Agri-informatics: A multi-disciplinary literature synthesis

Research in Progress

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Abstract

The agriculture industry has gained substantial productivity improvements and efficiencies due to the advancements in the information technologies (IT) landscape. While disparate knowledge in different disciplines is gaining substantial momentum, we need a consolidated interdisciplinary view of the salient findings of agricultural research to reach its full potential. Thus, information systems (IS) researchers have the potential to add value to this emerging theme. We reviewed 200 papers published on agriculture and IT from 2010 to 2016 and the prevailing literature demonstrates the value of this approach for advancing our understanding on agri-informatics. In this paper, we provide an overarching agri-informatics framework, possible theoretical lenses and research questions to encourage IS researchers to develop an effective cumulative tradition of research.

Keywords Agriculture, Agri-informatics, Archival Analysis.

1 INTRODUCTION

According to United Nations report, agriculture is one of the largest employers in the world, providing source of revenue for 40% of today's global population and the largest source of income for poor rural households in countries like India, China and Brazil (United Nations 2015). In addition, the United Nations also highlighted that food security and sustainability are global priorities. According to recent statistics, agriculture contributes to 1.1% of the gross domestic product (GDP) of the USA, 4% in Australia and 0.8% in Germany (Central Intelligence Agency 2018). Agriculture accounts for up to 18% of India's GDP and employs more than half of the country's workers (Cagliarini and Rush 2011). Further, according to McKinsey (2015a) food and agribusiness form a $5 trillion global industry that shows an uptrend. However, agriculture is a well-known sector for its own challenges such as great diversity in its geographic dispersion, complexity, diverse stakeholder knowledge, practices and policies (McKinsey 2015b). In some cases, agriculture is 'manned' by employees of low-socioeconomic standards and low literacy. A recent Indian government report estimated that over 30% of India's farming communities are illiterate (Tali 2015). Most of the farming locations, regardless of the type of agriculture, are in rural areas with less access to infrastructures like electricity and internet that facilitates connectivity, communication, learning, information and knowledge transfer (McKinsey 2015b; Raungpaka and Savetpanuvong 2017). Limited access to such infrastructural support coupled with low literacy rates directly translate into low-efficiency, low-productivity, trapping many farmers in a vicious cycle of poverty (McKinsey 2015a; Sedera et al. 2001).

However, despite such disadvantages in the industry, there is a growing trend of substantial opportunities that are presented through information technology (IT). Especially, the rise of the digital technologies like social media, mobile, analytics, cloud computing and internet-of-things (IoT) are presenting unprecedented opportunities for farmers to improve their literacy and knowledge sharing capacity (Sedera and Lokuge 2017; Tertiary Education Commision 2016). Such technologies defy boundaries established by the traditional technologies by making solutions that are easy-to-afford, easy-to-learn and easy-to-trial and easy-to-manage (Lokuge et al. 2016; Yoo et al. 2012). The digital technology platforms are creating new ecosystems of service providers that provide specific technology solutions to farmers. For example, the RFID technologies are now effectively being used for years in some agricultural sectors. Tagging of animals like sheep and cows allows farmers to have superior traceability, better breeding control, better conservation efforts and, data collection about all animals of the herd (Voulodimos et al. 2010). Tracking technologies such as RFID help farmers with automated feeding, weighing and disease management of animals, all with a simple tag, in addition to tracking capabilities of a lost animal (Samad et al. 2010). Similarly, the use of smart mobile phones has given rise to 'AgriApps' that can provide personalized agriculture advisory services via mobile phones, updating farmers about issues concerning soil, water resources, previous crops, pest issues, current crops and seed variety (Lokuge et al. 2016).

While there is a clear continuation of major socioeconomic issues in agriculture industry and the emerging role of technology in agriculture, information systems (IS) research community is largely absent from studying this important phenomenon. Therefore, the objective of this paper is to provide that vital discussion of the use of IT by reviewing interdisciplinary literature to provide a path for future research. In this paper, we term the use of IT in agriculture as "agri-informatics." We define agri-informatics as "the interdisciplinary study of the design, development, adoption and application of information systems in agriculture services delivery, management and planning." We argue that agri-informatics is an interdisciplinary domain that involves agriculture, information science, computer science, social and behavioral science, management science and other disciplines. Further, it deals with resources, devices and methods required to optimize acquisition, storage, retrieval, and use of information in agriculture. We believe that such an interdisciplinary approach will lead us to a better understanding of agri-informatics (i) by providing an integrated approach of the core disciplines, its impact to businesses and management, respectively and (ii) assist IS researcher to understand common research gaps and opportunities to foster cross-disciplinary research with agriculture, computer science and management. In conducting this archival analysis, we address the fundamental question of "*what are the important trends and patterns in interdisciplinary research in agriculture between 2010 and 2016 that would be of interest to the IS researchers?*" In here, while analyzing literature, we do not limit ourselves to use of IT inside a farm, but we consider use of IT in all aspects of agricultural sector (i.e. supply chain). This will provide us an overview to IT use in agricultural sector.

This paper proceeds in the following manner. First, we discuss the literature analysis process. Next, the outcomes of the analysis are discussed in the overview of the literature sample section. The key research areas for future research are provided and emerging implications are also highlighted in the discussion section. The discussion section also entails possible research questions to guide IS researchers.

2 METHODOLOGY

The archival analysis on agri-informatics literature includes studies published during 1st January 2010 to 31st December 2016. The analysis was done by following the guidelines of Tate et al. (2015). The selection of the journals favoured those that are in the disciplines of agriculture. Overall, we selected 23 journals that are relevant to the study scope. The selection of the journals preferred inclusion, over exclusivity. The inclusion of journals allowed the researchers to canvass substantial body of developing literature, even though some publication outlets may not be typically considered highly rigorous. The selection of journals were logical, in that we followed the globally accepted tiered journal structures. Due to page limitations the list of papers reviewed are not appended, however, upon request, the list of papers can be provided. Table 1 provides the list of journals that we reviewed. Each article identified was read in its entirety, the relevance was determined and then classified them into 4 categories of agriculture: (i) horticulture, (ii) dairy, (iii) pastoral and (iv) fisheries. Note that these four categories are not mutually exclusive, as some studies looked at the application of IT across the segments. Such a classification allowed the researchers to understand the breadth of research available in agri-informatics. Two researchers independently searched for the articles and categorized them. Additional papers were then identified by 'snowballing' through the papers that had already been accumulated.

Journal	**#**	**Journal**	**#**	**Journal**	**#**
Journal of Agricultural Technology	3	Computers and Electronics in Agriculture	11	Advances in Agriculture	2
Journal of Agricultural Economics	8	Canadian Journal of Agricultural Economics	10	IFAC Proceedings Volumes	3
Agriculture, Ecosystems & Environment	5	Journal Computer Standards & Interfaces	4	Journal of Agricultural Informatics	25
Agriculture and Human Values	4	European Review of Agricultural Economics	11	Journal of Development Economics	1
American Journal of Agricultural Economics	7	Food Policy	3	Journal of Advanced Agricultural Technologies	6
Animal Production Science	15	Information Processing in Agriculture	5	Journal of the Science of Food and Agriculture	17
Journal of Agricultural and Resource Economics	30	Journal of Agricultural Biological and Environmental Statistics	2	The Australasian Journal of Agricultural and Resource Economics	16
Technological Forecasting and Social Change	5	World Development	7		

Table 1. List of Journals reviewed

The range of technologies and applications were included as keywords in the search "mobile, cloud, GPS, automation, GIS, automated systems, smart phone, apps, social media, biotech* and IoT." In conducting the literature search, several academic databases and search engines were used such as ACM Digital Library, ScienceDirect, Emerald, Google Scholar, Emerald Engineering Database, InfoSci collection and IEEE Xplore Digital Library. Finally, 200 papers were considered relevant for the analysis. The initial review of the articles provided broad categories in research areas including strong reference to IT, such as how IT is benefiting agriculture, how IT is used in agriculture and pillars of agriculture and IT such as people, processes and technologies.

3 OVERVIEW OF THE LITERATURE SAMPLE

In the first analysis each paper was classified into 4 main sectors. Herein, we grouped each study into horticulture (143 studies), dairy (44 studies), pastoral (74 studies) and fisheries (22 studies). The results highlight that, while there are some overlaps between main segments, a specialization is required. Each sector has different characteristics, stakeholders, business processes and technologies. For an IS researcher who seeks to be involved in agri-informatics, an awareness of the salient differences between the four sectors would be required. It was noted that there are substantially more studies about the use of IT in the horticulture space, followed by pastoral and dairy.

3.1 Classification based on the technology type

The next classification was done based on the technologies used in agriculture and its purpose of use. Herein, the objective of the analysis was to understand the broad technology footprint in agricultural sector. The classification again did not seek to establish mutual exclusive categories, rather wanted to develop an overarching notion of the use of technologies and their purposes in agriculture. We noted that much of the studies had focused on either machine automation or office automation. Interestingly, there were studies where they have used mobile apps, social media and augmented reality to increase the literacy of the farmers (Benda et al. 2015), provide real-time weather information (Arslan et al. 2015), sharing production related information with the customers (Lassoued et al. 2015) and to increase productivity of agri-business (Bokusheva et al. 2011). Typically, such studies observed the role of digital technologies in agriculture and how such technologies lead digital transformation in the industry.

The office automation studies discussed the role of IT (more specifically enterprise systems) that made a change in the agriculture sector. In some ways, it can be argued that this is a missed opportunity for IS researchers not to lead the discussion on such central issues in agriculture. The strong momentum in agriculture for office and machine automation means that IS researchers can engage in this research now to provide leadership through the decades of expertise in system use. Moreover, there is an opportunity to contribute to the body of knowledge through the expertise on digital technologies. Specifically working on the agricultural emphasis (rather than making agriculture as the passive context), would help IS community to contribute to some of the unique challenges posed in the agricultural sector.

3.2 Classification based on the data sourced country

An analysis based on the country where data is sourced from provides an indication of countries that research on agri-IT initiatives. This is an important indicator as it demonstrates (i) mandatory record keeping activities in certain countries, (ii) willingness to reveal related information, and (iii) sophistication of technology. In general, where country does not include comprehensive tax regulations, then record-keeping and participation has been perceived limited. Moreover, we could not see a correlation between the number of studies and size of the agriculture industry. For example, India, one of the largest agriculture-based countries had only 4 studies aligned to its context. It was noted that the USA was the most cited country for use of IT in the agriculture sector with 20 studies. Australia was the second most frequent country with 18, followed by China (14), Hungary (9), Germany and Greece each with 7 studies. In general, there is a tendency in developed countries to lead this movements in the use of IT in agriculture by providing continuous government policy, support, both financially and by introducing regulations to create individual, business and national awareness, motivation and responsibility for effective agricultural practices. Overall, the study highlights (i) that there is a clear lack of focus on substantial agricultural nations like Brazil, Russia and India, (ii) lack of emphasis in data collection from multiple countries for this globally recognized issue, (iii) possibly vital role that journals can play in requesting authors to reveal the data collection sources. Moreover, (iv) for future researchers, this analysis revealed that some countries (like Australia and USA) are receptive to revealing data on their use of IT in agriculture.

3.3 Classification based on the types of issues

Then, the researchers classified the papers based on the types of issues that studies have reported. The highest number of issues cited in relation to 'lack of technical infrastructure' in remote farms. A root cause analysis using this term found that 'lack of technical infrastructure' relates to 'resistance of the work force' (78% of the studies reported resistance for IT). Similarly, 'technical infrastructure' was identified as a root cause for 56% of 'knowledge' related studies, which is the second highest cited issue in the data sample. Similarly, there has been much discussion on issues arising from the use of technology for domain related knowledge transfer and difficulty of codifying tacit knowledge of agriculture to explicit knowledge practices. Issues pertaining to knowledge, resistance, ethical use of IT, societal and political issues and measuring the value of IT are some of the strongest research themes in IS domain. Further, when analyzing these issues in detail, it was identified that researchers have highlighted aspects such as (i) lack of expertise in technology, (ii) no proper organisational strategy in place, (iii) lack of IT-business strategic alignment, (iv) lack of organisational readiness for IT initiatives, (v) no proper knowledge transition plans in place, (vi) lack of understanding of business processes and (vii) inexperienced staff as issues faced in agriculture sector.

4 DISCUSSION

Based on our compilation of 200 papers on agriculture and IT, it was evident that agricultural firms, regardless of the sectorial differences, employ similar technologies and face similar issues. Such trends observed in agriculture are like those that are well-established in IS (i.e., issues pertaining to technical infrastructure, knowledge, return-on-investment, ethics, resistance and societal issues). It is evident that technology-mix that we found in agricultural firms is similar to that of most modern firms' as their IT portfolio includes a mix of enterprise systems and digital technologies. Based on the analysis above, and based on the themes we identified, we propose Figure 1 as an initial framework to study this important field of global interest. The framework is inspired by the MIT90s framework (Scott Morton 1991). Originally, the framework was developed to understand the impact of IT to a firm's missions, structures and operating practices. As such, the inter-related elements can be applied to investigate IT use in agriculture as well. Overall it is evident that agri-industry is unique regarding (i) technology, (ii) organisational strategy and (iii) innate complexities in their business activities. The framework in Figure 1 that we adopted to embed all these facets. The analysis was used to identify different areas of research and to posit the relationships between these levels. Further using the agri-informatics framework, we propose research questions for future studies.

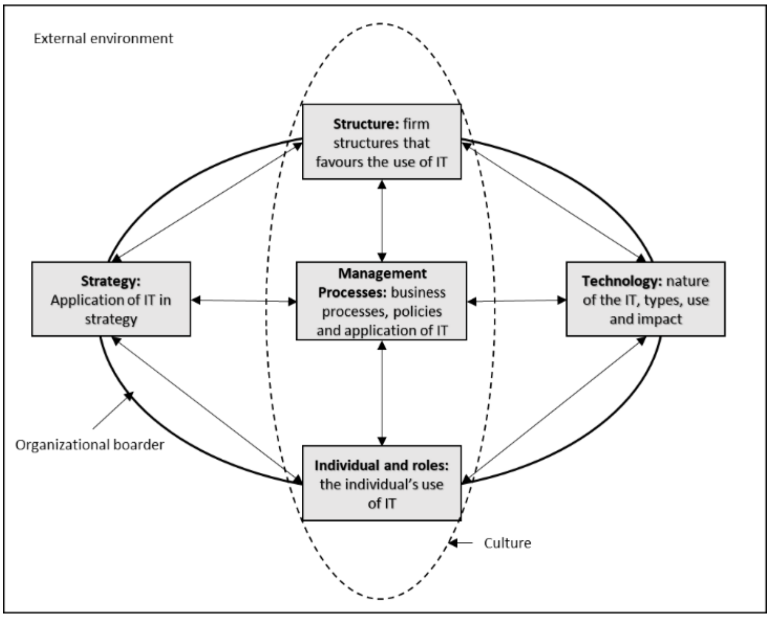

Figure 1: MIT90s Framework for Agri-informatics

Technology: The advent of affordable technologies like RFID, as a component of IoT, means that agri-informatics has the potential to take advantage of vast amounts of data that can be captured through crops (or animals), weather, seasonality indicators and large numbers of equipment (or workforce) being employed. Assessing the transformation of this sector to an information culture and its effects can be viewed through the lens of change and business process management theories (Davenport 2013). This element captures aspects such as (i) the use of unique systems by new user groups, (ii) differences in the IT use patterns, (iii) user expertise and (iv) different adoption patterns. The possible theoretical lenses include, representation theory and technology adoption model. Considering these, we propose the following research questions:

RQ1: *What is the role of IT for different stakeholders in agri-informatics?*

RQ2: *What are the organisational and individual outcomes of agri-informatics?*

Individual and role: This element encapsulates aspects such as: (i) unique environmental, human and social barriers that challenge the traditional IT value propositions and (ii) the value proposition of use of IT in agri-industry. These can be further analysed through IT business value, absorptive capacity, knowledge management (Rosemann et al. 2000) etc.

RQ3: *What are the benefits of agri-informatics to the firm / individual?*

RQ4: *How do low-IT literate agri-users increase decision making capabilities using agri-informatics?*

RQ5: *How do IT consultants and vendors provide value to agri-users?*

RQ6: *What are the salient characteristics of knowledge exchange in agri-informatics?*

Management Processes: This captures business processes and stakeholders involved in agri-business. While the core-internal business processes like financial controlling, reporting may be similar to any other industries, there are unique business processes in agriculture. For example, unstructured farming work-force requires invention of unique work practices for human capital management. Further, it captures the shorter lifecycles, seasonality and unstructured labour forces that challenge the agri-industry. The IS researchers can use punctuated equilibrium theory as a possible theoretical lens for studying this phenomenon.

RQ7: *How do unique industry-specific characteristics (e.g., seasonality) influence the use of IT artefact in agri-informatics?*

Structure: This element encapsulates firm structures that supports agri-informatics. In contrast to a common firm, the specialization of agri-industry is that it has different stakeholders with different levels of accesses and power. Further, there is a clear top-down hierarchy in agri-industry and most of the firms are family owned businesses. In initiating and managing IT use in such hierarchical firms, it is interesting to investigate this phenomena using control theory and leadership theories (Bass 1991).

RQ8: *How do managers in agri sector intermix their efforts in managing IT initiatives?*

RQ9: *What is the role of leadership in managing an unstructured labour force in agri-informatics?*

Strategy: The discussion of a strategy must entail unique contributions that IT makes for an effective and an efficient industry. In a context where the value of IT is less understood, it inherently becomes a challenge. Moreover, uncontrollable factors like weather, seasonality of crops and industry regulations will make agri-informatics challenging, yet invaluable. Agriculture is susceptible to global contexts like trade legislations, bio-security laws and logistics. Theories like the resource-based view of the firm and its variants like the contingent resource-based view would provide insights into how technologies can create unique technological value for agriculture. Furthermore, core competence (later Innovation) theory and competition theory could provide an elevated discussion to understanding the role of strategy in agri-informatics.

RQ10: *What are the ways of bundling IT to increase organisational efficiency in agri-informatics?*

RQ11: *How does the information strategy influence business processes in agricultural organisations?*

RQ12: *What is the role of information as a strategic resource in transforming agricultural firms?*

RQ13: *How does technology be integrated to strategic decision making in the agriculture sector?*

Culture: The rural settings, unstructured labour forces, largely family owned business structures, less IT sophistication create a unique culture in agriculture. IT adoption and the influence of culture is therefore would be a fitting agenda for research in agri-informatics. More specifically, future studies can apply learning theories (Bandura 1997) in this unique context.

RQ14: *What is the impact of low IT sophistication in knowledge transition in agri-industry?*

5 CONCLUSION

The objective of this study was to investigate the IT use in the agriculture sector by reviewing interdisciplinary literature to provide a path for future research. The analysis suggested that the agricultural firms require unique technologies for their unique business processes. In addition, stakeholders in agri-informatics range from the farmers, farm-hands, management to farm owners. Outside stakeholders could include government, policy makers and external business partners. Technology sophistication, knowledge, acceptance of technologies and perceived value for technologies by agri-informatics stakeholders would vastly differ from mature technology fields of study. As such, we highlighted the need to study and encourage IS researchers to focus on adding value to this field. Motivated by the global call for research in agriculture and lack of response from IS research, we began this study to create an awareness of what IS discipline could contribute to a vexing global issue. The study demonstrated that the role of IT in agriculture in relation to (i) use of technologies, (ii) breadth of activities and (iii) proliferation of studies in countries around the world. Herein, we argue that by treating agri-informatics as an important paradigm, IS researchers (and the world) will gain much. The framework that we have proposed in this paper will provide guidance for IS researchers to identify research areas where they need to pay attention. To provide further clarity, we have suggested possible theoretical lenses to be used in studying each of the categories in the framework.

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