INTELLIGENT AGRICULTURE

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Developing a System for Monitoring and Controlling Production

BY

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INVESTOR IN PEOPLE

We dedicate this book project to our families. Their love and constant and unconditional support have been an invaluable source of strength and inspiration to complete this project.

Gonzalo Maldonado-Guzmán
Jose Arturo Garza-Reyes
Lizeth Itziguery Solano-Romo

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INTRODUCTION

Agriculture is today one of the fields of knowledge least analyzed and discussed by various researchers, academics, and professionals not only in the field of agriculture but also in different areas of knowledge, although it is an elementary construct for the existence of humanity itself (Ding et al., 2018). Also, currently, the total world population amounts to a little more than seven billion people, and according to the estimates that have been made by the main international organizations, it is expected that by the year 2050, it will generate a substantial population growth of a little more than 2.5 billion people, which will be located primarily in the main urban cities, which will mean that a little more than 90% of the total world population will be concentrated practically in two continents: Asia and Africa (Lloyd, 2017).

However, world food production is totally limited, especially in Africa, and the serious problem of food shortages worldwide has not yet been resolved (Sánchez, 2002). In addition, the Asian continent has serious problems of shortage of drinking water (Pomeranz, 2009), even though 72% of the total surface of the earth is covered by water, and it is estimated that there are a little more than 1.45 billion cubic kilometers of water. Despite the existence of an extensive territorial extension covered by water, a little less than 1% of the total water on the planet is fresh water that is used not only for human consumption but also for agricultural irrigation, which represents a little more than 13 billion hectares; however, only 22% of that land is potentially arable (Lal, 1990).

In this context, there are currently diverse countries that apply traditional agriculture methods that have a high consumption of potable water, are intensive in labor, use fungicides and pesticides that are highly polluting, and are low in productive efficiency (Ding et al., 2018). Therefore, considering the significant increase in the world's population, the severe shortage of drinking water, the existing limitation of resources, and the low level of efficiency of agricultural productivity, among other factors, it is indispensable and urgent that researchers, academics, and professionals from all areas of scientific knowledge guide their studies in the analysis and discussion, not only of the efficiency of a regulated agriculture but also in the development of agrotechnology that propitiates an *Intelligent Agriculture*, because this will allow an adequate utilization of the available resources.

In this sense, even when the systems of Smart Agriculture are too complex, multivariate, and unpredictable (Kamilaris, 2018), it is also possible to incorporate classic technological controls, such as integral processes or differentiated integral processes (Christofides, 2013; Afram and Janabi-Sharifi, 2014), which are not only easy to implement but also to control the movement processes they generate, thereby allowing an adjustment in the control of energy and the time of consumption (Wang, 2001). In addition, the use of intelligent methods such as the control of fuzzy logic, linear regression, and artificial neural networks involves not only deterministic mathematical models but also generalized mathematical models and mixed models, which allow the development of predictive models of agricultural production more accurately (Afram and Janabi-Sharifi, 2014).

Likewise, the use of these mathematical methods require a high level of reasoning and understanding and are generally based on the use of historical data on agricultural or agroindustrial production, or on the generation of expert or high-level knowledge (Ding et al., 2018). Therefore, the performance of the mathematical models of control and prediction of agricultural production is superior to that of the classic models of production control, and they are generally simpler to implement when using intelligent algorithms through computers. Thus, the mathematical models of production control and prediction have a high reliability and accuracy of the levels of agricultural and agroindustrial production, in addition to significantly reducing the use of drinking water, electricity, and emission of CO_2 (Ding et al., 2018).

Similarly, control and prediction models of agricultural or agroindustrial production generally refer to the use of advanced algorithms through computers that are used to explain and develop predictive models of future growth that plants will have, or the growth that is estimated to have food production (Qin and Badgwell, 2003). Therefore, this type of control and prediction models work with a series of inputs that are controlled by the computers during a certain period of time, and they take the data usually from a selected sample of a dataset that reveals agricultural or agroindustrial production; however, only some of these models are implemented in the production prediction process (Bumroongsri and Kheawhom, 2014) because they generate the smallest possible error in the prediction of food production.

In addition, the use of advanced algorithms in the models of control and prediction of agricultural production is often done through three steps: prediction models, optimization in its implementation, and adjustment in the feedback (Zhang, 2017), with these three steps being equally important for the development of agricultural control and prediction models.

Production control and prediction models were developed at the beginning of the 1960s, and these types of models were used almost exclusively in the process of predicting industrial production (Garriga and Soroush, 2010); however, its use has expanded to all areas of scientific knowledge, and its use has been considered important and paramount in all production prediction processes, including, of course, agricultural and agroindustrial production.

Additionally, most of the production control and prediction models require a series of constraints, predictive information, and linear and nonlinear dynamics for their application (Ding et al., 2018). Linear models of control and production prediction are usually used to solve quadratic problems of online programming, and nonlinear production control and prediction models are generally used to control systems with nonlinear dynamics, for which undoubtedly greater mathematical calculations than linear models (Vukov, 2015) are required. In addition, matrices of control dynamics and controlled algorithm models, which are commonly based on linear quadratic mathematical models that are relatively easy to use, have recently been incorporated into the theory of production control and prediction models.

Within the models of controlled algorithms are the models of internal control, which are widely used by researchers, academics, and professionals in the field of computer science and mathematics, and which can be defined as a simple entry and/or exit of information through a discrete time series system (García and Morari, 1982). Therefore, it is possible to affirm that the internal control models are nothing more than a combination of a dynamic control matrix and a model of control algorithms, but theoretically it is better; and the internal control model is more complete than the two previous models, and usually the internal control model tends to solve the problems of control and production prediction more robustly and with a much smaller error, which makes the model more efficient and effective.

Therefore, given that industrial processes are increasingly complex, involve an increasing number of interfaces, and are strongly non-linear, it is essential that new production control and prediction models are adapted and implemented in the companies of all sizes and sectors, as is the case of internal control models, which are more robust and have the minimum possible error in their application (Ding et al., 2018). However, the time to perform the calculations for the internal control models should be relatively long and totally efficient, to aspire to obtain robust results and with a minimum error, for which researchers and academics have considered necessary that this type of models be stabilized (Ding et al., 2018), that is, that they adapt to the production processes of the companies where they will be applied (Zhang, 2017).

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- Ruben Michael Rodríguez-González, Student Research Assistant in MBA, Universidad Autónoma de Aguascalientes, Mexico.

CHAPTER 1

CONSUMER DISCOVERY

1.1. INTRODUCTION

The literature pertaining to business studies and management shows that various researchers, academics, and professionals belonging to that field are paying special attention to the use of data and information that reflects the changes that are being made to the current or future assets or services of the consumers and suppliers (Chien-Hsing et al., 2005). Therefore, it is extremely important for today's organizations to process all information regarding the use of technology by consumers. This would facilitate the use of currently available information and technology, and increase the value of future applications that would be developed. This, in turn, could generate a higher level of acceptance among current consumers, since new applications would not only facilitate the use of current technology but also increase its usefulness.

Consequently, the extensive development of technological support in decision-making processes that are based on data and information has increased significantly in the last two decades (Chien-Hsing et al., 2005). One of the pioneering works in this regard has been conducted by

Shim et al. (2002), who presented a descriptive analysis, through an extensive review of the literature, of the technological support prevailing in the decision-making capacity of the companies, with regard to their past, present, and future implementation. Thus, to use the existing data and information more efficiently with respect to potential consumers, new information technologies have introduced new developments and applications, technologically developed products, and new knowledge generated through the discovery of potential customers, which allows the creation of databases and its data mining in organizations (Chien-Hsing et al., 2005).

In this sense, databases and data mining fundamentally orient the integration of information management of current and future clients, are a representation of knowledge, and improve the understanding regarding the use of new machinery, equipment, or developed technology (Fayyad and Stolorz, 1997). This generally facilitates the descriptive and predictive processes for the discovery of new clients or business partners through a series of historical data that were previously collected. Therefore, databases and data mining are the two fundamental elements for the discovery of customers in any current business, and its use has been significantly extended in the last two decades by researchers, academics, and professionals of the business sciences as an effective measure for the making and management of decisions (Han and Fu, 1999).

Thus, for example, the discovery of new customers who prefer to have a low annual reward will reveal consumers who are more predisposed to buy the product or service that is being offered than those consumers who prefer high levels of rewards; this will facilitate in decision-making (Chien-Hsing et al., 2005). Pitta (1998) came to the conclusion that the generation of databases and data mining are important tools that marketing personnel of companies can use to discover customers who will be willing to consume their products: products, services, or technology. Feelders, Daniels, and Holsheimer (2000) in their study presented a fundamental concept for the generation of data mining, as well as the processes that are to be followed for their application; this would ensure that the application is carried out properly in a timely manner.

In this context, the application and development of databases and data mining in various business areas are increasing not only because of its usefulness but also because of their importance in making business decisions and for the discovery of customers for new products, services, or technology (Chien-Hsing et al., 2005). Thus, the studies oriented regarding the market data of hotels (Sung and Sang, 1998), the prediction of bankruptcy of personnel (Donato et al., 1999), the services of support for the clients, those that are dealt with in the special edition published by Kohavi and Provost (2001) in the *Journal of Data Mining and Knowledge Engineering*, and budget allocations for the acquisition of library materials (Wu, 2003) are clear examples of studies conducted that consider the generation and use of databases and data mining as essential in the discovery of business customers.

In addition, the development and implementation of databases and data mining usually follows six essential steps: (1) identification of the problem, (2) collection of data or information, (3) reprocessing of data or information, (4) processing of data or information, (5) implementation and interpretation of the data or information found, and (6) evaluation of the data or information found. Thus, the identification of the problem helps to specify the criteria or questions that should be commonly raised for the improvement of the decision-making capacities. Data collection involves the compilation of data and important information that is generally used for the definition of objectives and goals of the organization. The reprocessing of data uses diverse mathematical operations that redefine and reconstruct the consistency of the information, the attributes of the same, and a combination of data and information that are highly correlated with each other in order to reduce the maximum possible errors while decision-making.

Data processing generally employs a data mining mechanism to capture the knowledge discovered through association, classification, regression, clustering, and summarization – generalization. The interpretation of discovered or generated knowledge results in its use through different techniques that provide output in the form of text, tables, figures, graphs, animations, diagrams, etc. Implementation is nothing but the transformation of the results obtained while making business decisions. The results generated by the implementation of the knowledge are evaluated through various performance tests.

Finally, following the aforementioned six stages for the development and implementation of the databases and according to the requirements of the British Council and the Newton Fund, the discovery of the clients for the development of agrotechnology can usually be done by applying four fundamental elements: (1) benchmark analysis against other similar technologies, (2) technological roadmap, (3) intellectual property analysis, and (4) value proposal. All of these will be analyzed in detail in the following sections.

1.2. BENCHMARK ANALYSIS AGAINST OTHER SIMILAR TECHNOLOGIES

In recent years, in Mexico agriculture is gaining importance. In 2007, 20,184 hectares were under plantation. The main states involved in agriculture, in order of importance, are Guanajuato (with more than 50% of its area being planted), Puebla, and Michoacán. In these states, the usage of balers and freezers is very common. Such practices allow the produce to be shipped to other countries in America, Europe, and Asia. Broccoli (*Brassica oleracea*) is a crop that develops mainly during the autumn and winter seasons. For the plant to develop normally, temperatures during the growth phase must oscillate between 20 and 24°C. To start the floral induction phase, temperatures between 10°C and 15°C are required for several hours of the day.

The plant prefers soils that are acidic and not too alkaline, with an optimum level of pH (acidity) between 6.5 and 7. Additionally, the plant also requires soil of a medium texture, which supports an excessive salinity of the soil and a better irrigation of water. Currently, there are varieties that tolerate humid warm climates: Tamer, Avenger, and Maximum, which can adapt to the climatic conditions of southern Sinaloa, especially during the months of November to February (winter). For this reason, it is important to validate the broccoli varieties and determine whether it is feasible to grow them in that particular area as they are widely in demand by the freezing companies; moreover, broccoli cultivation could be an alternative for the horticultural producers of the southern regions of the state.

Broccoli is a vegetable that develops favorably in cold and fresh climates, tolerating temperatures of up to −2°C, as long as the inflorescence is not present in the plant; or else, it will be easily damaged by the drop in temperature. Its optimum development temperature is 17°C. It adapts almost to any type of soil, but, like all vegetables, it prefers not very light, uniform, deep soils with good drainage and with an optimum pH of 6 to 7.5 (although it grows even from 5 to 5.5 pH). It can be planted directly or transplanted, with the latter being currently considered to be the best form of establishment. This is because the new varieties require sowing in trays if 100% advantage is to be obtained from the seeds that are procured from the trading houses.

Planting densities are varied: ranging from 30,000 to 80,000 plants per hectare; this will depend on the prevailing climatic conditions of the region and the market where the final product is destined, that is, whether for the industry or for sale in the fresh market. In order to obtain these densities, different planting systems are also managed. In order to obtain a population density of 80,000 plants per hectare, it is necessary to make furrows to each meter and plant in a double row for every 22 cm; in a single row, each 33 cm, 30,000 plants per hectare can be obtained. In plantations of high densities, it is necessary to carry out the transplant in a triangular manner, since in this way space is better utilized and air circulation is much better, favoring the reduction of diseases.

Currently, broccoli has diverse varieties with different shapes, colors, and sizes; its grains range from fine to coarse, and from faint green to intense green; likewise, its inflorescence can be from very compact to semi-open. These aspects are taken into consideration in the production regions; there are varieties that can be classified into early, intermediate, and late. Over the years, the desirable characteristics have been selected and their property increased for producers so as to produce varieties with high productivity, resistance to pests and diseases, and adaptation to different types of climates, existing not only in the different regions of the geography of Mexico (north, central, and south) but also in every country of Latin America.

In Mexico, the main broccoli-producing states are Guanajuato, Michoacán, Puebla, and Jalisco, with 13,337, 2,509, 1,350, and 1,248 hectares, respectively, with yields ranging between 11 and 21 tons per hectare (t/ha). The prices of broccoli in the national market are diverse, but it usually remains constant almost all the year round: during 2009, they ranged between 12 and 17 Mexican pesos, with an average of 13.86 Mexican pesos per kilogram of fruit (*Central de Abastos de México*). The price in the US markets ranges from 1.16 to 1.32 dollars per pound of fresh fruit. All the aforementioned data show that broccoli cultivation is a profitable production option for Sinaloa; moreover, it is important to locate new regions for production, so that the export of the product is increased resulting in the generation of a large amount of foreign currency by its sale.

Currently, there are diverse companies offering technical and information services to agroindustrial companies, the following are the most important worldwide:

(1) VegHands
  - Together with several suppliers, VegHands offers the best of the market in terms of harvest systems – from harvesting bands to harvesting and packing solutions for the field.
  - It specializes in lettuce (iceberg), broccoli, cabbage, herbs, and similar products.
  - It provides harvesting bands.
  - It has mobile bands, with single or double band (on which one can also work with boxes). Strong but lightweight bands can be easily mounted next to the trailer, and can be moved along during the harvest for optimal logistics. The bands can be mounted from one trailer to the other in just a few minutes.
  - Fixed bands are mounted on trailer especially for the transport of boxes and baskets (construction of single

or double band). They are easy to mount next to the trailer during transport from field to field.

- Fixed chains are mounted on a trailer and are ideal for unloading boxes and baskets placed in the holder. They supply many alternatives, tailored to one's needs. It is possible to combine the fixed chains with a special system for rotation of baskets, with which one can change filled baskets without stopping or changing the truck basket.

(2) Brioagrow

- Brioagrow helps farmers improve the information they have obtained regarding the evolution of their crops by monitoring, in real time, the main variables in which they can intervene. Measuring seven fundamental variables, both environmental and edaphic, together with geolocalized weather forecasts, they allow the farmer achieve maximum production, with the best quality, and reduction in water consumption, fertilizers, and energy. Among the variables controlled by the farmer are soil moisture, at different depths, conductivity (to know the mineral salts of the soil), and temperature; and they help control temperature, humidity, luminosity, and leaf wetness in the environment. They integrate the geolocalized meteorological data plus rain forecasts, cloudiness, relative humidity, and wind speed and direction into their dashboards .
- The application of Big Data and data mining is fundamental for the detection of diseases in the field and the efficiency to which one can achieve today, as well as in the future, with this new technology.
- The more data one has, the greater the degree of reliability on the patterns and resolutions obtained