scope to promote growth in the Indian agriculture sector through various models such as direct farmer engagement and aiding operation improvements for stakeholders supporting farmers such as banks and insurers. As India transitions towards adopting policies and practices that centralise sustainability as a part of its agriculture strategy, insights from satellite big data analytics

can act as an independent source of truth and help policymakers base their decisions alongside other proofs. It is important to note that doubling farmers' income will depend on holistically addressing all agri-economic and agri-ecological issues and not just pushing the boundaries on low hanging fruits. Renowned figures in India's Green Revolution such as Prof. Swaminathan have rightly stated the need to marrying ecology with technology rather than using technology within pigeon holes.[45]

References

1. Srivastava, Pratap, Rishikesh Singh, Sachchidanand Tripathi, and Akhilesh Singh Raghubanshi. "An Urgent Need for Sustainable Thinking in Agriculture – An Indian Scenario." Ecological Indicators 67 (2016): 611-22. doi:10.1016/j.ecolind.2016.03.015.
2. Sunder, Sushruth. "India Economic Survey 2018: Farmers Gain as Agriculture Mechanisation Speeds Up, but More R&D needed." The Financial Express. January 29, 2018. Accessed January 25, 2019. https://www.financialexpress.com/budget/india-economic-survey-2018-for-farmers-agriculture-gdp-msp/1034266/.
3. Swami, Deepika, Prashant Dave, and Devanathan Parthasarathy. "Agricultural Susceptibility to Monsoon Variability: A District Level Analysis of Maharashtra, India." Science of The Total Environment 619-620 (2018): 559-77. doi:10.1016/j.scitotenv.2017.10.328.
4. PTI. "PM Has Set Target to Double Farmers' Income by 2022: Radhamohan Singh." The Economic Times. June 03, 2016. Accessed January 25, 2019. https://economictimes.indiatimes.com/news/economy/agriculture/pm-has-set-target-to-double-farmers-income-by-2022-radhamohan-singh/articleshow/52576009.cms.
5. Chand, Ramesh. "Doubling of Farmers Income Rationale, Strategy Prospects and Action Plan." NITI Aayog. March 2017. https://niti.gov.in/writereaddata/files/document_publication/DOUBLING FARMERS INCOME.pdf No. NITI Policy Paper No.1/2017
6. Ferencz, Cs., P. Bognár, J. Lichtenberger, D. Hamar, Gy. Tarcsai†, G. Timár, G. Molnár, Sz. Pásztor, P. Steinbach, B. Székely, O. E. Ferencz, and I. Ferencz-Árkos. "Crop Yield Estimation by Satellite Remote Sensing." *International Journal of Remote Sensing* 25, no. 20 (2004): 4113-149. doi:10.1080/01431160410001698870.

7. Houborg, Rasmus, and Matthew Mccabe. "High-Resolution NDVI from Planet's Constellation of Earth Observing Nano-Satellites: A New Data Source for Precision Agriculture." *Remote Sensing* 8, no. 9 (2016): 768. doi:10.3390/rs8090768.
8. Toth, Charles, and Grzegorz Jóźków. "Remote Sensing Platforms and Sensors: A Survey." ISPRS Journal of Photogrammetry and Remote Sensing 115 (2016): 22-36. doi:10.1016/j.isprsjprs.2015.10.004.
9. Kempeneers, P., and P. Soille. "Optimizing Sentinel-2 Image Selection in a Big Data Context." Big Earth Data 1, no. 1-2 (2017): 145-58. doi:10.1080/20964471.2017.1407489.
10. Nagendra, Narayan Prasad, and Tom Segert. "Challenges for NewSpace Commercial Earth Observation Small Satellites." *New Space* 5, no. 4 (2017): 238-43. doi:10.1089/space.2017.0014.
11. Donaldson, Dave, and Adam Storeygard. "The View from Above: Applications of Satellite Data in Economics." *Journal of Economic Perspectives* 30, no. 4 (2016): 171-98. doi:10.1257/jep.30.4.171. Down To Earth, 2017. Insurance companies have not paid 83% of farmers' claims.
12. Fafchamps, Marcel, and Bart Minten. "Impact of SMS-Based Agricultural Information on Indian Farmers." *The World Bank Economic Review* 26, no. 3 (2012): 383-414. doi:10.1093/wber/lhr056.
13. "Agri-GIS." Centre For Spatial Analytics and Advanced GIS. Accessed January 27, 2019. http://www.csag.res.in/activities/agri-gis/.
14. PTI. "Government Launches Two Mobile Apps for Farmers." The Economic Times. December 23, 2015. Accessed January 27, 2019. https://economictimes.indiatimes.com/news/economy/agriculture/government-launches-two-mobile-apps-for-farmers/articleshow/50299195.cms.
15. "Farmers in India Are Using AI to Increase Crop Yields." Microsoft News Center India. November 07, 2017. Accessed January 24, 2019. https://news.microsoft.com/en-in/features/ai-agriculture-icrisat-upl-india/.
16. Sen, Sunny. "Niti Aayog Pilots AI-based Initiatives in Agriculture, Education and Healthcare." FactorDaily. April 13, 2018. Accessed January 24, 2019. https://factordaily.com/niti-aayog-artificial-intelligence-in-agriculture-education-healthcare/.

17. Gooptu, D. "India's Farmers Turn to Mobile Apps." Enterprise Innovation. 2017. Accessed January 27, 2019. https://www.enterpriseinnovation.net/article/indias-farmers-turn-mobile-apps-1956219016.
18. Dev, S. Mahendra. "Financial Inclusion: Issues and Challenges." *Economic and Political Weekly* 41, no. 41 (October 14, 2006): 4310-313.
19. "First All India Rural Financial Inclusion Survey by NABARD Indicates 88% Rural Households Have Savings Account." NABARD. August 2018. Accessed January 27, 2019. https://www.nabard.org/PressReleases-article.aspx?id=25&cid=554&NID=43.
20. Sahu, Prasanta. "Crop Insurance: NITI Aayog Proposes Cashback Facility Under PMFBY." The Financial Express. October 17, 2018. Accessed January 24, 2019. https://www.financialexpress.com/industry/crop-insurance-niti-aayog-proposes-cashback-facility-under-pmfby/1353006/.
21. K., Mugunthan. "Crop Insurance Scheme: Awareness, Technology Key for Successful Implementation." The Economic Times. April 06, 2016. Accessed January 27, 2019. https://economictimes.indiatimes.com/news/economy/agriculture/crop-insurance-scheme-awareness-technology-key-for-successful-implementation/articleshow/50981150.cms.
22. Hussain, Siraj. "Despite Penetration of Institutional Credit, Farmers Continue to Rely on Moneylenders." The Wire. August 24, 2018. Accessed January 26, 2019. https://thewire.in/agriculture/despite-availability-of-institutional-credit-farmers-also-depend-on-informal-sources.
23. Shee, Apurba, and Calum G. Turvey. "Collateral-free Lending with Risk-contingent Credit for Agricultural Development: Indemnifying Loans against Pulse Crop Price Risk in India." Agricultural Economics 43, no. 5 (2012): 561-74. doi:10.1111/j.1574-0862.2012.00603.x.
24. Guirkinger, Catherine. "Understanding the Coexistence of Formal and Informal Credit Markets in Piura, Peru." *World Development* 36, no. 8 (2008): 1436-452. doi:10.1016/j.worlddev.2007.07.002.
25. Turvey, Calum G., Rong Kong, and Xuexi Huo. "Borrowing amongst Friends: The Economics of Informal Credit in Rural China." China Agricultural Economic Review 2, no. 2 (2010): 133-47. doi:10.1108/17561371011044261.

26. Nair, Reshmy. "Crop Insurance in India: Changes and Challenges." *Economic and Political Weekly* 45, no. 06 (February 10, 2010): 19-22.

27. Aggarwal, Chand, Bhutani, Kumar, Vijay, Goel, Rao, Poddar, Krishna Murthy, Ray, Murthy, Mishra, Choudhury, Choudhury, Joshi, Kumar, Sahoo, Kumar, Yadav, Singh, Kannan, Satish Raju, Sudhakar, Singh, Agarwal, Reddy, Shukla, Srivastava, Mehta, Gupta, Gopalakrishnan, Duggal, Vora, Kumar, and Lochan. "Report of the Task Force on Enhancing Technology Use in Agriculture Insurance." CMFRI Repository. December 2016. Accessed June 16, 2018. http://eprints.cmfri.org.in/12312/.

28. DTE. "Insurance Companies Have Not Paid 83% of Farmers' Claims." Down To Earth. June 05, 2017. Accessed January 2019. https://www.downtoearth.org.in/news/agriculture/insurance-companies-have-not-paid-83-of-farmers-crop-insurance-claims-s0e2017-58020.

29. Gulati, Ashok; Terway, Prerna; Hussain, Siraj (2018) : Crop insurance in India: Key issues and way forward, Working Paper, No. 352, Indian Council for Research on International Economic Relations (ICRIER), New Delhi

30. Mahul, Olivier, Niraj Verma, and Daniel J. Clarke. "Improving Farmers Access to Agricultural Insurance in India." Policy Research Working Papers, 2012. doi:10.1596/1813-9450-5987.

31. Hellin J, Hansen JW, Rose A, Braun M. 2017. Scaling up agricultural adaptation through insurance: Bringing together insurance, big data and agricultural innovation. Wageningen, Netherlands: CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS).

32. Ibid 29

33. Singh, G. "Crop Insurance in India." June 2010. Accessed January 2019. http://spandan-india.org/cms/data/Article/A2015413113838_20.pdf. W.P. No. 2010-06-01

34. Bhushan, Chandra, and Vineet Kumar. "Pradhan Mantri Fasal Bima Yojana - An Assessment." India Environment Portal. 2017. http://www.indiaenvironmentportal.org.in/files/file/Pradhan-Mantri-Fasal-Bima-Yojana-Report.pdf. Centre for Science and Environment, New Delhi

35. Cole, Shawn. "Fixing Market Failures or Fixing Elections? Agricultural Credit in India." American Economic Journal: Applied Economics 1, no. 1 (2009): 219-50. doi:10.1257/app.1.1.219.

36. Hertel, Thomas W. "The Challenges of Sustainably Feeding a Growing Planet." Food Security 7, no. 2 (2015): 185-98. doi:10.1007/s12571-015-0440-2.

37. Poppe, Krijn J., Sjaak Wolfert, Cor Verdouw, and Tim Verwaart. "Information and Communication Technology as a Driver for Change in Agri-food Chains." *EuroChoices* 12, no. 1 (2013): 60-65. doi:10.1111/1746-692x.12022.

38. Anderson, Katherine, Barbara Ryan, William Sonntag, Argyro Kavvada, and Lawrence Friedl. "Earth Observation in Service of the 2030 Agenda for Sustainable Development." Geo-spatial Information Science 20, no. 2 (2017): 77-96. doi:10.1080/10095020.2017.1333230.

39. Naik, Gopal, and D.n. Suresh. "Challenges of Creating Sustainable Agri-retail Supply Chains." IIMB Management Review 30, no. 3 (2018): 270-82. doi:10.1016/j.iimb.2018.04.001.

40. Tanksale, Ajinkya, and J.k. Jha. "Implementing National Food Security Act in India: Issues and Challenges." British Food Journal 117, no. 4 (2015): 1315-335. doi:10.1108/bfj-07-2014-0239.

41. Tian, Hanqin, Chaoqun Lu, Shufen Pan, Jia Yang, Ruiqing Miao, Wen Ren, Qiang Yu, Bojie Fu, Fei-Fei Jin, Yonglong Lu, Jerry Melillo, Zhiyun Ouyang, Cheryl Palm, and John Reilly. "Optimizing Resource Use Efficiencies in the Food–energy–water Nexus for Sustainable Agriculture: From Conceptual Model to Decision Support System." Current Opinion in Environmental Sustainability 33 (2018): 104-13. doi:10.1016/j.cosust.2018.04.003.

42. Zaveri, Esha, Danielle S. Grogan, Karen Fisher-Vanden, Steve Frolking, Richard B. Lammers, Douglas H. Wrenn, Alexander Prusevich, and Robert E. Nicholas. "Invisible Water, Visible Impact: Groundwater Use and Indian Agriculture under Climate Change." *Environmental Research Letters* 11, no. 8 (2016): 084005. doi:10.1088/1748-9326/11/8/084005.

43. Bhattacharyya, Ranjan, Birendra Ghosh, Prasanta Mishra, Biswapati Mandal, Cherukumalli Rao, Dibyendu Sarkar, Krishnendu Das, Kokkuvayil Anil, Manickam Lalitha, Kuntal Hati, and Alan Franzluebbers. "Soil Degradation in

India: Challenges and Potential Solutions." Sustainability 7, no. 4 (2015): 3528-570. doi:10.3390/su7043528.

44. Schmedtmann, Jonas, and Manuel Campagnolo. "Reliable Crop Identification with Satellite Imagery in the Context of Common Agriculture Policy Subsidy Control." Remote Sensing 7, no. 7 (2015): 9325-346. doi:10.3390/rs70709325.
45. "Dr M S Swaminathan Speaks on Use of Spatial Technologies in Agriculture." Geospatial World. March 20, 2018. Accessed February 03, 2019. https://www.geospatialworld.net/article/m-s-swaminathan-spatial-technologies-in-agriculture/. Dr M S Swaminathan speaks on use of spatial technologies in agriculture