Scientific Publications

Open Journal of Agricultural Research, 2024, 4, 1011
www.scipublications.org/journal/index.php/ojar
DOI: 10.31586/ojar.2024.1011

Article

A Hybrid Based Recommender System for Enhancing Data Availability on Crop Market

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Abstract: Smallholder farmers face challenges when they lack information on their agricultural activities. To address this, we suggest a web-based system that can be used by farmers to help them in decision making considering the fact that all necessary information is provided by the system. Farmers can input crop type they want to grow and area. This data will help to recommend them the best crops that are suitable to be grown in that area and the necessary growing practices that can be done to produce high yield and have maximum profits, considering the average rainfall of that year. A persistent issue we face in Zimbabwe is the lack of access to reliable agricultural data. In the agricultural sector, one major uncertainty for farmers is the outlook of their future harvest. Once their produce is ready for sale, the presence of other potential buyers compels traders to offer prices that align closely with those in the formal market. However, without timely information, traders can take advantage of the situation by purchasing crops at unfairly low rates. Having data that tracks prices across various markets in near real-time would enable farmers to have a precise and complete understanding of their selling choices to maximize their profits.

Keywords: Recommender System, Crop Market, Cosine Similarity, Item-Based Algorithm

How to cite this paper: Chibaya, Y., & Mutandavari, M. (2024). A Hybrid Based Recommender System for Enhancing Data Availability on Crop Market. *Open Journal of Agricultural Research*, *4*(1), 20–28. Retrieved from https://www.scipublications.com/journal/index.php/ojar/article/view/1011

Received: June 10, 2022
Revised: July 17, 2024
Accepted: July 31, 2024
Published: August 9, 2024

1. Introduction

A longstanding feature of human civilization is cultivation and agriculture. The agricultural sector is the cornerstone of any nation's economy and prosperity. The ability to access data and information is critical for decision-making regarding crop production. Data availability is the extent to which information or data is accessible and has been made available for use in procedures such as verification, aggregation, and comparison. Farmers in Zimbabwe find it challenging to decide what kinds of crops to grow and when to sow them, among other things, due to the existing lack of critical information, such as historical data and weather forecasts. Making decisions that will increase crop output and, ultimately, improve Zimbabwe's economic condition requires a framework that can improve data and information availability, given the crucial role that crop production plays in the economy.

Because of rising productivity, population expansion, and the use of modern technology, the market for analytics and recommendations in agriculture is projected to develop. The majority of people in Zimbabwe practice subsistence farming and are unable to efficiently participate in the marketing of their produce. The famers are emotionally and financially affected as their years of hard work go in vain [1]. To minimize risks and make well-informed decisions, farmers depend on fast and accurate forecasts of crop yields, crop recommendations and market trends [2]. Crop market analysis and recommendation techniques that are more traditional may find it challenging to fully represent the complex dynamics of agricultural markets since they usually rely on oversimplified statistical or machine learning models. In recent years, advice and analysis of the crop market and crop recommendation have increasingly relied on hybrid approaches. Hybrid solutions try to overcome the shortcomings of individual approaches and increase forecast accuracy and recommendations by integrating the benefits of many algorithms or methodologies. These hybrid techniques often integrate traditional statistical methods, machine learning algorithms, and domain-specific knowledge to leverage the benefits of each method [3].

1.1. Agricultural Data Availability Challenges in Zimbabwe

The current endeavor aims to expand data availability on the Zimbabwean crop market and develop a crop recommender system. Particular emphasis has been given to the agriculture industry since it is the main driver of Zimbabwe's economy. The government agency spearheading this project is the Ministry of Agriculture, Mechanization, and Irrigation Development. In the sections that follow, the crop market in Zimbabwe, the challenges associated with acquiring agricultural data, and the existing crop recommender systems—which offer a comparative analysis of many systems—are all thoroughly discussed. In general, agriculture is a science of sustainability. It is greatly impacted by the atmosphere in which this research must flourish. Every decision made on the farm is predicated on a study of the past, present, and future weather. This entails selecting the appropriate crops, controlling diseases and pests, and determining the ideal growing and harvesting seasons. These decisions are often difficult and driven more by intuition than by solid scientific evidence. Decision support systems can assist the farmer in making these decisions.

A few key components are necessary for a decision support system to function well. It must first help the user locate the precise data that is needed and identify the problem. Then, using the information gathered, it must generate many answers backed by empirical evidence rather than hunches. The system must then clearly explain each of these possibilities to assist the user in selecting one over the other.

In the last ten years, several decision support systems for various agricultural concerns have been developed. The main cause of these systems' low usage is the lack of expertise needed to use them. Most agricultural information can be found in agricultural databases. These databases are often fairly simple, and simplicity is better in terms of effectiveness and upkeep. Unfortunately, there is no common method for gathering or transferring data between databases, and these databases are often separated. As a result, few decision support systems exist that offer solutions based on local data. One method to address this problem is to use smart algorithms to harvest data from websites and add it to an agricultural database. A crop recommender system is one type of decision support system that can benefit from such a database.

1.2. Empowerment of Smallholder Farmers

Food, pandemic, and economic insecurity have made Zimbabwe's agriculture more vulnerable, necessitating innovative approaches for the industry that go beyond the introduction of the unusual virus. In Zimbabwe's semi-arid regions, smallholder farmers discuss how they mitigate the risks to agricultural productivity, such as by integrating crop and animal farming techniques to fend off shocks brought on by climate change. In this case, agricultural entrepreneurship, which includes raising small animals, offers substitutes for crop farming, supports the foundation of natural resources, and shores up short-term food and nutrition supplies. In the semi-arid smallholder agricultural and livestock sectors, the assessment of crop-livestock integration methods serves as a foundation for scaling up and supporting Zimbabwe's aim to move beyond survival tactics and change vulnerability to contestant strategies. Almost 80% of the land used for farming in sub-Saharan Africa is owned by smallholder farmers, who are a major source of food.

Their ability to produce and market their products, especially on a big scale, is a barrier preventing them from fully participating in the integration of national and international food supply networks because of their major position in rural livelihoods [5]. These wildly uneven production-to-consumption systems, which are mostly based on direct feed technologies, have caused the environment, ecosystem services, and natural resources to deteriorate and have resulted in high levels of food insecurity. As a result, there is enormous pressure on agricultural output. More recently, there have also been concerns about profitability because of market losses, ineffective production methods, and increasingly common natural disasters, particularly as a result of climate change.

1.3. The Structure and Functioning of the Crop Market Systems in Zimbabwe

The journal article by Chisango and Matondi focuses on investigating the structure and functioning of crop market systems in Zimbabwe [4]. The report makes an effort to clarify the workings of the country's agricultural markets, including the role intermediaries play and the challenges producers face. The researchers note that Zimbabwe's agricultural market systems are characterized by the presence of several middlemen. Agricultural product transactions are facilitated by intermediaries who act as a go-between for producers and customers. However, the data suggests that middlemen often lead to higher transaction costs for farmers, which reduces their profitability.

The primary conclusion of the study is that in crop market systems, middlemen are common. This dominance leads to a power imbalance and directly limits the access of smallholder farmers to official markets. Smallholder farmers frequently use middlemen as a result, and they may profit from this by offering lower prices for the produce. The paper also highlights how price discrepancies are exacerbated by smallholder farmers' limited access to official markets. A knowledge asymmetry and intermediaries may cause prices paid to farmers to be less than the actual value of their produce. This situation could deter farmers from pursuing agricultural ventures and negatively impact their income. To solve these problems, the researchers suggested that measures that promote fair trade standards and market efficiency be taken. Reducing the number of middlemen and increasing farmers' access to formal markets are crucial goals to pursue. Establishing direct market links and providing farmers with access to market information are two ways to do this.

1.4. The Role of Market Information Systems in Enhancing Crop Market Efficiency in Zimbabwe.

The journal explores the significance of market information systems in improving the efficiency of crop markets in Zimbabwe. The study aims to analyze the impact of access to timely and accurate market information on market dynamics and the welfare of farmers. The researchers emphasize that market information plays a crucial role in enabling farmers to make informed decisions regarding production, pricing, and marketing of their crops. Access to reliable market information helps farmers understand market trends, demand patterns, and prevailing prices, which in turn allows them to optimize their production and marketing strategies [4].

The report lists several ways in which crop market efficiency might be enhanced by market information systems. Firstly, it makes the market more transparent by providing farmers with up-to-date information on prices, supply, and demand. When information asymmetry is reduced, farmers are better able to negotiate fair pricing and make informed sales decisions. Second, market information systems promote market integration by strengthening market ties and streamlining the communication between producers and purchasers. By identifying potential customers and sales channels, farmers can increase their market share and benefit from more favorable market conditions.

Thirdly, having access to market information helps farmers better manage the risks associated with production and marketing. By modifying their production schedules, when to sell, and how to store their products depending on their understanding of price fluctuations and market dynamics, farmers can lower losses and boost revenues. Nonetheless, the paper acknowledges Zimbabwe's market information systems' shortcomings. Common issues include limited access to information and inadequate distribution channels. Obtaining accurate and timely market information is a challenge for many farmers, particularly those who reside in remote areas. The researchers propose a few remedies to address these problems. They emphasize that investments in information and communication technology (ICTs) are essential to improving information sharing and connecting with more farmers. This entails sharing market information on mobile, internet, and radio channels. In order to enhance farmers' understanding of market data and their ability to apply it, the researchers also emphasize the importance of capacity-building programs. Training programs can help farmers become more adept at analyzing market data, spotting trends, and applying their newfound knowledge to make informed decisions.

The importance of market information systems in enhancing the efficiency of Zimbabwe's crop market is emphasized in the article. It emphasizes the benefits of increased market integration, market transparency, and risk management in relation to having access to current and trustworthy market information. The paper recommends investments in ICTs, information dissemination methods, and capacity-building programs to give farmers wide access to market information and empower them to make informed decisions in the agricultural market.

2. Recommender Systems

The concept of recommendation started way back before the emergence of computers. Early forms of recommendation existed among ants, cave dwellers and other animals [7]. Ants spread into space looking for food. If one of them finds food, it goes back to the group leaving a scented trail that guides the rest of the community to the location of the food. Individual cave dwellers discovered new food by either trying it themselves or watching others try it. If one ate a new herb and got sick, that was a recommendation to others not to eat the herb. Otherwise, the herb was considered safe for consumption. Sharma and Singh argued that in ancient human civilizations (4,000 to 1,200BCE), recommendations took the form of what crop to cultivate and what religion to profess [7]. Much later between the 14th and 18th centuries, recommendations were about which territory to conquer. Very recently, senior family members found suitable individuals to marry their younger relatives. People also asked others where to buy the best food and what destinations to visit for holidays.

The emergence of computers brought new possibilities for recommendations. The capacity of computers to provide recommendations was recognized fairly early in 17 the history of computing [8]. Grundy, a computer-based librarian, used stereotypes derived from interviews to recommend books to readers who fell in those stereotypes. Soon, Tapestry was proposed to address overload in online information spaces. It enabled users to filter through their emails separating those from known contacts from the rest [7]. Automated recommender systems based on collaborative filtering emerged in the 1990s. Some of these included Ringo for music, Bell Core Videos Recommender for movies and Jester for jokes. Perhaps the most recognizable business application of recommender system is Amazon. Based on the user purchase history, browsing history, the current item the user is viewing and other users' behavior, Amazon can recommend items for the user to consider purchasing [8]. Recommender technology has gone beyond collaborative filtering to include content-based, Bayesian inference and case-based reasoning methods [9].

Users can now select things they like thanks to recommender systems. A recommendation system is a way to give users recommendations based on what interests them. This can also be applied to agricultural purposes. Farmers are offered recommendations for their production procedure based on agricultural elements. Additionally, new methods for enhancing agricultural farming may be suggested. Fertilizers and pesticides may also be suggested. Agaji Iorshase's hybrid recommender system, which suggests agricultural products, addresses problems with ratio dissemination, ramp-up, and serendipity [6].

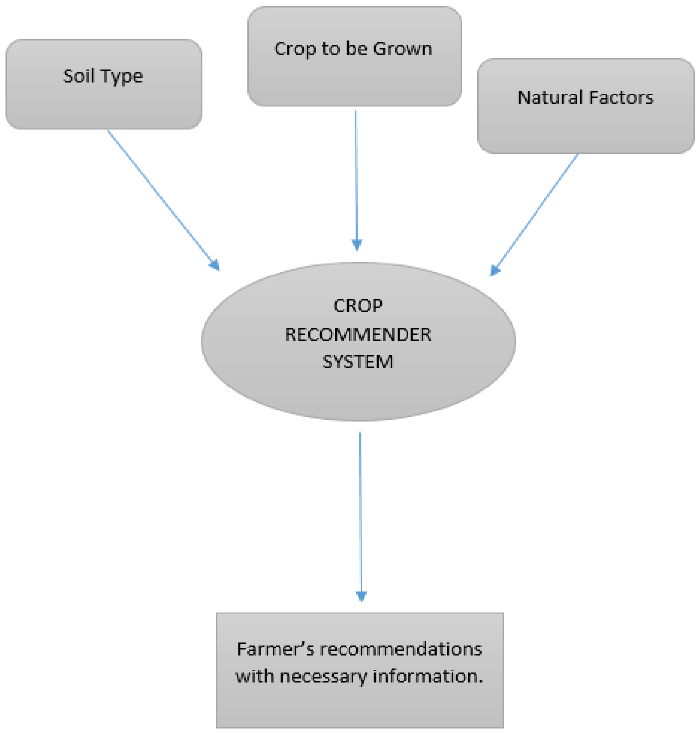

Figure 1. Crop Recommender System

3. Methodology

The proposed system tries to help small scale farmers, mainly in Mashonaland Central in decision making by being recommended crops that suits their environment and get necessary information for their cultivation, for profitability purposes for farmers. The system has to reduce costs incurred by farmers to get the crucial information on cultivation. The admin has to get authenticated first to see their dashboard, where he is responsible to add information needed by the system to make its predictions and recommendations. But this is different for the farmer. The farmer doesn't have a dashboard. They only have a page which contains a form with few fields to fill in, like area and crop to be grown. The recommended results will be based upon factors like area, rainfall etc.

On recommendation two techniques were used, that is, Content-Based Filtering Technique and Collaborative Filtering Technique, which constitute to give the Hybrid Technique. Each model was analyzed during the development of the project and the methods which used are to be highlighted in this section. For Content-Based Technique, the Cosine similarity algorithm was used which work out the similarities between the area and the crop's requirements. The Collaborative technique used the item-based algorithm which finds the similarities between two crops.

4. System Design

The Client-Server architecture was used in the development of the system and the communication channels used for the exchange of data in the entire system are also shown by Figure 2 below. The system uses a client-server model which is a computing model in which the server hosts, delivers and manages most of the resources and services to be consumed by the users.

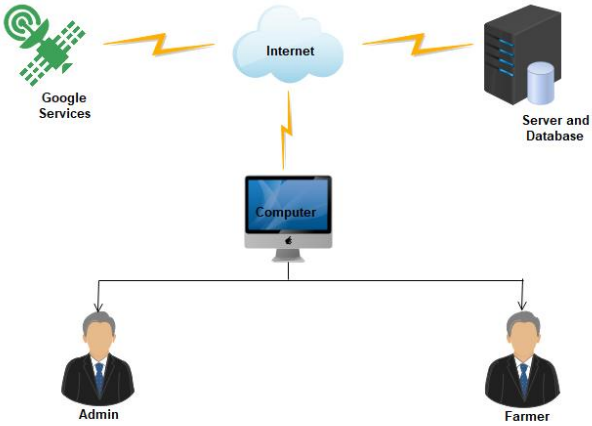

Figure 2. System Architecture

4.1. The Hybrid Technique in Crop Recommendation

A system that combines content-based filtering and collaborative filtering could take advantage from both the representation of the content as well as the similarities among things. Although there are several ways in which to combine the two techniques a distinction can be made between two basis approaches. A hybrid approach combines the two types of information while it is also possible to use the recommendations of the two filtering techniques independently.

4.1.1. Content-Based Technique: Cosine Similarity Algorithm

Cosine similarity can be used to compare the similarity between the area (e.g., location) and the crop's requirements.

1. **Representing Area and Soil Type Features:** The first step is to represent the area characteristics and the crop's requirements as vectors in a multi-dimensional feature space. For the area characteristics, the vector could include features like rainfall, soil type, soil pH, etc. For the crop's requirements, the vector could include features like optimal soil pH range, soil texture, nutrient requirements, etc.
2. **Calculating Cosine Similarity:** The cosine similarity between the area characteristics vector and the crop's requirements vector is calculated using the formula: **cosine_similarity(area_vector, crop_vector) = dot(area_vector, crop_vector) / (norm(area_vector) * norm(crop_vector))** This will give a value between 0 and 1, where 1 indicates a perfect match (the area characteristics are completely aligned with the crop's requirements), and 0 indicates no similarity (the area characteristics and the crop's requirements are completely different).
3. **Ranking and Recommendation:** The cosine similarity values are calculated for each crop in the recommendation system and the available area. The crops are then ranked based on their similarity scores, considering both the area characteristics and the crop’s requirements. The

top-ranked crops that are most suitable for the given area are then recommended to the farmer.

4.1.2. Collaborative Technique: Item-based Algorithm

1. **Item-Item Similarity Calculation:** The first step is to calculate the similarity between different crops (items) based on their characteristics. This is typically done using a similarity metric, such as cosine similarity or Pearson correlation coefficient. For example, the cosine similarity between two crop vectors (representing their attributes like climate, soil requirements, etc.) can be calculated to determine how similar the crops are to each other.
2. **Building the Similarity Matrix:** The similarity values between all pairs of crops are stored in a similarity matrix. Each element in the matrix represents the similarity score between the corresponding crops.
3. **Recommendations Based on Similar Crops:** When a user requests a crop recommendation, the system looks at the crop the user has asked information for. The system identifies the most similar crops based on the pre-computed similarity matrix and also using necessary features like rainfall for that year. The system then recommends the top-k most similar crops to the farmer.

Figure 3 below simplifies the whole recommendation:

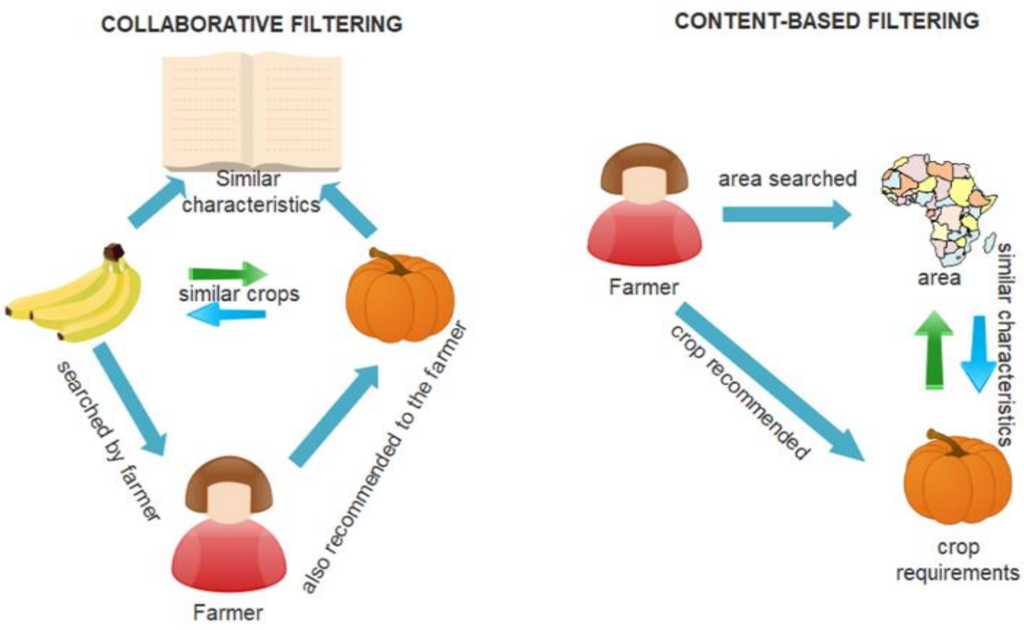

Figure 3. Item-based and Cosine Similarity algorithms

5. Expected Results

Figure 4 below shows the farmer's page where there is a search part to select the crop and area to grow the crop. The results comes below the search part, which shows necessary information of the searched crop. Other recommended crop which are also suitable to grow in that area are shown to the far right, whereby if you click on a crop it will show all necessary information to grow the crop.

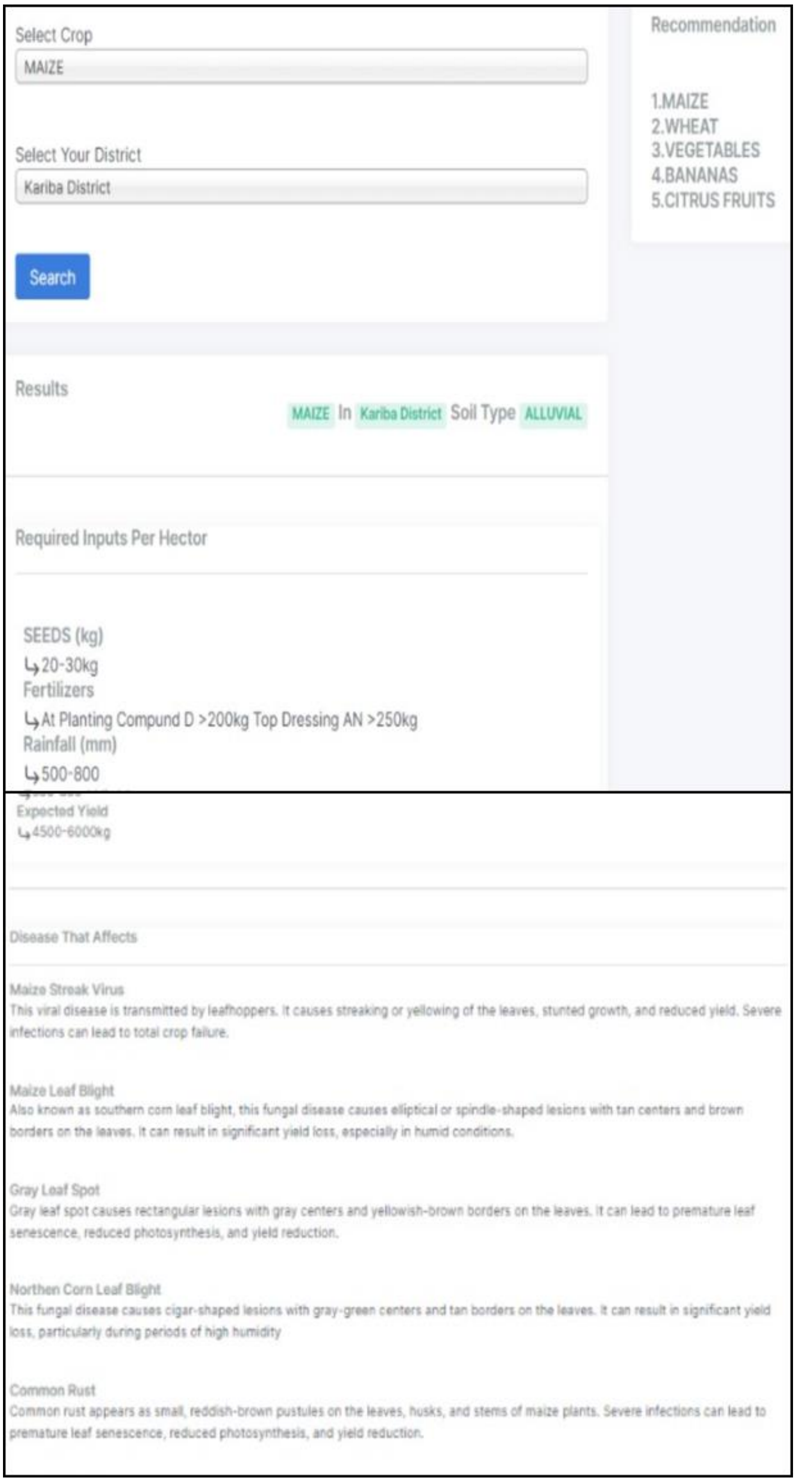

Figure 4. Results of the System.

6. Conclusion

In this paper, crop market and crop recommender systems were studied vastly, in order to enhance data availability to small scale farmers at reduced costs. Farmers need assistance in decision making on crops to grow considering factors like rainfall, market, etc. Many Machine Learning techniques have been used to analyze the agriculture parameters. In this case, hybrid techniques (collaboration and content-based filtering techniques algorithms) plays a role in crop recommendations.

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