INTERNET OF THINGS IN AGRICULTURE: A CASE STUDY OF SMART DAIRY FARMING IN ONTARIO, CANADA

Poonsri VATE-U-LAN, Ed.D.[1)], Donna QUIGLEY, Ph.D.[2)] and Panicos MASOURAS, Ph.D.[3)]

[1-2)] Full-time Lecturers
Graduate School of eLearning
Assumption University, Bangkok, 10240, Thailand
[1)] Email: poonsrivtl@au.edu
[2)] Email: home196726@hotmail.com

[3)] Assistant Professor
Department of Nursing, Cyprus University of Technology
Limassol, Cyprus
Email: panicos.masouras@cytanet.com.cy

ABSTRACT

The objective of this paper is to report a case study of smart dairy farming in Ontario, Canada which is the future of food production and ways that advancements related to the Internet of Things (IoT). It is impacting upon agricultural practice in the form of smart farming. Smart farming is the practice of intelligent agricultural management based upon technological data gathering farm practice for the purpose of increased levels of quality, production, and environmental protection. This paper will illustrate one example whereby partnerships among the academic world, government agencies and local food producing communities in Canada are adapting innovative thinking and smart technologies to address the need to implement the more effective agricultural practice. Food From Thought is a Canadian research project, based upon high-tech information systems to produce enough food for a growing human population while sustaining the Earth's ecosystems. The paper will outline how one dairy farmer in Ontario has been able to apply smart farming technologies to increase milk production while maintaining the health of his cattle and preserving the environment. The review of applications of smart farming in Ontario such as digital tracking for a cow, genomic testing, digitally signaled birth, sensor driven crop management and data driven dairy production also details in this article.

Keywords: Internet of Things; Dairy Farming; Food From Thought; Smart Farming

INTRODUCTION

Scientists have predicted a world food shortage by the year 2050 (Giovannucci et al., 2012). United Nations projections related to food shortages are based upon a future world population of 9.6 billion. Experts predict that the agricultural sector will need to increase food production by 70 per cent in order to avoid a food shortage catastrophe and its subsequent devastating results upon human populations. Researchers point to two critical variables which if remain unaddressed will spell disaster for future generations in terms of the planet's capacity to feed its people. Increments in world population growth will place unprecedented demands upon all stakeholders within the agricultural sector (Guerrini, 2015). Researchers have identified global environmental trends related to diminishing resources that are critical to the future of agriculture and horticulture.

Climate change as a consequence of global warming has resulted in a reduction of arable land and availability of fresh water on a world scale. This pattern is concerning because agriculture consumes 70 per cent of the planets' fresh water. Natural phenomena associated with earth's ever evolving change process have been altered significantly to the extent that in some regions of the planet water tables have deepened, the process and rate of desertification has been escalated, salination levels of underground fresh water resources have risen, and increased runoff due to flooding has decimated vast regions of agricultural land. The United Nations has predicted that warmer temperatures have the very real potential to alter natural growth patterns in plants and animals resulting in interrupted natural cycles of pollination and crop germination to give examples. Mega storms, drought, pollution, changes in animal reproduction cycles have the capacity to impact upon food production levels drastically. The agricultural sector is presently approaching a new threshold which represents a shift towards greater co-operation among stakeholders who have a role in the food producing industry (The University of Guelph, 2016a).

THE INTERNET OF THINGS DEFINITION

The Internet of Things or 'IoT' in short, an important advancement of the Internet is the spectrum of technology and society. A definition of IoT is not permanent but depending on the contexts involving with a global infrastructure for the information and communication technologies. Essentially, human-centered demand is the major effort that influence to innovate IoT (Gubbi, Buyya, Marusic, & Palaniswami, 2013; Shin & Jin Park, 2017). IoT in a smart environment contexts has been studied and defined as an interconnection system among the Internet and other sensing and actuating devices which be able to operate information across various platforms via a unified framework such as cloud computing with seamless information representation, data analytics, and ubiquitous sensing (Gubbi et al., 2013).

FOOD FROM THOUGHT: A CANADIAN INITIATIVE

Smart farming or what is otherwise referred to as bio-logical farming represents a digital revolution to increase capacity and quality of agricultural production based upon applications of sensing technologies that allow food producers to be more "intelligent" and more scientific through the practice of "precision agriculture" (The University of Guelph, 2016b).

The University of Guelph located in Ontario is recognized as a research-based university that is reputed to be one of Canada's leaders in the field of agriculture. In June of 2016, the Canadian federal government awarded Guelph University $76.6 million (CN) to initiate a digital revolution in sustainable food production. Canada's investment in the Food From Thought research project sets as its goal to use high–tech information systems to produce innovative solutions related to food production in response to future human population projections while responding to the critical need to protect and sustain the Earth's ecosystems. Food From Thought represents a network of global partnerships that include academic institutions, government agencies, industry and local innovation centers. IBM a major community partner "shares a vision of Food From Thought; ensuring that we sustainably resiliently and safely increase production while enhancing ecosystem services and livestock health and welfare using data-driven approaches" (The University of Guelph, 2016b).

APPLICATIONS OF SMART FARMING IN ONTARIO

Joe Loewith and Sons Ltd. farm, located in Ancaster, Ontario is recognized as a leader in raising Summitholm Holsteins within Canada's dairy farming industry (Joe, 2009). This is one of commercial farms which has over 200 heads. The following are examples provided during an interview with Carl Loewith a co-owner of Joe Loewith and Sons Ltd. Dairy Farm (Carl, 2016). The examples illustrate ways that agricultural research and innovative applications of smart technology are being incorporated into the daily operation of the dairy farm.

Digital Tracking for Each Cow

Figure 1: A cow with digital bracelet
Photo by Quigley (2016a)

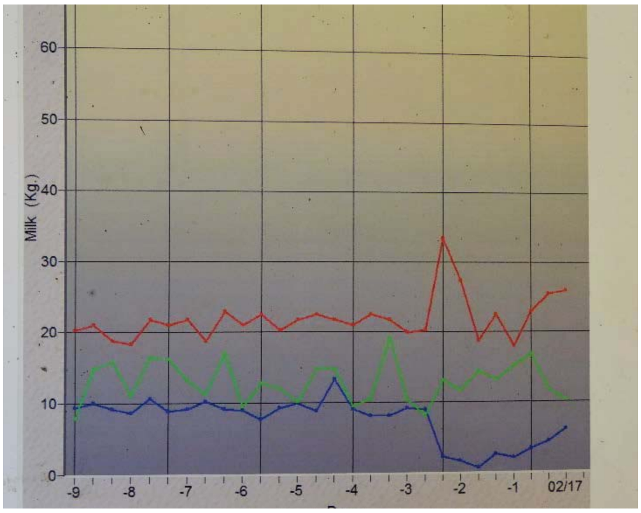

Figure 2: Graph activity and milk production
Photo by Quigley (2016b)

Advances in sensing technology and agricultural software allow farmers to create individual and demographic profiles for the dairy herd. Each cow is equipped with a digital bracelet or pedometer which identifies the Holstein, measures how much milk was produced at each milking, provides data about the cows' activity by recording the number of steps per hour, identifies conductivity levels of the milk which are indicators of the presence of infections or possible ruptured cells in the udder and the duration period for the udder to be drained (see Figure 1). The subsequent data is managed by software which allows each cow to be monitored for its overall health and levels of production in ways that previously were impossible.

Readings that signal changes in the Holstein's normal patterns allow the farmer to accurately predict the needs of each cow. The graph, Figure 2 indicates a pattern of change in the cow's system. The data from this example identify a combination of low milk in production in blue with high activity levels in red which signal that the cow is in heat and indicate that it is the ideal time for the cow to be inseminated (see Figure 2).

From a staff management perspective, the data profiles enable the farmer to supervise and monitor the effectiveness of employees. Workers who operate the milking equipment and oversee the milking process are responsible for the cleaning and stimulation of the udders as a preparation for milking. Changes to the readings over time identify potential health risks to the cow such as the presence of udder infections. Analysis of the data supports staff in addressing health risks that potentially threaten the cow's productivity. In some cases, training needs that support staff performance can be identified and managed easily so that the health of the cow is not compromised. Innovations in smart technology greatly support quality assurance of milk production and staff effectiveness because decisions are implemented through interpretation of data based upon input from each cow.

During the interview, Carl shared a similar but more sophisticated method of digital management of cows that currently is not available in Canada. An Israeli dairy farmer uses a sensing neck collar to monitor his Holsteins. Sensors imbedded in a neck collar are able to pick up and transmit "noises" that are made by the cow as it digests its feed. Information communicated via an app to a mobile phone allows the farmer to monitor how each cow is digesting its feed and feeling in real time. Applications of smart technology have removed the obstacles of distance and time so that from anywhere in the world a farmer can monitor every cow in the herd. Continued advancements in the field of intelligent dairy farming will be enable producers to manage larger herds, achieve higher production levels while ensuring the well-being and health of their herd.

Genomic Testing: Herd Intelligence

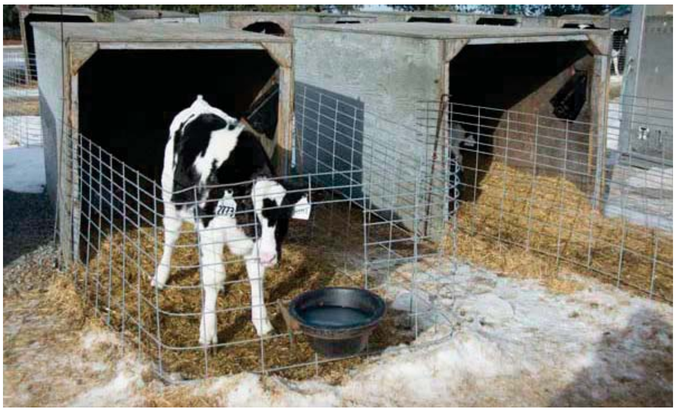

Figure 3: Three days old heifer
Photo by Birchall (2015b)

Advances in genetic science and technology have made it possible for dairy farmers to map the genome of a Holstein calf as early as one day after its birth. A sample of hair or blood can be used to isolate components of the calf's Deoxyribonucleic Acid (DNA). The process allows the farmer to predict with certainty how a heifer will mature to adulthood. Previously a waiting period of two years was necessary before a heifer could be assessed for its milk producing and breeding capacity. Applications of DNA testing provide firm indicators regarding the cow's future fertility, milk production levels, vulnerability to diseases and indicate the components of its milk such as percentages of buttermilk fat, protein, and lactose levels. The practice of artificial insemination of dairy cows added to the capacity to alter and select the structure of the DNA of males has far reaching implications to the quality of offspring. DNA testing has improved the effectiveness of the dairy cattle breeding process. Healthier more productive cows produce higher quality milk which affects operating costs and overall profitability.

A Digitally Signaled Birth

A system of sensing technology and software when connected to a computer or mobile phone provides the dairy farmer with information alerts when a cow is about to calf. Prior to the cow's expected calving date a small sensing device is placed inside the birth canal and has the capacity to detect and transmit information related to what is happening inside the cow's body. This means that should the mother be experiencing distress during any phase of the birthing process help can be available. Dystocia obstructed labour in cattle occurs when the calf cannot pass through the birth canal (Patterson, Bellows, Burfening, & Carr, 1987). The mother and calf become at risk to injury or possible death if assistance from a veterinarian or knowledgeable individual is not immediately made available. Studies conducted by the experts have shown that dystocia is responsible for 33 per cent of all calf losses in the United States. The prevalence of dystocia understandably has serious economic implications for the dairy producing industry. The losses to a farmer of an adult cow or calf are considerable when factored against projected milk production and breeding figures over the animal's lifetime. Veterinary costs to treat injury or death of either the mother or her calf can be greatly reduced when assistance during the calving process is timely. Smart technology allows large herds to be monitored so that where more than one cow is calving at the same time resources can be in place to ensure the safe delivery of each calf.

Sensor Driven Crop Management

Figure 4: GPS –driven crop harvesting equipment
Photo by Birchall (2015a)

A high percentage of dairy farms in Ontario grow their own feed to reduce operating costs. Innovations in sensing technologies have resulted in improved methods of crop management. Farmers are now able to apply geospatial sensor technologies such as Global Positioning System (GPS) applications to manage planting, fertilizing, crop spraying and harvesting with the outcome of improved crop management and cost-saving practice. Most applications of agricultural software are compatible with Windows 7/8, Vista or XP and can be downloaded to a cell phone, tablet or laptop using a UBS cable to connect with a GPS system. The result being that standard farm equipment can be transformed to function with digital precision capacity. Digital farming software allows the field to be mapped and worked according to a grid system which allows the operator to see the field from a 3D perspective. The operator has precision control and is able to direct fertilizers or chemical sprays in such a way as to cover the entire field. A GPS-driven crop sprayer
has the capacity to develop a digital record of factors such as date, time of day, area, soil condition, weather conditions and volume of fertilizer or chemicals that were sprayed.

GPS precision agriculture allows real-time data collection and analysis that is site specific, and perspective controlled so that fertilizers and pesticides can be worked to reflect the unique topography of the field. Data provided to the farmer is critical to effective crop management both in terms of the overall operational costs and from the perspective of preservation and protection of the environment.

GPS precision agriculture is cost effective because it requires less time to work the field than traditional methods and because the waste of fertilizer or chemicals is eliminated. GPS precision technology allows the operator to adjust the boom to match the width of the spray area which results in no over spraying or missed areas. Challenges that relate to conditions of low visibility are eliminated because the operator can adjust the spray nozzles to compensate for weather conditions such as fog, rain or, darkness.

Advances in precision agricultural technology have important implications in terms of benefits related to crop management to a dairy farmer. Specifically, the operator's control and degree of precision minimizes damage to the crop, and to fragile ecosystems within the environment.

Data Driven Dairy Production

Figure 5: Healthy dairy cows increase production levels
Photo by Quigley (2016c)

The Independent Milk Research Agency monitors 85,000 dairy herds across Canada. Each month every farm is visited for the purpose of gathering samples and recording production rates for the herd. Dairy production statics support research and quality control and are accessible in both provincial and national data bases that are both current and comprehensive. Information figures document readings submitted for milk production for each herd according to set criteria related to, udder health, age at first calving, the longevity of the herd, calving interval in terms of the number of pregnancies for each cow, and the rate of herd turnover. Each herd then is ranked against the above criteria. The Joe Loewith and Son's Ltd. operation has consistently ranked in third place within this national scale. Carl states that this level of achievement is based on his family's dedication to dairy production. The current standard of excellence achieved at this farm is in fact, a reflection of three generations of commitment towards improvement in dairy farming methods. He credits not only the team approach of his family partners but also the importance of community-based experts, publications, and networks that support advancement within the diary production industry. Gone are the days when dairy farmers are problem-solving in isolation (Ontario, Milk Marketing Board, 2016). The advent of the Internet and applications of smart farming technology allows the herd to be digitally monitored for quality control within the broader context of the dairy industry.

In Canada, an extensive network of agents exists to support advancements in dairy herd management. Carl sited his veterinarian, feed nutritionist, and crop consultant and genetics advisor as first line partners in his commitment to keep up with smart technologies that support the health and production levels of the herd.

SUMMARY

The future of agriculture is dependent upon strong partnerships between all stakeholders in the food producing industry. Developments related to agricultural research and intelligent technology must continue to advance in the fields of genetics, breeding, crop management, conservation and environmental protection as a strategy to develop solutions to the ever increasing challenge of feeding the planet. The impacts from Internet of Things (IoT) upon agricultural development in the form of smart farming in Ontario, Canada should be an interesting case study to other similar future of food production especially the ways that advancements related to smart farming. A case study in this current paper presents the implementation of intelligent agricultural management based upon technological data gathering farm practice for the purpose of increased levels of quality, production, and environmental protection. The innovative research integrate advanced technology in agriculture is on high demand especially in the top agricultural countries. The phenomenal of the Internet of Things (IoT) in agriculture is significant to ecosystems of the world since the smart technology can increase both quality and quantity of agricultural production.

REFERENCES

Birchall, G. (2015a). GPS –driven crop harvesting equipment. Kimberly Information Services Ltd. 36 Secinara Ave. Ancaster Ontario, Canada.

Birchall, G. (2015b). Three day old calf. Kimberly Information Services Ltd. 36 Secinara Ave. Ancaster Ontario, Canada.

Carl, L. (2016, October 18). Applications of Smart Farming in the Dairy Business by Co-owner and Manager of Joe Loewith and Sons Ltd.

Giovannucci, D., Scherr, S. J., Nierenberg, D., Hebebrand, C., Shapiro, J., Milder, J., & Wheeler, K. (2012). Food and Agriculture: The Future of Sustainability. SSRN Electronic Journal. https://doi.org/10.2139/ssrn.2054838

Gubbi, J., Buyya, R., Marusic, S., & Palaniswami, M. (2013). Internet of Things (IoT): A vision, architectural elements, and future directions. Future Generation Computer Systems, 29(7), 1645–1660. Retrieved from http://www.sciencedirect.com/science/article/pii/S0167739X13000241

Guerrini, F. (2015). The Future of Agriculture? Smart Farming. Forbes.

Joe, L. (2009). Joe Loewith and Sons Ltd. Summitholm Holsteins. Retrieved from http://www.joeloewithandsons.com/

Ontario, Milk Marketing Board. (2016, October). Problem Solving on the Farm. Canada's Best Read Dairy Magazine, 34–35.

Patterson, D. J., Bellows, R. A., Burfening, P. J., & Carr, J. B. (1987). Occurrence of neonatal and postnatal mortality in range beef cattle. I. Calf loss incidence from birth to weaning, backward and breech presentations and effects of calf loss on subsequent pregnancy rate of dams. Theriogenology, 28(5), 557–571. https://doi.org/10.1016/0093-691X(87)90273-1

Quigley, D. (2016a). Activity levels and milk production rates.

Quigley, D. (2016b). Digital bracelet at Joe Loewith and Son's Ltd.

Quigley, D. (2016c). Healthy dairy cows increase production levels at Joe Loewith and Son's Ltd.

Shin, D.-H., & Jin Park, Y. (2017). Understanding the Internet of Things ecosystem: multi-level analysis of users, society, and ecology. Digital Policy, Regulation and Governance, 19(1), 77–100. https://doi.org/10.1108/DPRG-07-2016-0035

The University of Guelph. (2016a, September 8). Food From Thought [Video]. Retrieved from https://www.youtube.com/watch?v=La7Xi65RyFo

The University of Guelph. (2016b, September 8). U of G Receives Nearly $77 Million to Launch "Food From Thought." Retrieved from http://news.uoguelph.ca/2016/09/u-g-receives-nearly-77-million-launch-food-thought/