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Review Article

The Economics of Applications of Artificial Intelligence and Machine Learning in Agriculture

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ABSTRACT

The global population is expected to reach more than nine billion by 2050, requiring a growing in agricultural production by 70 % in order to suit the demand. Only about 10 % of this growth may come from availability of unused lands, with the result that the rest of 90% will need to come from intensification of current production[3]. The agriculture sector needs a huge up-gradation in order to survive the changing conditions of Indian economy. The few techniques like artificial neural networks, Information Regression Analysis, Bayesian belief network. Markov chain model, k-means clustering and support vector machine are applied in the domain of agriculture.The major categories of applications of AI in agricultureare Agricultural Robotics, Crop and Soil Health Monitoring, Predictive Agricultural Analytics and Agri Supply Chain. Machine learning (ML) will have a dramatic impact on the field of economics within a short time frame. An abundance of easily accessible and high quality data has made it easier to use learning packages for R and Python to draw statistical inferences and make hypotheses. Artificial Intelligence can impact 70 million farmers in 2020, adding $9 billion to farmer incomes. AI comes as a great boon to the agricultural sector which is heavily dependent on climatic conditions which are often unpredictable.

Key words: *Artificial Intelligence, Applications, Accuracy, Learning, Technology.*

INTRODUCTION

India is an agrarian country and its economy largely based upon crop productivity. The economy improvement of agriculture towards India's GDP is strongly declining growth still agriculture is statistically the broadest economic background and plays a significant role in the various socio economic frame work of India. Agriculture is the mainstay of a developing economy like India. Majority of its population depends on agriculture for their income. With depleting resources, reducing land sizes and increase in input and labour costs, combined with the uncertainty of various factors like weather, market prices etc, agriculture in India has become a profession which is full of risks.

Indian agriculture is affected by various factors such as climate, due to topography, historical, geographical, biological, political, and institutional and socio economic factors.

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As time passed there are variations in natural factors and nature of technology so policies also changed. So agriculture production performance also changes in drastic path and large gaps in different geographic locations of the country. The advancements in technology must be worked upon across various disciplines and it has already shown dramatic improvements in many fields. However, agriculture has not benefitted much from such advancements. Smart farming is the need of the hour of the Indian economy. Smart farming[14] is important for tackling the challenges of agricultural production in terms of productivity, environmental impact, food security and sustainability[4].

Agriculture is facing new major challenges nowadays. The global population is expected to reach more than nine billion by 2050, requiring a growing in agricultural production by 70 % in order to suit the demand. Only about 10 % of this growth may come from availability of unused lands, with the result that the rest of 90% will need to come from intensification of current production[3]. Intensification in agriculture sets a high pressure on energy, mainly represented by fossil fuel, the supply of which is predicted to be insufficient to meet the demand over the next 15-20 years without radical measures and investments in all over the world[7,5].

Along with traditional methods of political and economic measures, Artificial Intelligence (A.I.) plays a growing role in the eyes of scientists and governments, in an attempt to face these challenges[15,2]. Despite the relatively short history of this field, complex platforms and devices for solving some specific problems have already been developed[12] and intensive research projects are ongoing. There are multiple ways to increase and improve the crop yield and the quality of the crops. To add to it, the present economic conditions and government policies of India are such that it necessitates the adoption of Precision farming or smart farming. Machine learning is an imminent field of computer science which can be applied to the farming sector quite effectively. It can facilitate the up-gradation of conventional farming techniques in the most cost-friendly approach. It will enable the farmers to maximize their crop yields and minimize the input costs as well as the losses due to reasons like uncertain rainfall, droughts etc. The agriculture sector needs a huge up-gradation in order to survive the changing conditions of Indian economy. A large subset of the volume of data collected through remote sensing involve images. Images constitute, in many cases, a complete picture of the agricultural environments and could address a variety of challenges[8,13].

There will be tremendous pressure to produce more food than we're producing today. We believe that precision agriculture will be one of the key technologies to enable that increased food production. We'll go from managing a field, or maybe today a section of a field, to managing every individual plant to maximize its yield. Precision agriculture is a critical strategy for farmers to unlock value and productivity in a sustainable way.

MEANING OF ARTIFICIAL INTELLIGENCE

Artificial intelligence ("AI"), a term first coined in 1956, is a branch of computer science that aims to create intelligent machines that work and react like humans. AI is technology that appears to emulate human performance by learning, coming to its own conclusions, understanding complex content, engaging in dialog with people, enhancing human cognitive performance, or replacing humans in executing both routine and non routine tasks.

AI is the simulation of human intelligence processes by machines, especially computers systems. These processes include learning (the acquisition of information and rules for using the information), reasoning (using the rules to reach approximate or definite conclusions) and self correction. Particular applications of AI include expert systems, speech recognition and machine vision.

MEANING OF MACHINE LEARNING

Machine learning (ML) is a category of algorithm that allows software applications to

become more accurate in predicting outcomes without being explicitly programmed. The basic premise of machine learning is to build algorithms that can receive input data and use statistical analysis to predict an output while updating outputs as new data becomes available. Machine learning focuses on the development of computer programs that can access data and use it learn for themselves.

The process of learning begins with observations of data, such as examples, direct experience or instruction, in order to look for patterns in data and make better decisions in the future based on the examples that we provide. The primary aim is to allow the computers learn automatically without human intervention or assistance and adjust actions accordingly.

Difference between AI and Machine Learning

AI	**Machine Learning**
Is to train the computers so that computers can do things which at present human can do better	Is a current application of AI based around the idea that we should really just be able to give machines access to data and let them learn for themselves.
AI involves machines that can perform tasks that are characteristic of human intelligence	ML is simply a way of achieving AI
The goal is to simulate natural intelligence to solve complex problem	The goal is to learn from data on certain task to maximize the performance of machine on this task
It leads to develop a system to mimic human to respond behave in a circumstances.	It involves in creating self learning algorithms

All machine learning is AI, but not all AI is machine learning.

AI and ML techniques

The few techniques like artificial neural networks, Information Fuzzy Network, Decision Tree, Regression Analysis, Bayesian belief network, Time series analysis, Markov chain model, k-means clustering, k nearest neighbor, and support vector machine are applied in the domain of agriculture.

The major categories of applications of AI in global agriculture

I. Agricultural Robotics

a) Blue River Technology – Weed Control

The ability to control weeds is a top priority for farmers and an ongoing challenge as herbicide resistance becomes more commonplace. Companies are using automation and robotics to help farmers find more efficient ways to protect their crops from weeds. Blue River Technology has developed a robot called *See & Spray* which reportedly leverages computer vision to monitor and precisely spray weeds on plants. Precision spraying can help prevent herbicide resistance.

According to its website, the company claims that its precision technology eliminates 80 per cent of the volume of chemicals normally sprayed on crops and can reduce herbicide expenditures by 90 per cent.

b) Harvest CROO Robotics – Crop Harvesting

Automation is also emerging in an effort to help address challenges in the labor force. The industry is projected to experience a 6 per cent decline in agricultural workers from 2014 to 2024.

Harvest CROO Robotics has developed a robot to help strawberry farmers pick and pack their crops. Harvest CROO Robotics claims that its robot can harvest 8 acres in a single day and replace 30 human labourers

II. Crop and Soil Health Monitoring.

a) PEAT – Machine Vision for Diagnosing Pests / Soil Defects

Deforestation and degradation of soil quality remain significant threats to food security and have a negative impact on the economy. Domestically, the USDA has estimated that the annual cost of soil erosion is approximately $44 billion dollars.

Berlin-based agricultural tech startup PEAT has developed a deep learning application called Plantix that reportedly identifies potential defects and nutrient deficiencies in soil. Analysis is conducted by software algorithms which correlate particular foliage patterns with certain soil defects, plant pests and diseases.

The image recognition app identifies possible defects through images captured by the user's smartphone camera. Users are then provided with soil restoration techniques, tips and other possible solutions. The company claims that its software can rapidly achieve pattern detection with an estimated accuracy of up to 95 percent. Available in most of the local language of India.

b) Trace Genomics – Machine Learning for Diagnosing Soil Defects

Similar to the Plantix app, California-based Trace Genomics, provides soil analysis services to farmers. Lead investor Illumina helped develop the system which uses machine learning to provide clients with a sense of their soil's strengths and weaknesses. The emphasis is on preventing defective crops and optimizing the potential for healthy crop production.

According to the company's website, after submitting a sample of their soil to Trace Genomics, users reportedly receive an in-depth summary of their soils contents. Services are provided in packages which include a pathogen screening focused on bacteria and fungi as well as a comprehensive microbial evaluation. As of February 2017, the company has raised $8 million in total equity funding from six firms including the Illumina Accelerator. Product packages begin at $199 for the Pathogen Screen. Favorable quotes from two farms are featured on the Trace Genomics website.

c) Sky Squirrel Technologies Inc. – Drones and Computer Vision for Crop Analysis

According to a report by the MIT Technology Review, drones in agriculture are used for soil and field analysis, planting, crop spraying, crop monitoring, irrigation, and health assessment.

The market for drones in agriculture is projected to reach $480 million by 2027. Today, companies are leveraging AI and aerial technology to monitor crop health.

Sky Squirrel Technologies Inc. is one of the companies bringing drone technology to vineyards. The company aims to help users improve their crop yield and to reduce costs. Users pre-program the drone's route and once deployed the device will leverage computer vision to record images which will be used for analysis. Once the drone completes its route, users can transfer a USB drive from the drone to a computer and upload the captured data to a cloud drive. Sky Squirrel uses algorithms to integrate and analyze the captured images and data to provide a detailed report on the health of the vineyard, specifically the condition of grapevine leaves.

The company claims that its technology can scan 50 acres in 24 minutes and provides data analysis with 95 percent accuracy. 10 percent increase in the yield.

III. Predictive Agricultural Analytics

a) A Where – Satellites for Weather Prediction and Crop Sustainability

a Where, a Colorado based company uses machine learning algorithms in connection with satellites to predict weather, analyze crop sustainability and evaluate farms for the presence of diseases and pests.

For example, daily weather predictions are customized based on the needs of each client and range from hyper local to global. Types of clients mentioned on the company's website include farmers, crop consultants and researchers. The company claims to specialize in providing a high quality of data that is continuously updated at a rapid rate.

The company also claims that it provides its users with access to over a billion points of agronomic data on a daily basis. Data sources include temperature, precipitation, wind speed, and solar radiation, "along with comparisons to historic values for anywhere on the agricultural earth".

A Where delivers agricultural intelligence to its clients, 7 billion data points across the planet, reaches the 580 million farmers.

b) Farm Shots – Satellites for Monitoring Crop Health and Sustainability

Based in Raleigh, North Carolina, Farm Shots is another start up focused on analyzing agricultural data derived from images captured by satellites and drones. Specifically, the company aims to "detect diseases, pests, and poor plant nutrition on farms".

For example, the company claims that its software can inform users exactly where fertilizer is needed and can reduce the amount of fertilizer used by nearly 40 per cent. The software is marketed for use across mobile devices. Farm Shots comes with a responsive design that is simple and optimized for use on all tablets, laptops, and phones. When you first sign up with an account, you'll have a test farm to play with.

Artificial Intelligence in Indian Agriculture

Agriculture plays a vital role in India's economy. According to the Department of Industrial Policy and Promotion (DIPP), the Indian agricultural services and agricultural machinery sectors have cumulatively attracted Foreign Direct Investment (FDI) equity inflow of about $2.45 billion and the food processing sector has attracted around $7.81 billion during April 2000 to June 2017. With an aim to boost innovation and entrepreneurship in agriculture, the government of India is introducing a new AGRI-UDAAN programme to mentor start ups and enable them to connect with potential investors.

On the back of increased FDI and conducive government initiatives, the agriculture sector is increasingly looking at ways to leverage technology for better crop yield. Many technology companies and start ups have emerged in the past few years with targeted agri-based solutions that benefit the farmers.

The most popular applications of AI in Indian agriculture appear to fall into three major categories:

- **Crop and Soil Monitoring** – Companies are leveraging sensors and various IoT-based technologies to monitor crop and soil health.
- **Predictive Agricultural Analytics** – Various AI and machine learning tools are being used to predict the optimal time to sow seeds, get alerts on risks from pest attacks, and more.
- **Supply Chain Efficiencies**– Companies are using real-time data analytics on data-streams coming from multiple sources to build an efficient and smart supply chain.

Details of each category of AI applications in the agricultural industry, along with re presentative companies and use cases.

I. Crop and Soil Monitoring:

These techniques will enhance the productivity of fields along with a reduction in the input efforts of the farmers.Companies involved in this fieldAre

a) Crop In-Using AI to Maximize per-Acre Value. CropIn is a Bengaluru-based start up which claims to be an intuitive, intelligent, and self-evolving system that delivers future-ready farming solutions to the agricultural sector.

With CropIn's 'smart farm' solution, all the plots were geo-tagged to find the actual plot area. The solution helped in remote sensing and weather advisory, scheduling and monitoring farm activities for complete traceability, educating farmers on adoption of right package of practices and inputs, monitoring crop health and harvest estimation, and alerts on pest, diseases etc.

Essentially, Crop In uses technologies such as AI to help clients analyze and interpret data to derive real-time actionable insights on standing crop and projects spanning geographies. Its agri-business intelligence solution called Smart Risk "leverages agri-alternate data and provides risk mitigation and forecasting for effective credit risk assessment and loan recovery assistance.

- Helps 8000+ marginal farmers in India
- Functioning -17countries
- Benefitted 1.6 million farmers.
- 265 crops and 3500+ crop varieties
- 175 clients

b) Intello Labs – Using Deep Learning for Image Analysis

Bengaluru-based Intello Labs was started by IIT-Bombay alumnus Milan Sharma in May 2016. The company claims to provides advanced image recognition technology that can recognize objects, faces, flora fauna and tag them in any image.

The company claim to use deep learning algorithms on which a new generation of intelligent applications are being built for applications including agriculture, e Commerce, advertising, manufacturing, and curation.

Small farmers around the world follow traditional farming practices due to lack of access to scientific understanding of crop lifecycle, pests, quality metrics and the latest micro-fertilizers. "Our Image based solutions provide insights on the crops' health during the growing season and its final harvested quality by click of photograph," the company states on its website.

Intello Labs claims to provide:

- **Agricultural Product Grading:** Automated quality analysis of images of food products is an accurate and reliable method for grading fresh products (fruits, grains, vegetables, cotton etc.) characterized by colour, size and shape. Their solution reads the image that a farmer has taken on his phone and determines the product quality in real time, without any manual intervention.
- **Alerts on Crop Infestation:** Farmers can click an image of their crop and use their solution to understand the pests, diseases, and foreign plants (weeds) growing in their farms. The solution uses deep learning and image processing models to identify any crop diseases or pest infestation in the crops. Along with the parameters, it gives recommendations on how that disease can be cured and prevented from increasing further.
- Reduces QTT(Quality Testing Time)15 min to 2min with 95% accuracy
- 10000 farmers in rajastan getting benefit (wheat and grain analysis)

II. Predictive Agricultural Analytics

Microsoft India – AI-based Sowing App

Determining the right time to sow crops is often one of the biggest challenges for Indian farmers where drought and excess rainfall can be equally serious challenges. Microsoft in collaboration with ICRISAT (International Crops Research Institute for the Semi-Arid Tropics), developed an AI Sowing App that uses machine learning and business intelligence from the Microsoft Cortana Intelligence Suite.

The app sends sowing advisories to participating farmers on the optimal date to sow. "The best part – the farmers don't need to install any sensors in their fields or incur any capital expenditure. All they need is a feature phone capable of receiving text messages," a Microsoft India report stated.

To calculate the crop-sowing period, historic climate data (spanning over 30 years from 1986 to 2015) for the specific area in Andhra Pradesh was analyzed using AI. To determine the optimal sowing period, the Moisture Adequacy Index (MAI) was calculated. MAI is the standardized measure used for assessing the degree of adequacy of rainfall and soil moisture to meet the potential water requirement of crops.

Microsoft has also partnered with United Phosphorous (UPL), India's largest producer of agrochemicals, to create the Pest Risk Prediction App that again leverages AI and machine learning to indicate in advance the risk of pest attack.

Today, these farmers across the Indian states of Andhra Pradesh and Karnataka wait to get a text message before sowing the seeds. As per the report cited above, in a few dozen villages in Telangana, Maharashtra, and Madhya Pradesh, farmers receive automated voice calls alerting them whether their crops are at risk of a pest attack based on weather conditions and stage of the crop.

The pilot project uses an AI sowing app to recommend sowing date, land preparation, soil test-based fertilization, farm yard manure application, seed treatment, optimum sowing depth and more to farmers which has resulted in 30 per cent increase in average crop yield per hectare.

Technology can also be used to identify optimal sowing period, historic

climate data, real time Moisture Adequacy Data (MAI) from daily rainfall and soil moisture to build predictability and provide inputs to farmers on ideal sowing time.

To identify potential pest attacks, Microsoft in collaboration with United Phosphorus Limited is building a Pest Risk Prediction API that leverages AI and machine learning to indicate in advance, the risk of pest attack. Based on the weather condition and crop growth stage, pest attacks are predicted as High, Medium or Low.

III. Agri Supply Chain

Gobasco — The Intelligent Agri Supply Chain

Based in the North Indian state of Uttar Pradesh, Gobasco has the advantage of a high-tech team. Gobasco claims to employ real-time data analytics on data-streams coming from multiple sources across the country aided with AI-optimized automated pipelines to dramatically increase the efficiency of the current agri supply chain. Through our carefully engineered tech-driven pipeline, designed for the Indian agri supply-chain, we operate at a higher profit margin than the traditional companies," the company stated in its website.

Gobasco uses AI and related technologies in the various stages of the agri supply chain to ensure it is efficient and fast. Some of them are listed below:

- **Transition Discovery:** Real-time data analysis on multiple data-streams along with crowd-sourced data from producer/buyer marketplaces and transporters feeds their automatic transaction discovery algorithm to obtain high-margin transactions.
- **Quality Maintenance:** Computer vision and AI-based automatic grading and sorting is done for vegetables and fruits for creating an international agri-commodity standard for reliable trading across country boundaries.
- **Credit Risk Management:** Crowd-sourced data, algorithms and analytics overcome the credit default problem, the most challenging problem of current supply-chain, to ensure a very low risk operation.
- **Agri-Mapping:** Deep-learning based satellite image analysis and crowd-sourced information fusion obtains a real-time agri map of commodities at a resolution of 1 sq-km.

MACHINE LEARNINGAND ECONOMICS

Machine learning (ML) will have a dramatic impact on the field of economics within a short time frame. Indeed, the impact of ML on economics is already well underway, and so it is perhaps not too difficult to predict some of the aspects[1]. Economists are generally more interested in the ramifications of certain existing policies or those proposed by our government officials, as opposed to building a model with the sole purpose of predicting a price or quantity such as those used in quantitative trading strategies. Machine learning will not only help an economist figure out the relationship between the user and external factors but also will use that data to predict on how much that same house is worth and what should be expected from potential buyers. Machine learning is impacting economics right now. There have already been a number of successful applications of prediction methodology to policy problems. Kleinberg *et al*.[6] have argued that there is a set of problems where off-the-shelf ML methods for prediction are the key part of important policy and decision problems. An abundance of easily accessible and high quality data has made it easier to use learning packages for R and Python to draw statistical inferences and make hypotheses. Another feature of machine learning is it allows economists to analyze language as data. Algorithms can be used to identify news articles too. It can gauge if the sentiment of the text is negative or positive. Economists are generally very interested in causality. And we should be! But lots of policy problems have a prediction component to them as well:

Causal question: how do consumers get into financial distress?

Predictive question: which consumers will become financially distressed?

A good starting point here is that machine learning is focused on maximising predictive power. Of course, standard econometric models can also produce decent forecasts at times, but they are really better suited to understanding causal relationships between different aspects of the economy (e.g. if I adjust a key tax rate, what does it do to growth and employment across the economy?). However, when it comes to prediction, standard econometric models tend to "over-fit" samples and sometimes generalise poorly to new, unseen data. While econometric models are best kept relatively simple and easy to interpret, machine learning methods are capable of handling huge amounts of data, often without sacrificing interpretation. More broadly, the ability to use predictive models to measure economic outcomes at high granularity and fidelity will change the types of questions we can ask and answer. For example, imagery from satellites or Google's street view can be used in combination with survey data to train models that can be used to produce estimates of economic outcomes at the level of the individual home, either within the U.S. or in developing countries where administrative data quality can be problematic[9,10]. Finally, the combination of ML and newly available datasets will change economics in fairly fundamental ways, ranging from new questions, to new approaches to collaboration (larger teams and interdisciplinary interaction), to a change in how involved economists are in the engineering and implementation of policies[1].

CHALLENGES IN ADOPTION OF AI IN AGRICULTURE

Artificial intelligence capable of dealing with the complexities and uncertainties of agricultural production is still an emerging technology. Further, the technology faces a number of regulatory and ethical challenges, as the possibilities for the use of artificial intelligence expand at a pace greater than the general public's capacity to understand the opportunities.

Availability of data

Creating an artificial intelligence system that can autonomously operate an entire farm is a goal of developers of this emerging technology. One challenge is the variety of data used in supporting an artificial intelligence approach to agriculture, including different research areas (agronomy, climate, economics) that need to be analysed, and the different objectives, formats, vocabularies and standards of each discipline. In addition, uncertainty in agriculture and the high number of variables that must be considered will require enormous amounts of high-quality and real-time data. Add to this the sheer volume of plants and animals on any one farm that will need monitoring, and the scale of the challenge becomes apparent.

Quality of data

A critical component of machine learning is knowledge acquisition as this supports better predictive capacity. This requires the consistent input of high quality, real-time data, which will be compromised by poor quality sensors or equipment that breaks down. Artificial intelligence decisions are only going to be as good as the information analysed to make the decision, and farmer capacity to invest in adequate technology may be a challenge to adoption.

Return on investment

In the absence of high quality data for input into intelligent software, some developers will need to start from scratch and artificial intelligence will be created with a set of standard rules in relation to the data it is collecting and analysing. Machine learning will improve the accuracy of predictions but will need several years of local data before meaningful decisions can be made. This will delay returns on investment for both the developer and the farmer. A key barrier to adoption of artificial intelligence on farm may be the capital investment required in new machinery and equipment noting that optimal productivity returns won't be realised for at least five years.

Social acceptance

Artificial intelligence may require an element of deep learning to enable consideration of complex and uncertain decisions, particularly when managing livestock that can act unpredictably. This may require the artificial intelligence to use an element of 'intuition' to ensure the safety of animals. In this instance, the social acceptability of empowering software to make decisions in relation to animal welfare may also need to be considered.

SCOPEOF AI IN AGRICULTURE

- ✓ India has been ranked third after USA and China in terms of artificial intelligence (AI) implementation, according to BCG study(April 26, 2018)
- ✓ By 2030, AI could contribute an additional $19.8 trillion or 14 per cent to global GDP (PWC report).
- ✓ Artificial Intelligence to Contribute $957 Billion to the Indian Economy By 2035
- ✓ Artificial Intelligence can impact 70 million farmers in 2020, adding $9 billion to farmer incomes (financial express report)
- ✓ Currently, Microsoft is working with 175 farmers in Andhra Pradesh, India to provide advisory services for sowing, land, fertilizer and so on. This initiative has already resulted in 30 percent higher yield per hectare on an average compared to last year.
- ✓ Importance of Drone: As per a recent PWC Study, the total addressable market for Drone-based solutions across the globe is $127.3 billion and for agriculture it is at $32.4 billion. Drone-based solutions in agriculture have a lot of significance in terms of managing adverse weather conditions, productivity gains, precision farming and yield management.

CONCLUSION

The emergence of new age technologies like Artificial Intelligence (AI), Cloud Machine Learning, Satellite Imagery and advanced analytics are creating an ecosystem for smart farming. Fusion of all this technology is enabling farmers achieves higher average yield and better price control. AI comes as a great boon to the agricultural sector which is heavily dependent on climatic conditions which are often unpredictable. Artificial Intelligence can impact 70 million farmers in 2020, adding $9 billion to farmer incomes (financial express report)

REFFERENCES

1. Athey, S., The impact of machine learning on economics. *The Economics of Artificial Intelligence: An Agenda. University of Chicago Press* (2018).
2. Gelb, E., Maru, A., Brodgen, J., Dodsworth, E., Samii, R., Pesce, V., Adoption of ICT Enabled Information Systems for Agricultural Development and Rural Viability, Atsugi Japan, p. 4-5 (2008).
3. Food and Agriculture Organization Investing in food security, I/I1230E/1/11. 09 /1000, Italy, p.3 (2009).
4. Gebbers, R., & Adamchuk, V. I., Precision agriculture and food security. *Science*, **327(5967):** 828-831 (2010).
5. International Energy Agency – World Energy Outlook, Paris, *Cedex* **15:** France, p. 3, 5-7, 14 (2009).
6. Kleinberg, J., Ludwig, J., Mullainathan, S. and Obermeyer, Z., Prediction policy problems. *American Economic Review*, **105(5):** 491–95, (2015).
7. Schindler, K. J., Zittel, W., Crude Oil – The Supply Outlook, 2008/02/11 LBST, Ottobrunn Germany, p. 6-9 (2008).
8. Liaghat, S., & Balasundram, S. K., A review: The role of remote sensing in precision agriculture. *American journal of agricultural and biological sciences*, **5(1):** 50-55 (2010).
9. Jean, N., Burke, M., Xie, M., Davis, W. M., Lobell, D. B. and Ermon, S., Combining satellite imagery and machine learning to predict poverty. *Science*, **353(6301):** 790–794, (2016).
10. Naik, N., Philipoom, J., Raskar, R. and Hidalgo, C., Streetscore-predicting the

perceived safety of one million streetscapes. In Proceedings of the IEEE Conference on Computer Vision and Pattern Recognition Workshops, pages 779–785, (2014).

11. National Agricultural Statistics Service (2016).
12. National Research Council Precision Agriculture in the 21st Century: Geospatial and Information Technologies in Crop Management, Academy Press, Washington DC, USA, p. 65-89 (1997).
13. Ozdogan, M., Yang, Y., Allez, G., & Cervantes, C., Remote sensing of irrigated agriculture: Opportunities and challenges. *Remote sensing*, **2(9):** 2274-2304 (2010).
14. Tyagi, A. C., Towards a Second Green Revolution. *Irrigation and Drainage*, **65(4):** 388- 389 (2016).
15. Cortés, U., & Sànchez-Marrè, M., (Eds.) Workshop Notes on 2nd ECAI Workshop on Binding Environmental Sciences and Artificial Intelligence, European Conference on Artificial Intelligence Berlin (2000).
16. World Internet Usage and Population Statistics http://www.internetworldstats. Com / stats. htm (2016).
17. http://epaper.financialexpress.com
18. *www.pwc.in*
19. www.bcg.com
20. https://www.accenture.com