

DATA CHAIN MANAGEMENT ON CROP MAINTENANCE IN PRECISION AGRICULTURE

Paweena Suebsombut^{1,2}, Aicha Sekhari², Pradorn Sureephong¹, and Abdelaziz Bouras³

¹College of Arts, Media and Technology, Chiang Mai University, Chiang Mai, Thailand

²University Lumiere Lyon 2, Bron, France

³Qatar University

Introduction

Agriculture or Agricultural Activities is the farm practices and activities of crops production including the soil's tillage, crops' planting, fruit trees' growing, and harvesting of any agricultural and horticultural commodities, and operated by a farmer on a farm excepting the processing or manufacturing of farm products [1][2]. The cycle of crops production consists of the sowing of seeds, the maintenance of crops during growth and development, harvesting, storage, and distribution [3] as shown in Figure 1.

Previously, farmers cultivate and maintain their crop using indigenous knowledge, natural resources, and cultural beliefs of the farmers. The number of world population in the next 40 years was predicted by the Food and Agriculture Organization (FAO) that will increase around 1.5 thousand million people [4]. Additional, the unpredictable environment, for example climate change; drought; etc., is the major problem of crop's cultivation which affects to crop maintenance process and yields. Therefore, farmers have to more emphasize on the significance for increasing the quality awareness of productivity and foods' sufficiency for the world population.

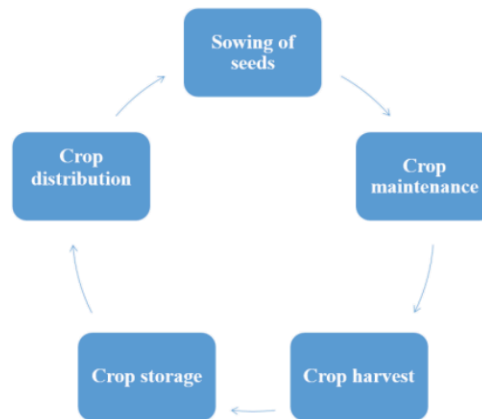


Figure 1: Lifecycle of growing crops

Consequently, the limited amount of crops grown is the negative results from these impacts. To reduce the risk from highly damages of farming operation is to adopt the concept of Precision Agriculture (PA) for farms management by following the conditions of farm situation. The Precision Agronomics or Precision Agriculture (PA) is adopted to enhance crop maintenance process and to improve quality of productivity. According to the concept of Smart Farming from European Network Mainstreaming Smart Farming Technologies among the European farmer community (Smart AKIS Network), PA is one of the three pillars of modern information and communication technologies (ICT) application which is a concept of farm management to observe and measure variance in cultivation using smart technology and decision support system (DDS) for managing whole farm including fertilizing, irrigation, pesticides, etc., and enhancing quality of productivity [5]. PA techniques use data obtained by closely monitoring related variables using smart technologies like sensors and remote sensing technology [6]. PA has developed and applied in many countries such as Canada, USA, European, Japan, etc. For example, vineyard adopts precision agriculture by installing sensors on farm and using smart technologies and sensing technologies for monitoring farm's environment (comprising air temperature, soil moisture, air humidity, rainfall, wind speed and direction) via smartphone or tablet that helps farmers for farm management

effectively and grapes' quality controlling [7]. Another example is proposed by [8] which is tractor's tracking in large farm areas using Global Positioning System (GPS) technology for tracking and ZigBee wireless network for communicating so that tractors will be tracked when it is running on the farm field. In PA, the data is very significant. Numerous data are relevant for crop maintenance which the management of data chain is necessary. Consequently, this paper proposes the approach to manage data chain for crop maintenance. The paper is structured as follows: starting from Concept of crop Maintenance, Data relevance crop maintenance, Data chain management approach, and ending with the Conclusion and future work.

Crop Maintenance

Crop management is the process to manage the crop cultivation in whole life cycle of crop production consisting of beginning of life, middle of life and end of life. It is one of the processes on crop production to protect the crop cultivation against issues which affect to yields such as weather, diseases and insect, etc. A variety of cultural treatments also may be required to meet the purpose of the crop cultivation. On the crop maintenance, the factors affecting to crop growth consists of growth regulator and hormone, soil, nutrient, water, climatic, diseases, insect pests, and weeds [9]. Additional, there are six main methods of crop maintenance [10]. Firstly, irrigation is one of important methods of crop maintenance that crops need water for growth, dissolving nutrients into the soil, keeping moisture and cool, and carrying nutrients through the crop. Secondly, fertilizing is the method to maintain crop to healthy conditions and to increase their resistance to harm from diseases and pests. Thirdly, pruning is the method for improving structure of crop, controlling size of crop, or removal of diseased, dying, or dead branches. Fourthly, disease control is the method to protect crop by interfering crop as little as possible so that forecasting and avoidance the occurrence of diseases, pests, and weeds are the most reliable way to deal with them. Fifthly, insect pests control is the methods to avoid the insect pest attack to crop including to care crop after attacked. Finally, weeds control is the method to avoid weed occurrence which affect to soil properties, he habitat of poisonous animals like snacks.

Crop maintenance is relevant lifecycle of growing crop to care the crop from the beginning to the end of crop's life. Generally, the lifecycle of growing crop includes sowing the seeds into soil, young crop, mature crop, flowering, ripening, dormancy, and death [11][12][13] as illustrated in Figure 2. Some crops like grain, rice, the lifecycle is always starting from sowing the seed and ending with the death of crops. On the other hand, the lifecycle of some crops like horticulture is starting from sowing the seeds at the first time of planting, but it is ending at the dormancy stage, and it will start its next growing with mature crop stage.

In each stage of crop's lifecycle, the process to maintain crop (including irrigation, fertilizing, pruning, diseases control, insect pests control, and weeds control) is different depending on the needs of crop and environment. For example, crop in the flowering stage needs less water than other stages because it helps to stimulate the sprout of flowers.

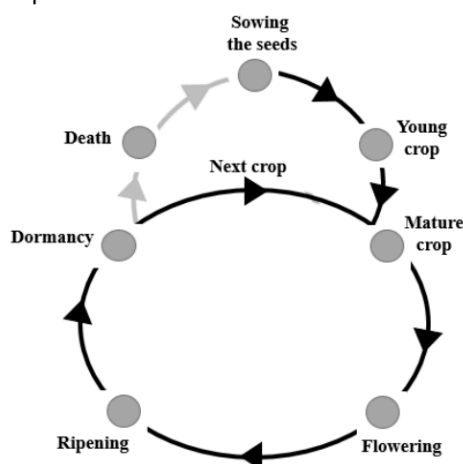


Figure 2: Lifecycle of growing crops

Data Relevance Crop Maintenance

Data is information or raw data collected using particular methods for a particular purpose of analyzing and/or studying. In crop maintenance, numerous data are relevant that are classified based on the sources of data comprising on-farm data, off-farm data, and expert's knowledge as shown in Table 1.

Table 1: Classification of crop maintenance data [14-32]

Method	On-farm data	Off-farm data	Knowledge
Irrigation	<ul style="list-style-type: none"> - Air temperature - Air humidity - Canopy temperature - Rainfall - wind speed - solar radiation - vapor pressure - evapotranspiration (ET0) - day length - soil moisture - soil temperature - Drainage - electrical conductivity - leaf wetness - Crop canopy -Trunk diameter 	<ul style="list-style-type: none"> - Weather forecast, - Daily climatic datasets, - Daily ET0 	<ul style="list-style-type: none"> - Crop coefficient (Kc), - water requirement of crop, - irrigation method, - timing of irrigation water application, - days of irrigation during cultivation
Fertilizing	<ul style="list-style-type: none"> - leaf area - Crop canopy - soil PH - soil salinity - rainfall - temperature 	<ul style="list-style-type: none"> - Harvest index, - Grain weight, - type of soil, - soil diagnostic, - farm location, - weather forecast 	<ul style="list-style-type: none"> - timing of fertilizer application, - nutrient requirement of crop
Pruning	<ul style="list-style-type: none"> - Image of crop canopy 		<ul style="list-style-type: none"> - crop architecture, - methods of pruning
Diseases Control	<ul style="list-style-type: none"> - Air temperature - humidity - rainfall - day length - wind speed and direction - evapotranspiration - air pressure - canopy temperature - leaf wetness - soil moisture - soil PH 	<ul style="list-style-type: none"> - historical climatic data, - historical diseases occurrence data, - soil diagnose data, - particular field of a geographical area information, - weather forecast 	<ul style="list-style-type: none"> - Method to control diseases
Insect pests Control	<ul style="list-style-type: none"> - Air temperature - humidity - solar radiation - rainfall 	<ul style="list-style-type: none"> - Historical of insect pests occurrence 	<ul style="list-style-type: none"> - the life cycle of the insect pests, - methods to control insect pests
Weeds Control	<ul style="list-style-type: none"> - Air temperature - humidity - rainfall - soil temperature - soil moisture - soil PH 	<ul style="list-style-type: none"> - Historical of weed occurrence, - Weed species density data, 	<ul style="list-style-type: none"> - Methods to control weed occurrence, - irrigation method

Data Chain Management Approach

Data chain is a combination of two or more data elements in a prescribed sequence to yield meaningful information. Nowadays, there has been the gap between the raw data collection and decision-making process in terms of data management so that the data chain will help to close this gap. [33]. Therefore, we propose the approach of data chain management for crop maintenance in precision agriculture. This approach aggregates the data from heterogeneous data sources including on-farm data, off-farm data, and experts' knowledge before using these data for decision-making. The chain of our data starts from data collection, data processing, data storage, and data analysis as illustrated in Figure 3.

Figure 3: Data chain management in context of crop maintenance in precision agriculture

In figure 3, the chain of data starts from data collection which is the process to collect data relevant to crop maintenance from data sources as a raw data of the chain. The next step of the data chain is data processing and integration comprising data processing and data storage. Data processing is the stage of collected data processing that has two methods which are used for capturing experts' knowledge and transforming knowledge base in human language to machine language for analyzing. Data storage is the stage to store processed data and distribute data to the analysis stage. The last step of the data chain is data analysis which is the stage to process data for making decisions on crop maintenance. In this paper, we will focus on the chain of data from the data collection stage until data dissemination to the analysis stage.

In this approach, the expert's knowledge or knowledge base will be captured by interviewing experts and transformed from human language to machine language by using Natural Language Processing (NLP) so that machines will understand the data captured from experts. And, on-farm and off-farm data that are collected by installing smart sensors on the farm and accessing other data sources respectively, will be integrated to be the input data of the decision model. The combination of data processing from heterogeneous data sources into a unified view, making it more meaningful and valuable information is the concept of data integration that users, organizations, and applications can merge different types of data (such as tables, data sets, and documents) for use as business or personal functions and/or processes.

Natural Language Processing (NLP)

The format of knowledge is categorized into two sources including structured and unstructured knowledge. The structured knowledge includes XML files and relational databases and the unstructured knowledge includes images, documents, and text files. The creation of both knowledge sources is the concept of knowledge extraction. The expert's knowledge is captured or extracted by interviewing experts. After that, it will be converted from human language to machine language for machine-readability in the decision-making process.

For capturing and transforming knowledge, the artificial intelligence (AI) technique is necessary. One AI's branch is NLP, which is the combination of computational linguistics and computer science to fill the gap between human communication and the understanding of computers [34]. NLP is the method helping computers to understand, interpret, and manipulate the language of humans. The function of NLP is the transformation of information in human language to machine language that is a useful and smart way helping computers to analyze and understand the meaning of human language. The steps of data processing in NLP consist of lexical analysis, syntactic analysis, semantic analysis, discourse integration, and pragmatic analysis [35].

Extract, Transform and Load (ETL)

ETL is a data integration process for transforming raw data from diverse databases and then preparing the information for downstream uses [36][37]. The step of ETL consists of three steps comprising extract, transform, and load. First step, the data reading from the database is called the extract step that data will be collected from numerous and heterogeneous types of data sources. Then, extracted data will be converted into the user need form called the transform stage so that it can be placed into another database. Final step, the data will be written into the target database that is called the load step.

Relational Database management system (RDBMS)

To store the set of data, the database is significant. Generally, there are two main types of data comprising structured and unstructured data which most of data is structured data for easily accessible. Several types of database are used to store set of data. However, the most used of database is relational database which is organized into table and allows users to access and to identify the relationship of data in database. To manage the relational database, the RDBMS is applied that is the program allowing administrators to create, to update, manipulate the relational database [38]. Most of RDBMS uses the Structured Query Language (SQL) for database accessing [39][40]. The function of SQL is for data communication that are stored in relational database to manage the storing and disseminating data in database for analyzing.

Conclusions and Future Work

This paper proposes the approach of data chain management on crop maintenance in precision agriculture. This benefit of this approach is helping to manage the chain of numerous data that collected from heterogeneous data sources including on-farm data, off-farm data, and expert's knowledge. The chain of crop maintenance data starting from data collection, data processing, data storage, and data analysis. Natural Language Processing (NLP) will be used to capture and to transform knowledge base captured from experts in human language to machine language for machine-readable data. Extract, Load and Transform (ETL) is the method to integrate on-farm and off-farm data to be the inputs data of decision system. And, Relational Database management system (RDBMS) based on the Structured Query Language (SQL) language will be used to create database and to manage data for storing and disseminating to/from database.

For the future work, the data will be collected and processed based on the proposed approach. Additional, the method for data analyzing in decision model is not proposed yet in this paper. Therefore, the appropriate method of data analyzing in decision model on crop maintenance processing will be proposed in the future work.

Acknowledgement

The authors would like to acknowledge the support of Decision and Information Systems for Production System (DISP), Université Lumière Lyon 2 (France), College of Arts Media and Technology, Chiang Mai University (Thailand), and Qatar University (Qatar). We also would like to acknowledge all of our colleagues who worked together and provided encouragement to the authors.

References

- [1] Ben G. Bareja. " What is Agriculture, Definition of Agriculture." Cropsreview: Welcome and Let's Go Crop Farming, August 2014.
- [2] Kipps, M.S., "Production of field crops. A textbook of agronomy." Production of field crops. A textbook of agronomy., (Edn 6). 1970.
- [3] Madsen, Eugene L. "Impacts of agricultural practices on subsurface microbial ecology." Advances in agronomy (USA) (1995).
- [4] Beecham Research Ltd., "Towards Smart Farm Agricultural Embracing The IoT Vision," BRL Smart Farming Exclusive Summary, 2014 (online: <http://beechamresearch.com/>: accessed on; July 20, 2018)
- [5] Bongiovanni, Rodolfo, and Jess Lowenberg-DeBoer. "Precision agriculture and sustainability." Precision agriculture 5.4 (2004): 359-387.
- [6] Pablo J. Zarco-Tejada, et al., "Directorate-General for Internal Policies Department B: Structural and Cohesion Policies Agriculture and Rural Development Precision Agriculture: an Opportunity for EU Farmers." Potential Support with the CAP 2014-2020 (2014), [online], http://www.europarl.europa.eu/RegData/etudes/note/join/2014/529049/IPOL-AGRI_NT%282014%29529049_EN.pdf (Retrieved: July 2018)
- [7] Tongrod N, Tuantranont A, Kerdcharoen T. "Adoption of precision agriculture in vineyard." In Electrical Engineering/Electronics, Computer, Telecommunications and Information Technology, 2009. ECTI-CON 2009. 6th International Conference on 2009 May 6 (Vol. 2, pp. 735-738). IEEE.

- [8] Watthanawisuth N, Tongrod N, Kerdcharoen T, Tuantranont A. "Real-time monitoring of GPS-tracking tractor based on ZigBee multi-hop mesh network." In Electrical Engineering/Electronics Computer Telecommunications and Information Technology (ECTI-CON), 2010 International Conference on 2010 May 19 (pp. 580-583). IEEE.
- [9] Sungcom Techawongstien. "Factors Affecting Plant Growth and Development." Faculty of Agriculture, Khon Kaen University, 2004
- [10] Anucha Chantaraboon. "Fruit production." Faculty of Sciences and Agricultural Technology, Rajamangala University of Technology Lanna (Nan campus), ISBN: 978-616-361-604-3, 2010
- [11] Nikky Tilley, "Basic Plant Life Cycle and The Life Cycle of A Flowering Plant." 15 June 2015 (online: <https://www.gardeningknowhow.com/special/children/basic-plant-life-cycle-and-the-life-cycle-of-a-flowering-plant.htm>: accessed on July 21, 2018)
- [12] SpaceHero, "Biennial Plants Life Cycle." January 2018 (online: <https://superstarfloraluk.com/6624>
- 805-Biennial-Plants-Life-Cycle.html: accessed on July 21, 2018)
- [13] Trevor Hennings, "Stages of the Cannabis Plant Growth Cycle." July 18, 2017 (online: <https://www.leafly.com/news/growing/marijuana-plant-growth-stages>: accessed on July 21, 2018)
- [14] Putjaika, N., Phusae, S., Chen-Im, A., Phunchongharn, P. and Akkarajitsakul, K., 2016, May. A control system in an intelligent farming by using arduino technology. In Student Project Conference (ICT-ISPC), 2016 Fifth ICT International (pp. 53-56). IEEE.
- [15] Goldstein, Anat, Lior Fink, Amit Meitin, Shiran Bohadana, Oscar Lutenberg, and Gilad Ravid. "Applying machine learning on sensor data for irrigation recommendations: revealing the agronomist's tacit knowledge." *Precision Agriculture* 19, no. 3 (2018): 421-444.
- [16] Mbabazi, Deanroy, Kati W. Migliaccio, Jonathan H. Crane, Clyde Fraisse, Lincoln Zotarelli, Kelly T. Morgan, and Nicholas Kiggundu. "An irrigation schedule testing model for optimization of the Smartirrigation avocado app." *Agricultural water management* 179 (2017): 390-400.
- [17] Nguyen, Duc Cong Hiep, James C. Ascough II, Holger R. Maier, Graeme C. Dandy, and Allan A. Andales. "Optimization of irrigation scheduling using ant colony algorithms and an advanced cropping system model." *Environmental Modelling & Software* 97 (2017): 32-45
- [18] Fernández, José Enrique, Félix Moreno, María José Martín-Palomo, María Victoria Cuevas, José Manuel Torres-Ruiz, and Alfonso Moriana. "Combining sap flow and trunk diameter measurements to assess water needs in mature olive orchards." *Environmental and experimental botany* 72, no. 2 (2011): 330-338.
- [19] Bosch-Serra, A. D., C. Ortiz, M. R. Yagüe, and J. Boixadera. "Strategies to optimize nitrogen efficiency when fertilizing with pig slurries in dryland agricultural systems." *European Journal of Agronomy* 67 (2015): 27-36.
- [20] Snoeck, Didier, A. A. Afrifa, K. Ofori-Frimpong, E. Boateng, and M. K. Abekoe. "Mapping fertilizer recommendations for cocoa production in Ghana using soil diagnostic and GIS tools." *West African Journal of Applied Ecology* 17 (2010): 97-107.
- [21] Eiji Morimoto, Hiromi Fuji, Tsuyoshi Yoshida, Shinkai Shu, Norihiro Kamijima, Yoshiaki Hasegawa, "7th Asian-Australasian Conference on Precision Agriculture," Precision Agriculture Association New Zealand Technology for Sustainable Growth
- [22] Ohio country journal, "The right time for fertilizer application pays (because the wrong time is so costly)," September 30, 2016
- [23] Adhikari, Bikram, and Manoj Karkee. "3D reconstruction of apple trees for mechanical pruning." In 2011 Louisville, Kentucky, August 7-10, 2011, p. 1. American Society of Agricultural and Biological Engineers, 2011.
- [24] Takanashi, Hiroyuki, Hiromitsu Furuya, and Seiji Chonan. "Prediction of Disease Infection of Welsh Onions by Rust Fungus Based on Temperature and Wetness Duration." In Control Applications, 2007. CCA 2007. IEEE International Conference on, pp. 325-330. IEEE, 2007.
- [25] Tripathy, A. K., J. Adinarayana, S. N. Merchant, U. B. Desai, S. Ninomiya, M. Hirafuji, and T. Kiura. "Data mining and wireless sensor network for groundnut pest/disease precision

protection." In Parallel Computing Technologies (PARCOMPTECH), 2013 National Conference on, pp. 1-8. IEEE, 2013.

- [26] Wani, Hemantkumar, and Nilima Ashtankar. "An appropriate model predicting pest/diseases of crops using machine learning algorithms." In Advanced Computing and Communication Systems (ICACCS), 2017 4th International Conference on, pp. 1-4. IEEE, 2017.
- [27] Sannakki, S., V. S. Rajpurohit, F. Sumira, and H. Venkatesh. "A neural network approach for disease forecasting in grapes using weather parameters." In Computing, Communications and Networking Technologies (ICCCNT), 2013 Fourth International Conference on, pp. 1-5. IEEE, 2013.
- [28] Arya, Prawin, Ranjit Kumar Paul, Anil Kumar, K. N. Singh, N. Sivaramne, and Pradeep Chaudhary. "Predicting pest population using weather variables: an ARIMAX time series framework." *Int. J. Agricult. Stat. Sci.* Vol 11, no. 2 (2015): 381-386.
- [29] Collier, Rosemary H., Stan Finch, N. M. Endersby, and P. M. Ridland. "Forecasting attacks by pest insects of cruciferous crops." In *The Management of Diamondback Moth and Other Crucifer Pests. Proceedings of the Fourth International Workshop on Management of the Diamondback Moth and Other Crucifer Pests.* Department of Natural Resources and Environment. Melbourne, Australia, pp. 163-168. 2001
- [30] Padalia, Hitendra, Vivek Srivastava, and S. P. S. Kushwaha. "How climate change might influence the potential distribution of weed, bushmint (*Hyptis suaveolens*)?." *Environmental monitoring and assessment* 187, no. 4 (2015): 210.
- [31] Dille, J. Anita, David A. Mortensen, and Linda J. Young. "Predicting weed species occurrence based on site properties and previous year's weed presence." *Precision agriculture* 3, no. 3 (2002): 193-207.
- [32] Heisel, Torben, Annette Kjær Ersbøll, and Christian Andreasen. "Weed mapping with co-kriging using soil properties." *Precision Agriculture* 1, no. 1 (1999): 39-52.
- [33] Ehmke, Jan Fabian, Stephan Meisel, Stefan Engelmann, and Dirk Christian Mattfeld. "Data chain management for planning in city logistics." *International Journal of Data Mining, Modelling and Management* 1, no. 4 (2009): 335-356.
- [34] R. Mihalcea, H. Liu, and H. Lieberman, "NLP (Natural Language Processing) for NLP (Natural Language Programming)," *Computational Linguistics and Intelligent Text Processing Lecture Notes in Computer Science*, pp. 319–330, 2006. [Online: https://www.sas.com/en_us/insights/analytics/what-is-natural-language-processing-nlp.html] (accessed on July 12, 2018)
- [35] Tutorialspoint. "AI - Natural Language Processing.", 2018 [online: https://www.tutorialspoint.com/artificial_intelligence/artificial_intelligence_natural_language_processing.htm] (Accessed on: July 2018)
- [36] MSBI Tutorials. "HOW TO IMPLEMENT ETL PROCESS USING SSIS WITH AN EXAMPLE.", 2017 [online: <http://www.learnmsbitutorials.net/etl-process-ssis-example.php>] (Accessed on: July 2018)
- [37] Ghadiyali, Tejas, Kalpesh Lad, and Bankim Patel. "ETL techniques and challenges in agriculture intelligence." *Proceedings of AIPA, India* (2012): 85-91.
- [38] Vassiliadou, Sophia, Dimosthenis Mpoutakidis, and Michail Karikas. "Application of Relational Database in Listing Pesticides Used In Greece According to their Hazards In Human Health and the Environment." In *HAICTA*, pp. 463-471. 2011.
- [39] Krintz, Chandra, Rich Wolski, Nevena Golubovic, Benji Lampel, Varun Kulkarni, Bruce Roberts, and Bo Liu. "SmartFarm: improving agriculture sustainability using modern information technology." In *KDD Workshop on Data Science for Food, Energy, and Water*. 2016.
- [40] Margaret Rouse, "SQL (Structured Query Language)." Sept. 2016 (online: <https://searchsqlserver.techtarget.com/definition/SQL>: accessed on July 28, 2018)