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Design of a Digital Logistics System for Cabya (Piper retrofractum Vahl) Commodities to Optimize Export Needs

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Abstract. *Madura Island has a variety of quality crops, such as medicinal plants, one of which is Cabya (Piper retrofractum Vahl). The need for Cabya for exports is enormous, but Indonesia can only meet the demand for about a third. The highest production of Cabya is in East Java, especially in Madura. This research proposes a digital logistic system to forecast demand for Cabyaexports and manage Cabya stocks through forecasting yields and inventory management processes. The research was conducted in Sumenep regency that produce the highest number and the best quality Cabya in East Java. The Markov Chain method forecasts yields for the next five years. Then Forecasting results are integrated with an information system to manage the logistics of Cabya. The logistics system resulting from this research can be used by the government and export managers of Cabya to optimize the demand for Cabya exports. Further research can be carried out by integrating Inventory control methods to improve the logistics system's accuracy and calculate the inventory's total cost.*

Keywords: *Medicinal plants, export demand forecasting, Logistic digital systems, Markov Chain*

I. INTRODUCTION

Indonesia, especially in East Java Province, is one of the leading producers of Cabya (Hawa et al., 2021). Up to 90% of the most extensive Cabya production comes from Madura (Faramayuda et al., 2021) di Four sub-districts in Sumenep Regency, including Bluto, Lenteng, Ganding, and Guluk-guluk produce about six tons of Cabya each year. Cabya has a Latin name (Piper retrofraCtum Vahl) and is commonly referred to as Cabya (Evrizal, 2013). Cabya plants have spread throughout Indonesia in Java, Sumatra, Bali, Nusa Tenggara, and Kalimantan. Cabya plants are extensive in several countries, including Singapore, Malaysia, China, the Middle East, Europe, and America (Bahruddin et al., 2021).

Cabya is used in dry form as a spice and for traditional herbal medicine. Cabya has a unique and pungent taste and aroma, which is also commonly used for various therapeutic purposes (Hawa et al., 2021). Cabya is used to treat several respiratory disorders, such as gastrointestinal disorders, disorders of metabolic imbalance, aphrodisiacs, emmenagogues, circulatory stimulants, and analgesics (Ulya, Wasilah and Faridz, 2020; Yadav, Krishnan and Vohora, 2020). Some experts have researched the benefits of Cabya as a treatment for diseases caused by COVID-19 (Lakhera et al., 2021; Kataria et al., 2022). In other fields, Cabya are also used as raw material for insecticides (Yadav, Krishnan and Vohora, 2020; Pumnuan et al., 2022) and Bioreductor in the formation of Nanoparticles (Amaliyah et al., 2020; Huang et al., 2020)

In 2010 the area of Cabya plantations was 4,211 ha. The production of 1,329 tons of dried fruit with a productivity of 481 kg/ha. Madura Island is the largest and main production site in four districts, including Sumenep with 1,709 ha, Pamekasan with 715 ha, Sampang with 1,017 ha, and Bangkalan with 356 ha (Evrizal, 2013).

Based on the 2018 National Socioeconomic Survey, the use of traditional medicine in Indonesia has increased to 44.2% (Rahayu, Araki and Rosleine, 2020). In 2010 it increased to 45.17% (DEWI, 2019). In the world, the use of traditional medicines in various countries, both developed and developing countries, almost 80% of the population uses traditional medicines. The world's need for Cabya exports can reach 114 tons, while Indonesia can only meet the demand for about a third. Therefore, it is hoped that the

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results of Cabyacultivation will be more developed and can compete internationally. This development can be carried out by increasing the capability and network of Cabya from farmers, consumers, and the government to meet export needs. To meet Cabya's export needs must also consider the inventory management process.

Forecasting agricultural commodity yields is needed in planning a logistics system. Some of the methods used by researchers to predict crop yields include machine learning (Lee et al., 2022; Paudel et al., 2022), satellite and ground data (Broms et al., 2023), The discriminant function analysis technique (Kumar et al., 2021), and Time-series analysis (Amankulova, Farmonov and Mucsi, 2023). Previous researchers have used the method to predict crop yields based on satellite land images and weather forecasts. However, the prediction results have not been used for commodity logistics planning which is the object of research.

Logistics information systems support decision-makers in monitoring and controlling information and material flows of supply chains, automated transactions, and data storage services (Helo and Rouzafzoon, 2021). Digitalisasi logistic Agricultural commodities must be developed to maintain business sustainability and competitive advantage in that field (Ismahane and MERZOUG, 2021; Remondino and Zanin, 2022), which can help reduce operational costs (Siali, Yao and Kie, 2013). Agricultural products are products that require special methods in terms of distribution and storage. Therefore, a smart logistics system is very potential to be implemented (Ramirez-Asis et al., 2022). In Indonesia, the logistics information system for agricultural commodities has been developed by several previous researchers. Traditional markets that sell agricultural products can optimize their efficiency by applying a logistics system (Perdana, 2012). A logistics information system that helps actors in the supply chain of agricultural commodities that have the potential to be exported has not yet been designed.

This study uses harvest data simulated by the Markov Chain method to obtain the transition probability of changing yields. The yield prediction data is then used as a target in planning the amount of Cabya needed. The planning results are implemented into an information system designed to manage the logistics of Cabya. It is hoped that the government and export managers can use the logistics system resulting from this research for Cabya to record the amount harvested for each farmer and the number of Cabya sent to exporters.

II. RESEARCH METHOD

The research was conducted on the yields of Chilli Jamu in four sub-districts in Sumenep Regency, namely Bluto, Lenteng, Gading, and Guluk-guluk sub-districts. This study designed a herbal medicine logistics system with two stages. Forecasting yields for five years using the Markov Chain method (Tolver, 2019), Starting from 2022 to 2026, is the first stage. The forecasting results are then used as supporting data in designing a logistics information system to facilitate managing the logistics of Cabya.

Data collection was carried out using several methods: historical data from the central logistics agency and data from the agriculture and food security service in Sumenep, such as the yield of Cabya, the need for Cabya exports, and the area of Cabya land. The second observation method is carried out directly on the supply chain flow of the Cabya commodity, starting from the Cabya farmers to the Cabyacollectors in the Sumenep area.

Markov chain is a method associated with the model of several systems and business processes. Chain is the ongoing process of a mathematical model carried out in stages, commonly referred to as move in sequence. According to Markov's probability theory, the occurrence of probabilities is based on direct events from the start and can be used as forecasts for subsequent events. It is called transitional and fixed probabilities. (Susilo, 2011). The stages carried out in the data processing using the Markov chain method, such as:

a. Determine the transition probability with the formula: Pij = $\frac{n_{ij}(t)}{n_i(t)}$

b. Probability of n-step transition with formula : P(n) = Pn

The second stage is designing a logistics information system that uses several tools, including forming a user interface using HTML. Furthermore, Backend design using PHP. Database creation is done using MySQL (S Pasaribu, 2021).

III. Result and Discussion

The supply chain process in a logistics system starts with farmers or collectors inputting stock. Based on observations made for the main harvest season of Cabya in the third to the eighth month. After collecting the harvest, the farmers sell it to collectors at a price that adjusts to the chili season because the harvest of chili herbs takes about 2 to 3 years. If the herbal chilies are not yet harvested, and many customers are looking for them, the price can soar up to Rp. 90,000/kg for the type of dried herb chili.

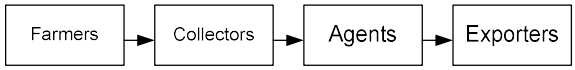

Figure 1. Supply chain flow of Cabya

Herbal chilies collected at collectors are then sent to Bali to export to India and China through agents in Mojokerto and Surabaya. Delivery of chili herbs, of course, in quite large quantities, one shipment of up to 3 containers, each containing 18 tons. The path is taken for shipping by sea by ship.

Yield data for Cabya from 2018 to 2021 from the four sub-districts in Sumenep Regency are shown in Table 1. The average annual yield of the four sub-districts is 5.5 tons. The highest yields were generated from Bluto District. Cabyacultivation is an activity that has been carried out for generations in Sumenep. The Cabyaharvest is not the main economic source for the people in the area. Therefore, the surrounding community lacks the motivation to develop and increase the yield of Cabya. Establishing a digital inventory system is expected to inform farmers about the market price of Cabya and meet export standards. Thus, farmers will be motivated to increase yields and maintain quality.

Table 1. Data on Cabya harvests in Sumenep 2018-2021

Year	Yields (Kilogram)				Total
	Bluto	Lenteng	Ganding	Guluk-Guluk	
2018	2737	909	1300	616	5562
2019	2762	914	1291	618	5585
2020	2762	911	1277	615	5565
2021	2746	904	1260	610	5520

The yields obtained are then continued to determine the transition opportunity matrix or transition probability matrix to find the optimum probability. Table 2 shows the transition probabilities from calculating harvest data for four years. In 2018, the Bluto sub-district had a transition probability of 49.21%, Lenteng was 16.34%, Ganding was 23.37%, and Guluk-guluk was 11.08%.

Table 2. Transition probability

Year	Yields			
	Bluto	Lenteng	Ganding	Guluk-Guluk
2018	0,49209	0,16343	0,23373	0,11075
2019	0,49454	0,16365	0,23115	0,11065
2020	0,49632	0,16370	0,22947	0,11051
2021	0,49746	0,16377	0,22826	0,11051

Based on the calculation results using the probability matrix , Table 3 shows the transitional probability used to determine the Markov chain forecasting outcome to obtain crop yield data. Transition probabilities are calculated for five years, from 2022 to 2026.

Table 3. Summary of the results of the five-year transition opportunities using Markov chains

Tahun	Yields			
	Bluto	Lenteng	Ganding	Guluk-Guluk
2022	0,49209	0,16343	0,23373	0,11075
2023	0,49407	0,16357	0,23171	0,11065
2024	0,49406	0,16357	0,23172	0,11065
2025	0,49406	0,16357	0,23172	0,11065
2026	0,49406	0,16357	0,23172	0,11065

Forecasting the yields of Cabya for the next five years is shown in Table 4. Based on calculations using the Markov chain, an average annual increase of approximately 2 tons to 15 tons is obtained. The yield data for the next five

years with the percentage change obtained is 2% to 10%.

Table 4. Recapitulation of five-year forecasting yields using the Markov chain.

Tahun	Yields (Kilogram)				Total
	Bluto	Lenteng	Ganding	Guluk-Guluk	
2022	2748	910	1289	615	5562
2023	2757	911	1281	615	5564
2024	2756	910	1277	614	5557
2025	2750	907	1271	612	5540
2026	2752	910	1283	614	5559

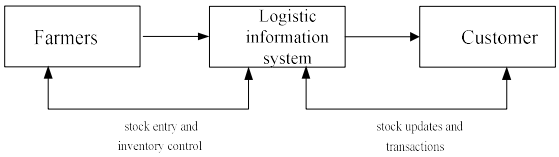

Figure 1. Product and information flow in the logistic system

The logistic information system in this research is expected to operate by the community cooperation eager to help farmers sell Cabya. Figure 1 shows a conceptual model of product and information flow in the logistic system. The flow starts when farmers can sell and enter the Cabya stock into the system. Then customers could buy the Cabya from the transaction in the system.

An activity diagram is a description of the activity of a system process. The activity of the Cabya logistics information system can be seen in Figure 2. The activity diagram of the Cabya stock inventory starts with the farmer entering the stock of the herbal chili product with the data entered, namely the weight of the herbal chili and the price per kg. Admin can edit and delete stock and do stock management. Customers make purchases more easily through the system by logging in and then selecting stock from the type of region and price. After that, make a payment transaction.

The sequence diagrams connect components based on activity in the system. The flow of the information system process can be seen in Figures 3 and 4. The advantages of the herbal

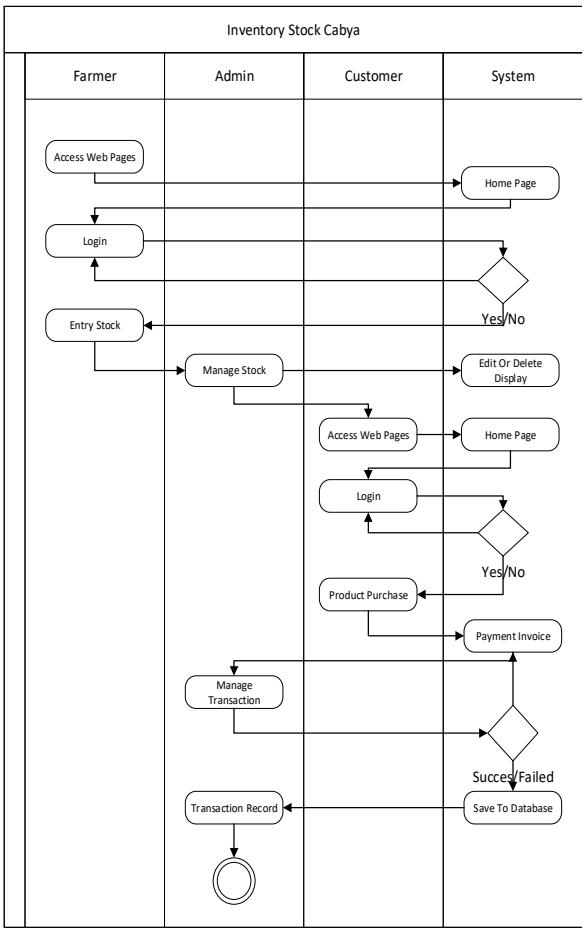

Figure 2. Activity Diagram

chili logistics information system are that it is easier to find out.

The proposed platform consists of some core features necessary to become operational. This application aims to aid the organization in storing information on Cabya stocks from various areas of farmers' land. The main features of this system are being able to update farmers' stocks and purchase Cabya for consumers. It can also be used as a marketing facility to expand market segments and targets. Three types of users are used in this document: Farmers, Buyers, and managers. Farmers can register as a user and include the price offered. Buyers register and input how much stock to buy and receive a purchase receipt. Managers can activate the program, manage stock items, make stock edits if there is a mistake in the name, quantity, price, and type of stock, and manage stock purchases.

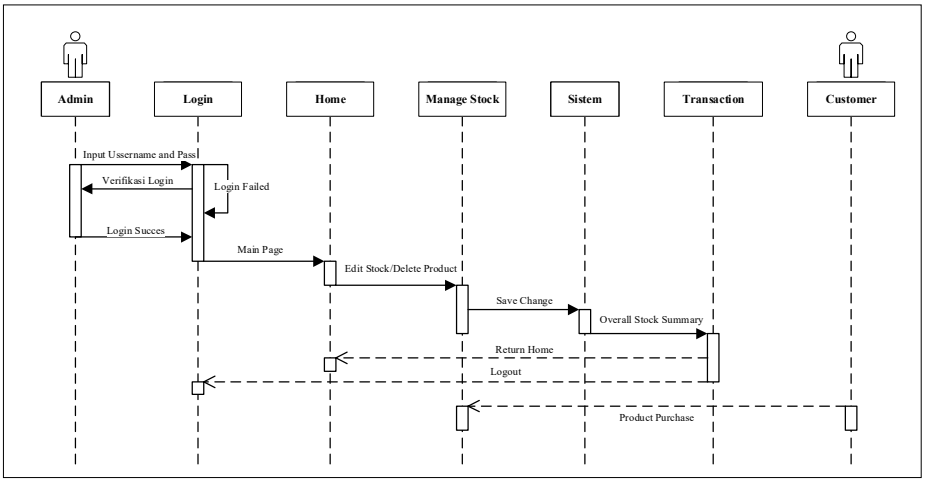

Figure 3. Sequence diagram Admin

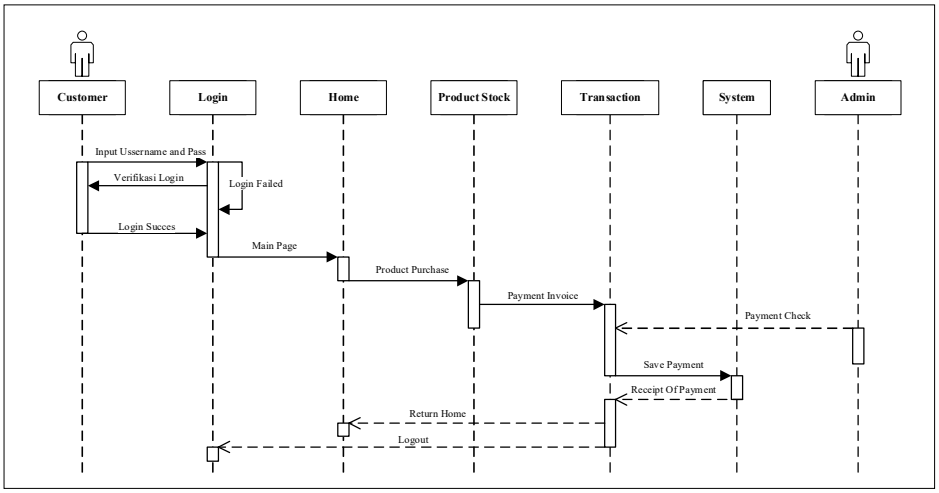

Figure 4. Sequence diagram Customer

The Interface of the system is shown in Figure 3. The main purpose of the Interface is to provide easy access for users to certain features with their functions and information. The implementation of the Interface is decentralized web page based.

User features represent each user accessing the platform to communicate or cooperate with other platform features. Usually, users are looking for services provided by the platform. For example, the most common use is an organization looking to store or transport its goods. Of course, it can also be an individual that finds some use in the platform. The user feature is composed of two parts: the first one is for Farmers, and the second one is the buyers. The service feature represents actors that are providing services in the supply chain. The service serves as a bridge between farmers and buyers for providers of the service. The main component of these nodes is the Application Programming Interface in any form they want as long as it enables the other nodes to use it as a means of communication over the Internet. The goal is that the whole service process would be fully automated.

The Graph feature serves as a list of connections between information. It can display a graph that represents the result of yield forecasting for each region, calculated with the Markov chain formula. The feature also displays the number of stocks and price of Cabya accumulated from some transactions.

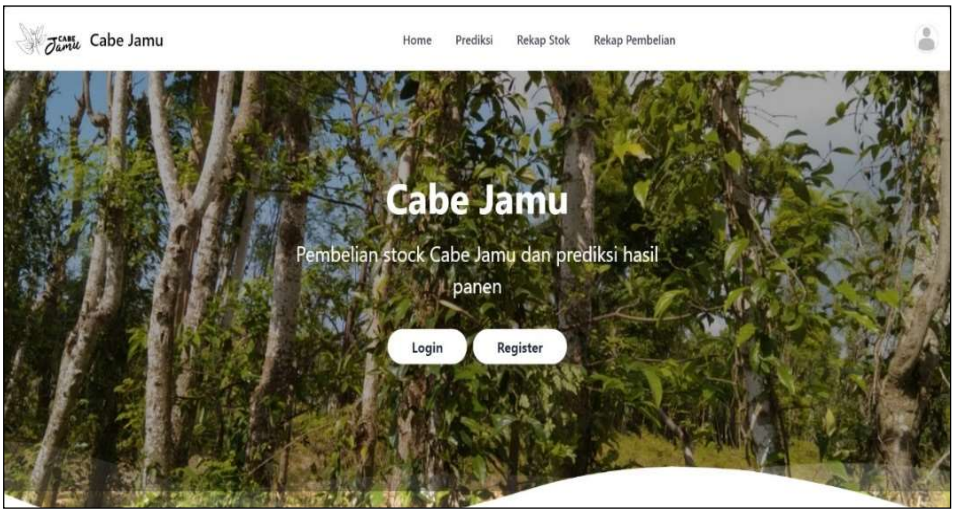

Figure 5. The Interface of the logistics system

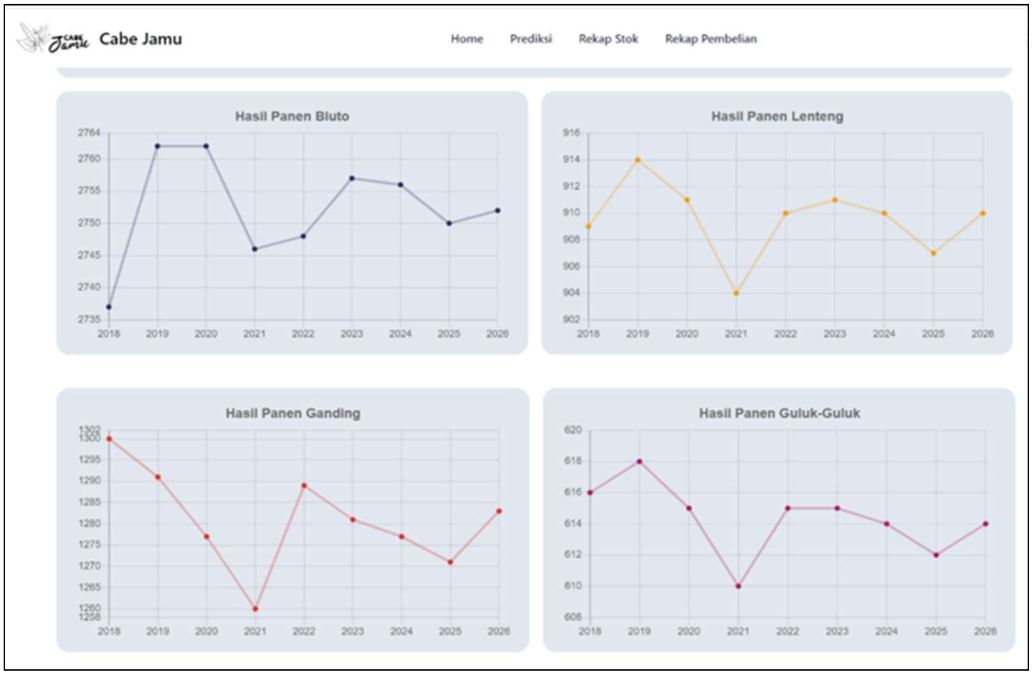

Figure 6. Harvest forecasting chart

Transaction feature aid the user in managing stock and transaction of Cabya selling to buyers. When a transaction happens, the feature writes it down as a report.

Figure 3 shows one of the outputs of the logistics system, which can present a graph of harvest yields from four sub-districts from 2018 to 2026. These yields are obtained from forecasting using a Markov chain for the next five years, which are input to the program. The logistics system is expected to help farmers sell their crops, thereby reducing storage costs and maintaining the quality of their commodities (Ramirez-Asis et al., 2022). Documentation of harvest data from various regions in Madura can be done more easily by managers or the government. (Soegoto and Palalungan, 2020).

Figure 7. Input stock from farmers

Figure 8. Customer purchase transactions

Figure 9. Transaction record and edit view on admin

This data can be used as a basis for planning the development of Cabya cultivation. (El Abbouyi et al., 2014). Ecosystem maintenance also needs to be considered in developing sustainable inventory management. (Becerra, Mula and Sanchis, 2022)(Salas-Navarro et al., 2022).

IV. CONCLUSION

Most herbal chili farmers in Sumenep do not have gardens or special land to cultivate herbal chilies. Farmers let the Cabya grow without special care in the yard, such as a tree or fence. The price of the herbal chili itself starts from Rp. 60,000 to Rp. 90,000 per kg of it. The price of herbal chilies is distinguished between wet and dry ones; for wet ones, it is cheaper because the water content is still too high.

Most farmers at harvest time prefer to store it in advance for years until several sacks have been collected, and each sack can contain approximately 8-10 kg. Once collected, they are sold to collectors at a different price each year or season. Therefore, the best strategy for farmers is to save up to more and adjust the highest price of herbal chilies.

After obtaining Cabya from various farmers, herbal chili collectors are resold to agents to be distributed to various cities and abroad. Exports of Cabya are mostly in India and China. India is famous for its distinctive spice preparations, and China still uses herbal medicines. Therefore, most of the herbal chilies are exported to that country. One shipment can be up to 3 containers with a capacity of 1 container is 18 tons.

This research was conducted to determine the future harvest using Markov chain forecasting to prepare to meet the demand for the export needs of Cabya. Each year's average percentage change

in yields changes by approximately 2% to 10%. Based on the calculation of yields from the Markov chain, a graph of yields is obtained in the Cabya logistics system. This system can facilitate the recording or updating of the stock of Cabya.

The logistics system resulting from this research can be developed for applications in other regions in Indonesia. Research can be developed towards sustainable inventory management, which considers the three pillars of the bottom line. Factors of transportation facilities supporting the logistics system can also be integrated into the logistics system.

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REFERENCES

El Abbouyi, P. A. *et al.* (2014) 'Inventory of medicinal plants prescribed by traditional healers in El Jadida city and suburbs (Morocco)', *International Journal of Green Pharmacy*, 8(4), pp. 242–251. doi: 10.4103/0973-8258.142681.

Amaliyah, S. *et al.* (2020) 'Green synthesis and characterization of copper nanoparticles using Piper retrofractum Vahl extract as bioreductor and capping agent', *Heliyon*, 6(8), p. e04636. doi: 10.1016/j.heliyon.2020.e04636.

Amankulova, K., Farmonov, N. and Mucsi, L. (2023) 'Time-series analysis of Sentinel-2 satellite images for sunflower yield estimation', *Smart Agricultural Technology*, 3(June 2022), p. 100098. doi: 10.1016/j.atech.2022.100098.

Bahruddin, A. *et al.* (2021) 'Pemanfaatan Dan Prospek Budidaya Cabe Jamu Di Dusun Nung Malaka Desa Daleman Kecamatan Galis Kabupaten Bangkalan', *Jurnal Pengabdian Masyarakat*, (2), p. 1.

Becerra, P., Mula, J. and Sanchis, R. (2022) 'Sustainable Inventory Management in Supply Chains: Trends and Further Research', *Sustainability (Switzerland)*, 14(5), pp. 1–19. doi: 10.3390/su14052613.

Broms, C. *et al.* (2023) 'Combined analysis of satellite and ground data for winter wheat yield forecasting', *Smart Agricultural Technology*, 3(August 2022), p. 100107. doi: 10.1016/j.atech.2022.100107.

DEWI, R. S. (2019) 'Penggunaan Obat Tradisional Oleh Masyarakat di Kelurahan Tuah Karya Kota Pekanbaru', *Jurnal Penelitian Farmasi Indonesia*, 8(1), pp. 41–45. doi: 10.51887/jpfi.v8i1.781.

Evrizal, R. (2013) 'Status Fitofarmaka dan Perkembangan Agroteknologi Cabe Jawa (Piper Retrifractum Vahl.)', *Jurnal Agrotropika*, 18(1), pp. 34–40. Available at: infestasi.trunojoyo.ac.id/agrovigor/article/download/230/212.

Faramayuda, F. *et al.* (2021) 'Pemberdayaan masyarakat melalui pelatihan budidaya dan peningkatan potensi agribisnis cabe jawa', *Jurnal Pengabdian Masyarakat*, 4(2), pp. 56–63. Available at: http://abditani.jurnalpertanianunisapalu.com/index.php/abditani/article/view/71.

Hawa, L. C. *et al.* (2021) 'Drying kinetics of cabya (Piper retrofractum Vahl) fruit as affected by hot water blanching under indirect forced convection solar dryer', *Solar Energy*, 214(August 2020), pp. 588–598. doi: 10.1016/j.solener.2020.12.004.

Helo, P. and Rouzafzoon, J. (2021) 'Logistics Information Systems', *International Encyclopedia of Transportation*, pp. 76–84. doi: 10.1016/b978-0-08-102671-7.10223-4.

Huang, H. *et al.* (2020) 'Synthesis, optimization and characterization of silver nanoparticles using the catkin extract of Piper longum for bactericidal effect against food-borne pathogens via conventional and mathematical approaches', *Bioorganic Chemistry*, 103(August), p. 104230. doi: 10.1016/j.bioorg.2020.104230.

Ismahane, B. B. and MERZOUG, S. (2021) 'Impact of Logistics Information Systems on Logistics Performance', *La Revue des Sciences Commerciales*, 20(1), pp. 147–167.

Kataria, S. *et al.* (2022) 'A pilot clinical study of an add-on Ayurvedic formulation containing Tinospora cordifolia and Piper longum in mild to moderate COVID-19', *Journal of Ayurveda and Integrative*

Medicine, 13(2), p. 100454. doi: 10.1016/j.jaim.2021.05.008.

Kumar, J. *et al.* (2021) 'Pre-harvest forecast of rice yield based on meteorological parameters using discriminant function analysis', *Journal of Agriculture and Food Research*, 5(June), p. 100194. doi: 10.1016/j.jafr.2021.100194.

Lakhera, S. *et al.* (2021) 'In silico investigation of phytoconstituents of medicinal herb "Piper Longum" against SARS-CoV-2 by molecular docking and molecular dynamics analysis', *Results in Chemistry*, 3(June), p. 100199. doi: 10.1016/j.rechem.2021.100199.

Lee, D. *et al.* (2022) 'Maize yield forecasts for Sub-Saharan Africa using Earth Observation data and machine learning', *Global Food Security*, 33(June), p. 100643. doi: 10.1016/j.gfs.2022.100643.

Mutua, N. (2015) 'ER', (August 2013).

Paudel, D. *et al.* (2022) 'Machine learning for regional crop yield forecasting in Europe', *Field Crops Research*, 276(December 2021), p. 108377. doi: 10.1016/j.fcr.2021.108377.

Perdana, Y. R. (2012) 'Logistics Information System for Supply Chain of Agricultural Commodity', *Procedia - Social and Behavioral Sciences*, 65, pp. 608–613. doi: 10.1016/j.sbspro.2012.11.172.

Pumnuan, J. *et al.* (2022) 'Insecticidal activities of long pepper (Piper retrofractum Vahl) fruit extracts against seed beetles (Callosobruchus maculatus Fabricius , Callosobruchus chinensis Linnaeus , and Sitophilus zeamais Motschulsky) and their effects on seed germin', *Heliyon*, 8(October), p. e12589. doi: 10.1016/j.heliyon.2022.e12589.

Rahayu, Y. Y. S., Araki, T. and Rosleine, D. (2020) 'Factors affecting the use of herbal medicines in the universal health coverage system in Indonesia', *Journal of Ethnopharmacology*, 260, p. 112974. doi: 10.1016/j.jep.2020.112974.

Ramirez-Asis, E. *et al.* (2022) 'Smart Logistic System for Enhancing the Farmer-Customer Corridor in Smart Agriculture Sector Using Artificial Intelligence', *Journal of Food Quality*, 2022. doi: 10.1155/2022/7486974.

Rees, L. P. *et al.* (2011) 'Decision support for Cybersecurity risk planning', *Decision Support Systems*, 51(3), pp. 493–505. doi: 10.1016/j.dss.2011.02.013.

Remondino, M. and Zanin, A. (2022) 'Logistics and Agri-Food: Digitization to Increase Competitive Advantage and Sustainability. Literature Review and the Case of Italy', *Sustainability (Switzerland)*, 14(2). doi: 10.3390/su14020787.

S Pasaribu, J. (2021) 'Development of a Web Based Inventory Information System', *International Journal of Engineering, Science and Information Technology*, 1(2), pp. 24–31. doi: 10.52088/ijesty.v1i2.51.

Salas-Navarro, K. *et al.* (2022) 'Inventory Models in a Sustainable Supply Chain: A Bibliometric Analysis', *Sustainability (Switzerland)*, 14(10). doi: 10.3390/su14106003.

Siali, F., Yao, L. and Kie, C. J. (2013) 'Inventory Management and Logistics Cost Reduction: A Case of a Malaysia Herbal Medicine Company', *Technology and Investment*, 04(03), pp. 204–212. doi: 10.4236/ti.2013.43024.

Soegoto, E. S. and Palalungan, A. F. (2020) 'Web Based Online Inventory Information System', *IOP Conference Series: Materials Science and Engineering*, 879(1). doi: 10.1088/1757-899X/879/1/012125.

Tolver, A. (2019) *An Introduction to Markov Chains*, *Basics of Probability and Stochastic Processes*. doi: 10.1007/978-3-030-32323-3_12.

Ulya, M., Wasilah, W. and Faridz, R. (2020) 'Pengembangan Produk Minuman Herbal Berbasis Teh Cabe Jawa (Piper retrofractum Vahl.) Menggunakan Metode Value Engineering', *Industria: Jurnal Teknologi dan Manajemen Agroindustri*, 9(2), pp. 119–127. doi: 10.21776/ub.industria.2020.009.02.5.

Yadav, V., Krishnan, A. and Vohora, D. (2020) 'A systematic review on Piper longum L.: Bridging traditional knowledge and pharmacological evidence for future translational research', *Journal of Ethnopharmacology*, 247, p. 112255. doi: 10.1016/j.jep.2019.112255.