Agricultural Price Prediction Models: A Systematic Literature Review

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Abstract

Agricultural product price prediction is an effort to anticipate the impact of changes in product prices. Various methods have been used to predict the prices of various agricultural products. The purpose of this study is to review various methods of predicting agricultural product prices in the literature study and to provide future research challenges. A comprehensive review of the research topic is presented in the Systematic Literature Review. The text mining approach is used to see an overview of research based on the appearance of words in the article. The results showed that the methods commonly used to predict the price of agricultural products are Artificial Intelligence (30%), Data Mining (22%), and Regression (18%). The contribution of this research includes the latest research positions, recommendations for the best methods, and proposals for future research taking into account the current pandemic conditions

Keywords
Agriculture, Price Prediction, Systematic Literature Review

1. Introduction

Agriculture plays an important role in human life in the world. Data from the Food and Agriculture Organization (FAO) of the United Nations shows an increase in the production of agricultural commodities every year by 4.1% in the last 10 years to 2019 (FAO, 2019). In the conditions of the Covid19 pandemic, FAO has observed a slowdown in demand for agricultural commodities (Schmidhuber et al., 2020). Regardless of these conditions, the issue of price is a key factor in financial and business activity in agriculture (Hasan et al., 2020).

Price is the link between seller and buyer to transact. In the case of agriculture, farmers can also act as sellers of their crops. The buyer in this case is the final consumer of the agricultural product. For strategic agricultural commodities, the role of the government is needed to maintain price stability at the consumer level. Prediction of the selling price of agricultural products is needed to anticipate the impact of price changes. These agricultural price predictions are used to benefit farmers, governments, the agribusiness industry, central banks, policymakers, companies and consumers whose decisions depend on future inflation expectations (Kyriazi et al., 2019). Prediction of prices for agricultural products is needed for the government to control prices in the market and subsidy policy (D. Zhang et al., 2018). With accurate predictions, it will increase farm income and study the risks that exist in the market (Y. Zhang & Na, 2018). So that farmers can make better and more informed decisions about prices and production (Mahida & Patel, 2018).

The era of agriculture 4.0 was marked by the use of various information technologies in agriculture (IPB, 2019). Some of the commonly used technologies are Artificial Intelligence and Big Data. These technologies are used for yield prediction, crop disease detection, crop management, pest control, disease control, irrigation management, soil nutrient management, production monitoring, and storage monitoring of agricultural products. (Bannerjee et al., 2018; Jha et al., 2019; Liakos et al., 2018).

Previous research on reviews of agricultural commodity price predictions has been conducted by (Kadlimatti & Saboji, 2019; Kaur et al., 2014; Mahida & Patel, 2018; L. Wang et al., 2020). Research (Mahida & Patel, 2018) has reviewed data mining techniques for the prediction of vegetable commodity prices. Research [12] and [13] provide recommendations on suitable methods to predict the price of agricultural products using data mining. Research (L. Wang et al., 2020) reviews comprehensively various methods in predicting agricultural prices and classifies the methods into 3 parts: traditional, intelligence and hybrid.

In contrast to the above, this paper presents a descriptive analysis of scientific articles related to price predictions for agricultural products. The approach utilized in this paper are the Systematic Literature Review (SLR) and text mining. Text mining is utilized to depict of existing examination dependent on the words in each chose article. SLR is utilized to give a comprehensive review of agricultural product price prediction research. The contribution of the article lies in the current research position as well as future research proposals on the prediction model for agricultural product prices.

1.1 Objectives

This study aims to determine the position of research on agricultural commodity price predictions during 2006 - 2020.

2. Methods

The Systematic Literature Review (SLR) process with text mining is presented in Figure 1. This process is a development of the SLR method (Xiao & Watson, 2019) with the addition of a descriptive analysis process. The text mining process is used to provide an overview related to research on agricultural product price prediction models based on words that appear in every scientific article (O'Mara-Eves et al., 2015).

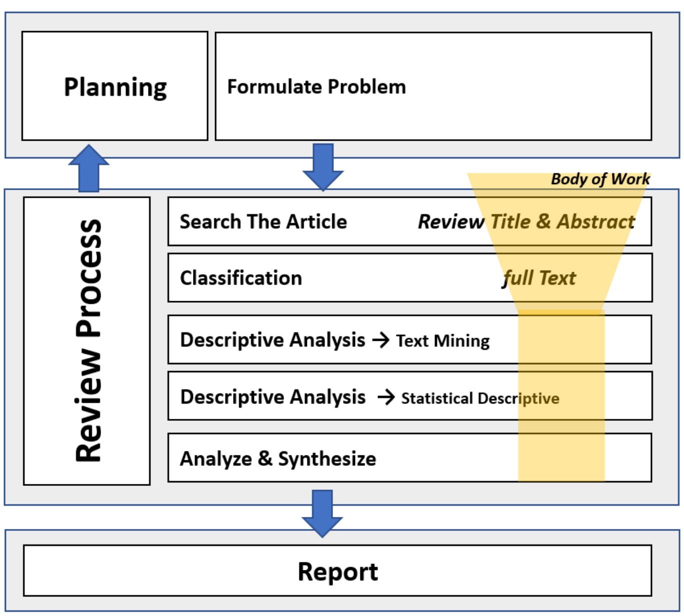

Figure 1. SLR Process with Text Mining

General guidelines used in the search process and article classification process are as follows, (1) The search keywords used: *price prediction, smart pricing, price recommendations* and *agriculture price.* (2) Articles for the period 2006 - September 2020 with reputation and index. (3) The process of clustering is carried out by classifying the articles into subtopics. If there is 1 scientific article with more than 1 subtopic, then one dominant subtopic will be selected. In terms of method selection, if there is a paper comparing several methods, it will be classified into the method with the highest level of accuracy.

Descriptive analysis is used to provide an overview of agricultural product price prediction research. The text mining process uses NVIVO 12 software with results in the form of word clouds, clustering trees and searches for connected words. This process provides an overview of the research based on the words that appear throughout the scientific article. Descriptive statistics are used to see the position of the research on price prediction of agricultural products. The results in this process are presented in diagrams and graphs. The synthesis process is carried out based on the results of the descriptive analysis. The development of research proposals is obtained from the results of the analysis and taking into account the current agricultural conditions.

3. Results and Discussion

3.1. Search Results and Article Classification

Based on the search results according to keywords, 27 papers were obtained from the 2006 - September 2020 period and had a big theme of predicting agricultural product prices. Collected scientific articles are then reclassified based on the sub-theme of scientific articles. The grouping process is carried out *based on* the large number of methods used in scientific articles. Based on the settlement methods are categorized into artificial intelligence, regression, data mining, other methods, stochastic modeling and dynamic modeling. Based on the data, the research is grouped into time series data and others. Based on the commodities, they are classified as agricultural food products, plant-based food products, animal-based food products and other specific food products. The classification results are presented in the descriptive analysis in Figure 2.

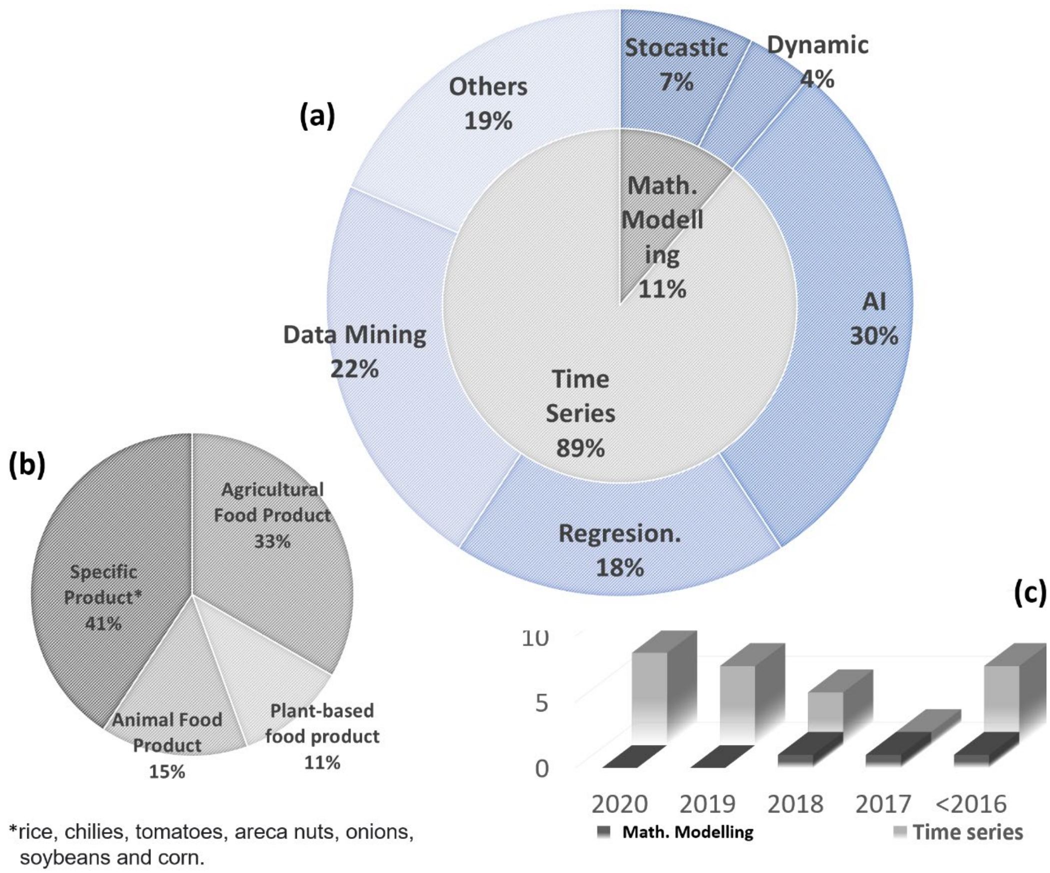

Figure 2. Paper classification results

3.2. Descriptive Analysis Results

The results of text mining are presented in Figure 3 (a) in the form of word clouds. In the picture, we can see the dominance of words in scientific articles including price, model, forecast, agriculture, data, prediction and neural network. The dominance of the word forms clusters in the form of a tree as shown in Figure 3 (b). In this picture, it can be seen that neural network is a word that is often used for data prediction.

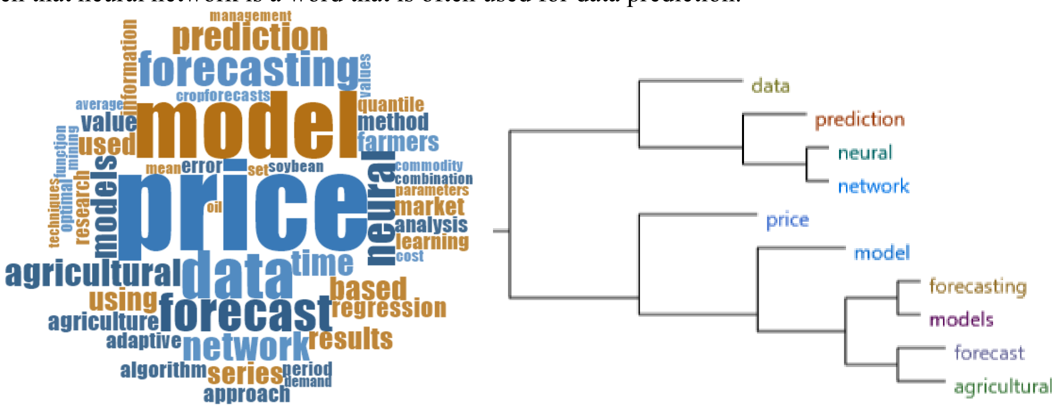

Figure 3 (a) word-based clustering results; (b) Word Clouds

Based on Figure 2 and Figure 3, it can be seen that the dominance of research related to the prediction model for agricultural product prices is as follows :

1. As many as 89% of research uses time-series data to predict agricultural commodity prices.
2. The majority of the research focuses on one type of agricultural food product (41%). Products that have been discussed include rice, chilies, tomatoes, areca nuts, onions, soybeans and corn.
3. In terms of prediction using time series data, the methods commonly used are artificial intelligence as much as 30%, data mining 22% and regression as much as 18%..
4. As many as 11% of the research uses mathematical modeling in predicting commodity prices, with 7% using the stochastic model and 4% using the dynamic model.

3.3. SLR Result

In summary, the SLR results are shown in Table 1. Artificial intelligence is a technique that is often used in predicting prices for agricultural products. Artificial intelligence itself is a machine or program that has intelligence in it to complete a job (Dinh & Thai, 2018). Generally, the method used is based on a neural network.

Data mining is a stage for processing data into knowledge (Han et al., 2012). The stages include data retrieval, data preprocessing, mining processes, evaluation and use of knowledge. The ARIMA (autoregressive integrated moving average regression) method is a method commonly used with data mining techniques. However, it is not impossible to gain knowledge using other methods such as neural networks and regression.

Regression in the case of price data is an analysis of the correlation between the factors affecting the price and to form an equation that relates price to time (L. Wang et al., 2020). This method is widely used because of its simplicity in building models. Also, the regression model has a good model interpretation. The regression problem can be viewed as a classification problem so that some regression work can be solved by a classification algorithm.

According to (J. Wang et al., 2019) the most popular time series data prediction methods are autoregressive integrated moving average regression (ARIMA), gated recurrent neural network (GRU), long-short term memory neural network, (LSTM), support vector regression (SVR) and recurrent neural network (RNN). The mathematical modeling approach is used to model problems without using time series data. The approach taken is to use stochastic models and dynamic models.

There are 8 cases of comparison of methods from the articles found. Apart from data differences and differences in the scope of the research used, the neural network method is the dominant method (50%) of cases with high accuracy performance. In four different cases the KNN-regression method, DP Meals, Lagrange Numerical Method and Gray Method have superior performance compared to neural networks.

Table 1. Results of Literature Studies

No	Ref. No	Method						Data		Object				Description
		a	b	c	d	e	f	g	h	i	j	k	l	
1	(Brown & Rogers, 2006)			●				●		●				The price simulation uses the concept of data mining on agricultural products
2	(Shih et al., 2009)				●			●				●		Price prediction of chicken with CBR
3	(Lia et al., 2010)		●					●				●		Egg price prediction with regression
4	(Karia & Bujang, 2011)	●						●					●	Oil price prediction using ARMA and NN
5	(G. qiong Li et al., 2012)		●					●				●		The price prediction model uses regression for animal-based food products.
6	(Zong & Zhu, 2012)				●			●		●				Price prediction of agricultural production with gray prediction
7	(Nasira & Hemageetha, 2012)			●				●			●			A data mining approach to price predictions for vegetables
8	(Ahumada et al., 2012)					●			●				●	Development of a stochastic model based on distribution and production for commodity tomatoes.
9	(Z. min Li et al., 2013)	●						●				●		Weekly egg price prediction with neural network
10	(Kaur et al., 2014)			●				●		●				The concept of data mining for prediction of agricultural prices
11	(Shivam Gupta et al., 2017)						●		●				●	The price prediction model uses Stochastic Dynamic Programming in rice commodities
12	(Mahida & Patel, 2018)			●				●			●			Data mining techniques for predicting vegetable prices
13	(D. Zhang et al., 2018)	●						●					●	Prediction of soybean prices with Neural Network
14	(Y. Zhang & Na, 2018)	●						●		●				Price prediction uses fuzzy milk, meat, cereals
15	(Widodo et al., 2018)						●		●		●			Multi period price prediction model for local fruit based on SCM
16	(Vohra et al., 2019)		●					●					●	Price prediction of rice, chili & wheat using price averages
17	(J. Wang et al., 2019)	●						●					●	Use of bee colony for prediction of maize prices.
18	(Kyriazi et al., 2019)		●					●		●				Prediction of agricultural product prices by adaptive learning.
19	(Kadlimatti & Saboji, 2019)			●				●			●			Agricultural price prediction with data mining
20	(Varun et al., 2019)				●			●			●			Use of the M1 technique to solve the agricultural price problem
21	(Deepalakshmi et al., 2019)			●				●					●	Development of statistical price prediction methods for potato and carrot products
22	(Hasan et al., 2020)	●						●					●	Comparison of NN performance with other algorithms on onion price predictions
23	(Sarthak Gupta et al., 2020)				●			●					●	Comparison of the performance of the Lagrange interpolation method with other algorithms at the lowest selling price recommendation from the Indian government for rice products
24	(H. Li et al., 2020)				●			●					●	Comparison of the performance of the DP-MEALS method for soybean price predictions
25	(Yuan & Ling, 2020)	●						●		●				Comparison of LSTM performance for prediction of tomato, chicken and chili prices
26	(Sabu & Kumar, 2020)	●						●					●	Comparison of LSTM performance for betel nut price predictions
27	(Mukhlisin et al., 2020)		●					●					●	Comparison of the performance of the KNN regression for the prediction of the national rice price

Note:
a: AI, b: Regression, c: Data mining, d: Others, e: Stochastic Model, f: Dynamic Model; g: time series, h: nontime series;
i: Agricultural Food Products, j: Plant-based Food Product, k: Animal Food Products, l: specific food products..

3.4. Future Work

The search results based on keywords for future research are presented in Figure 4. Based on Figure 4, it can be seen that the future challenge in this study is how to predict prices in complex supply chain management. Besides, fluctuations in production levels are also a research challenge. Based on this and in terms of the results of research dominance and considering the current pandemic conditions, it is suggested that future research developments on Figure 5

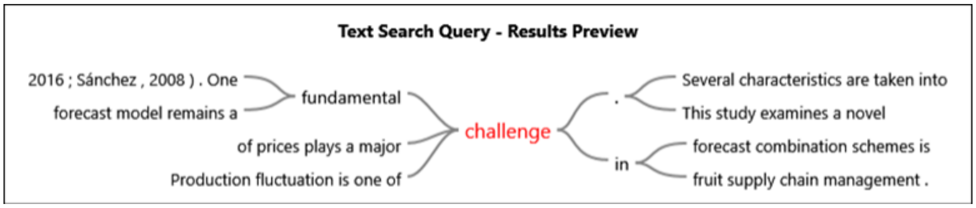

Figure 4. Search results for sentences related to keywords

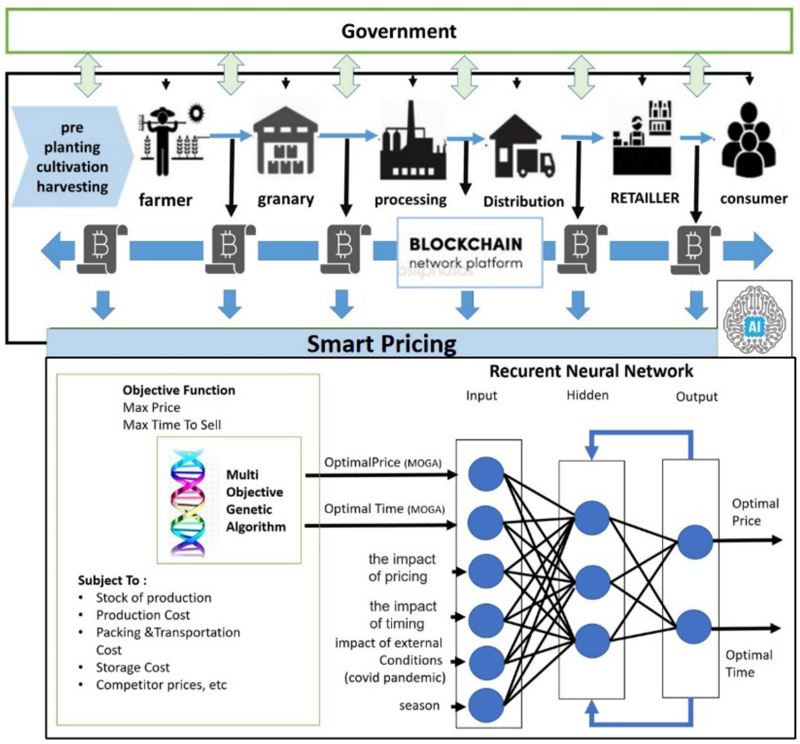

Figure 5. Integrated Smart Pricing Model

The smart pricing model was developed using the concept of Multi Objective Optimization Problem (MOOP) and Neural Network. In the MOOP model, the optimal price and optimal sales time will be sought by considering the economic constraints of the agricultural business. This MOOP model is useful for startup activities where generally they do not have initial data to be studied by machines. The completion of the MOOP model can use a genetic algorithm (MOGA).

Over time, the system will store all activities so that there will be time series data in large sizes (big data). This data can be studied further by adding attributes such as price influence, time effect, weather conditions to sales impact data due to the Covid 19 pandemic. This model will provide price and time recommendations for all actors involved with the necessary attribute adjustments.

The smart pricing model is proposed by considering the complex supply chain concept, in which there are many actors involved, from farmers to consumers. In this case, data security is a matter to consider considering that there are many actors with their interests. For this reason, the use of Blockchain technology is proposed to increase data security from farmers to consumers (Salah et al., 2018; Wihartiko et al., 2021). The government can access the data needed to control the policies issued.

4. Conclusion

The prediction model for agricultural product prices is needed by various stakeholders to anticipate price changes. The results of the critical study provide a research position regarding the prediction model for agricultural product prices. The neural network method is a method that is often used and has the potential for high accuracy. Opportunities for novel research are still wide open, especially in price predictions using mathematical modeling. Suggestions for the continuation of research is to use the right method and according to user needs so that the system being developed can be of benefit to all stakeholders

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