Anadolu Tarım Bilimleri Dergisi,
Anadolu Journal of Agricultural Sciences

e-ISSN: 1308-8769, ANAJAS Haziran 2024, 39 (2): 365-379

Development of Rule-Based Expert System for Variable Cost and Gross Profit Calculations of Agricultural Products: A Case Study

Tarım Ürünlerinde Maliyet ve Brüt Kar Hesaplamalarına Yönelik Kural Tabanlı Uzman Sistemin Geliştirilmesi: Bir Vaka Çalışması

Oğuz ŞAHİN[1], Fatih TOPALOĞLU[2]

[1]Apricot Research Institute Directorate, Malatya
· **karaoguz_44@hotmail.com** · ORCID > 0000-0002-6698-9072

[2]Malatya Turgut Özal University, Department of Computer Engineering, Faculty of Engineering and Natural Sciences, Malatya
· **fatih.topaloglu@ozal.edu.tr** · ORCID > 0000-0002-2089-5214

Makale Bilgisi/Article Information

Makale Türü/Article Types: Araştırma Makalesi/Research Article
Geliş Tarihi/Received: 31 Aralık/December 2023
Kabul Tarihi/Accepted: 11 Mart/March 2024
Yıl/Year: 2024 | **Cilt-Volume:** 39 | **Sayı-Issue:** 2 | **Sayfa/Pages:** 365-379

Atıf/Cite as: Şahin, O. Topaloğlu, F. "Development of Rule-Based Expert System for Variable Cost and Gross Profit Calculations of Agricultural Products: A Case Study" Anadolu Journal of Agricultural Sciences, 39(2), Haziran 2024: 365-379.

Yazar Notu/ Author Note: "Summarized from the master's thesis."

Sorumlu Yazar/Corresponding Author: Fatih TOPALOĞLU

https://doi.org/10.7161/omuanajas.1412844

DEVELOPMENT OF RULE-BASED EXPERT SYSTEM FOR VARIABLE COST AND GROSS PROFIT CALCULATIONS OF AGRICULTURAL PRODUCTS: A CASE STUDY

ABSTRACT

Cost and gross profit calculations of agricultural products are a comprehensive and difficult process. Many different parameters, such as soil cultivation, pruning, spraying, irrigation, storage, drying, harvesting, transportation, and marketing, need to be evaluated together. Currently, cost calculations of agricultural products are made with classical programs and simple mathematical methods. For this reason, the results vary depending on the person and organization making the evaluation. This creates some limitations, making cost planning, which is a dynamic process, unreliable. In the study, a rule-based expert system was developed for the cost and gross profit calculation of apricots. The expert system developed is called Apricot Information System (APRIS). The developed expert system aims to provide more accurate solutions by adding the precision and speed of the computer to the calculation process. The main contribution of this study is the development of a complete decision support set covering all processes from tillage to marketing and the design of rule-based user-system interaction. The designed system found the apricot variable cost calculation to be 1126.36 TL/da for 2020. This value largely overlaps with the values obtained from the field in the previous year. The developed expert system will be a platform that can be used in cost calculations of many agricultural products.

Keywords: Expert System, Apricot Information System, Cost Calculation, Gross Profit Calculation.

❁❁❁

TARIM ÜRÜNLERİNDE DEĞİŞKEN MALİYET VE BRÜT KAR HESAPLAMALARINA YÖNELİK KURAL TABANLI UZMAN SİSTEMİN GELİŞTİRİLMESİ: BİR ÖRNEK OLAY İNCELEMESİ

ÖZ

Tarım ürünlerinin maliyet ve brüt kar hesaplamaları kapsamlı ve zor bir süreçtir. Toprağın işlenmesi, budama, ilaçlama, sulama, depolama, kurutma, hasat, nakliye ve pazarlama gibi birçok farklı parametrenin bir arada değerlendirilmesi gerekmektedir. Günümüzde tarım ürünlerinin maliyet hesaplamaları klasik programlar ve basit matematiksel yöntemlerle yapılmaktadır. Bu nedenle sonuçlar değerlendirmeyi yapan kişi ve kuruluşa göre farklılık göstermektedir. Bu durum bazı sınırlamalar yaratarak dinamik bir süreç olan maliyet planlamasını güvenilmez hale getirir. Çalışmada kayısının maliyet ve brüt kâr hesaplaması için kural tabanlı bir uzman sistem geliştirilmiştir. Geliştirilen uzman sisteme Kayısı Bilgi Sistemi (APRIS) adı verilmektedir. Geliştirilen uzman sistem, hesaplama sürecine bilgisayarın hassasiyetini ve hızını da ekleyerek daha doğru çözümler sunmayı amaçlamaktadır. Bu çalışmanın temel katkısı, toprak işlemeden pazarlamaya kadar tüm süreçleri kapsayan eksiksiz bir karar destek setinin geliştirilmesi ve kural tabanlı kullanıcı-sistem etkileşiminin tasarlanmasıdır. Tasarlanan sistemde kayısı maliyeti 2020 yılı için 126,36 TL/da olarak bulunmuştur. Bu değer geçen yıl sahadan elde edilen değerlerle büyük ölçüde örtüşmektedir. Geliştirilen uzman sistem birçok tarım ürününün maliyet hesaplamalarında kullanılabilecek bir platform olacaktır.

Anahtar Kelimeler: Uzman Sistem, Kayısı Bilgi Sistemi, Maliyet Hesabı, Brüt Kar Hesabı.

❁❁❁

1. INTRODUCTION

Crop yield and cost estimation in the agricultural sector is a fundamental task for decision-makers at national and regional levels (e.g., EU level) for rapid decision-making (Klompenburg et al., 2020). Internet of Things, Big Data, Artificial Intelligence, Expert System, Cloud Computing, Remote Sensing, Machine Learning, etc. Using technologies such as this OR the use of technologies can) can significantly increase the efficiency of agricultural activities (Zhai, 2020). The difference between the expert system and other techniques is that it uses the defined information at hand, not algorithmic models.

Expert systems, an artificial intelligence technique, have a wide range of uses in many areas of computer technology. In other words, expert systems are used for every field where information is actively used.

Agricultural production is rapidly changing towards smart agricultural systems, driven by the fast pace of technological developments (Janssen et al., 2017; Tzounis et al., 2017; Kamilaris and Prenafeta-Boldú, 2018; Zhai, 2020; Verdouw et al., 2021). Expert systems hold promise for bringing smart farming to new levels of farming productivity and sustainability. Because in such systems, knowledge is transferred from real-life expertise, appropriately represented, and organized in a knowledge base (Mostafa et al., 2022). However, there are likely to be broader impacts resulting from the digitalization of agricultural innovation systems (Fielke et al., 2020). Agricultural knowledge and expert systems are important components of agricultural innovation systems. The proposed benefits of expert systems in agricultural applications focus on increased efficiency through precision mechanization, automation, and improved decision-making. However, emerging AI in agricultural applications is also likely to create solutions for agricultural stakeholders as it learns to grasp new ways of working.

When we look at agricultural studies on expert systems that have applications in many different fields, (Musleh and Abu Naser, 2000) developed an expert system to ensure accurate diagnosis and treatment of potato disease. The expert system proposed for potato disease has diagnosed 11 potato diseases. (Üstün and Baytorun, 2003) have developed an expert system that determines the live and fixed loads on the greenhouse for people who want to build a greenhouse, and minimizes material loss for display elements of different sizes used in the truss system. (Shahzadi et al., 2016) developed an expert system integrated with IoT technology that predicts irrigation and disease damages in cotton products and guides farmers. (Çaylı and Temizkan, 2018) developed an expert system to determine the effect of cover material and heat-saving measures on the heating load in greenhouses for the Kahramanmaraş region. (HeiB et al., 2021) have designed a fuzzy expert system that evaluates the environmental damage associated with variable nitrogen rates in the fertilization used by farmers.

According to the Food and Agricultural Organization (FAO) data, apricots, which are produced in a wide area around the world, were produced in 562,475 hectares of land worldwide in 2020. Turkey is the world's highest apricot production area, with a rate of 23.60% and a production area of 132,748 hectares. According to the data of the International Hazelnut and Dried Fruit Council (INC), when dried apricot-producing countries are examined, Turkey ranks first in the world dried apricot production with a share of 57.34%, while Malatya province produces 85-90% of Turkey's dried apricot production. It is the dominant sector that keeps the provincial economy alive due to the high production values it provides.

In the study, it was aimed to design the apricot information system with the rule-based expert system technique and thus calculate the cost and gross profit. The developed software is a rule-based, modular, fast-reporting, dynamic, and up-to-date platform that is free from incorrect and missing data problems. This article aims to increase clarity regarding potential impacts on apricot production systems, institutional norms and governance, considering interactions between technological developments and existing stakeholders.

The main contributions of this study can be summarized as follows;

1. Development of a user-system interactive APRIS expert system for apricot cost calculation and production planning.

2. Development of a complete decision support set covering all processes from tillage to marketing.

3. Creating a digital database where all data related to apricots are stored.

The organization of this study is as follows: Section 2 presents the material and method for the rule-based expert system. Section 3 describes the proposed APRIS approach and design, and Section 4 concludes the work.

2. MATERIALS AND METHODS

2.1. Data Set and Study Region

In the model, supported by the General Directorate of Agricultural Research and Policies (TAGEM) and carried out at the Apricot Research Institute (KAEM), Data obtained from the field were used with the project named 'Determination of Dried Apricot Production and Marketing Efficiency in Malatya Province' with project number TAGEM / TEPAD / A / 20 / A8 / P1 / 5015. These data were obtained through a face-to-face survey with 15 farmers in 2020. Land data was entered into the system by classifying it as 5 large (40 da and above), 5 medium (20-40 da) and 5 small (1-20 da).

For software, the software development platform Microsoft Visual Studio, software language .net framework MVC, C#, database, MSSQL for graphic design, and Photoshop and Illustrator were used.

2.2. Expert System

Artificial intelligence is using computers to perform human characteristics such as acquiring information, thinking, making decisions, benefiting from past experiences, and establishing cause and effect relationships. Expert systems are one of the sub-branches that make up artificial intelligence (Babalık, 2000). The knowledge engineering part of artificial intelligence includes expert systems (Gutierrez and Branch, 2011). Therefore, it is also known as decision support systems or information application systems. They are well suited to problems that require experience, knowledge, judgment, and a complex, interactive process to arrive at a workable solution (Winstanley and Courvalin, 2011). Because in such systems, knowledge is transferred from real-life expertise, represented, and appropriately organized in a knowledge base (Mostafa et al., 2022). Although expert systems have different design methods, the method of the rule-based expert system used in the article is shown in Figure 1 (Negnevitsky, 2005).

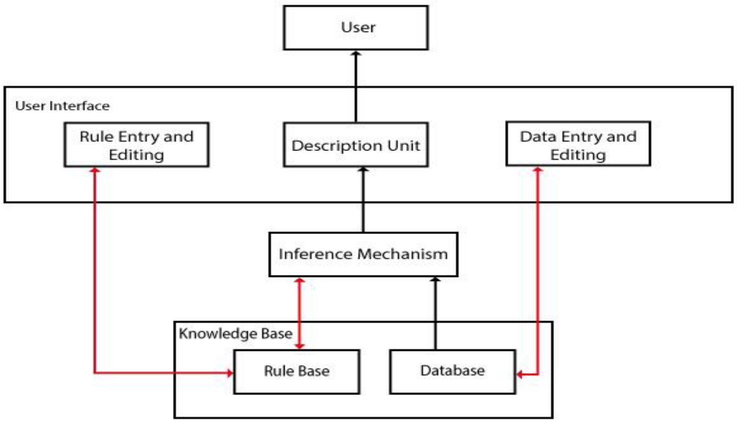

Figure 1. Rule-based expert system diagram

The rule-based expert system method consists of 5 main elements. These are the database, rule base, explanation unit, logical inference engine, and user interface (Negnevitsky, 2005).

The Rule Base consists of expressions and rules that define the work on the subject of the problem, showing the knowledge of the expert. The knowledge base is prepared by working together with an expert in one or more fields and a knowledge engineer. The knowledge engineer creates a knowledge base of the knowledge and experience of the expert who will be consulted in solving the identified problem. The information in the knowledge base is expressed with rules in the form of IF…THEN (Çetinyokuş et al., 2010).

Database is the area where the data forming the IF (condition) section of the rules in the form of IF…THEN the knowledge base is kept (Negnevitsky, 2005). Databases occupy more space in the system by holding all kinds of data and creating the memory of the expert on the subject. The knowledge base works towards solving the problem by using the query and reasoning features of the data in the database.

Logical Inference Engine is a piece of code coded by the knowledge engineer that covers the core of the expert system structure, which operates the system on the lowest level information, makes inferences by looking at the data it accesses through the database and knowledge base, and provides solutions to defined problems (Golanski and Madrzycki, 2015).

User Interface enables two-way communication between the user and the expert system (Angeli, 2010). It is also thought that the expert system facilitates the use of users, developers, and administrators (Abraham, 2005).

2.3. Apricot Production and Cost Elements

Although there are more than 1750 apricot varieties and hybrids in the world today, the number of apricot varieties grown economically in each country does not exceed 5-10 (Demirtaş et al., 2011). Apricot cultivation is carried out by following a series of processes, as in the production of other agricultural products. The process begins with soil cultivation and continues with harvesting and post-harvest operations. Apricot production and marketing stages are shown in Figure 2.

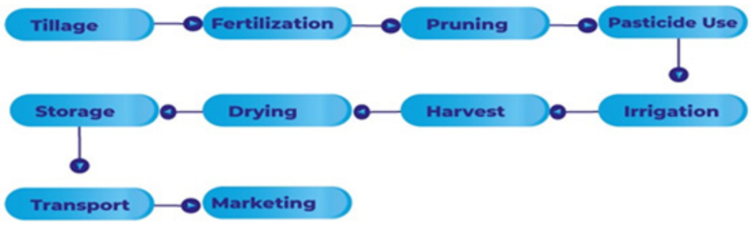

Figure 2. Apricot production and marketing stages

The economic problem of an agricultural enterprise can be summarized as the problem of achieving a certain goal under certain technology, market, and resource constraints. It is possible to express the long-term economic problem of a business that produces in input and output markets where perfect competition conditions prevail and whose aim is profit maximization (in cases where the production technology is fixed but all production inputs are variable), with the following solution:

Maximum K = PQQ - PXX (1)

Restrictions Q = f(X) $\rightarrow \begin{cases} \nearrow x^n \rightarrow P_x\ x^n \searrow \\ \searrow Q^n \rightarrow P_Q\ Q^n \nearrow K \end{cases}$ PX, PQ (2)

PQ = (pq1 , pq2, …….., pqn) (3)

Q = (q1, q2, …..……..., qn) (4)

Px = (px1, px2, ………, pxm) (5)

X = (x1, x2, ……….….., xm) (6)

In the equation, K: Snow amount; Q: Production quantities vector; X: Input usage vector; f: Production functions or technology matrix; Px: Input prices vector; PQ: Output prices vector; *: Denotes optimum values.

The fact that some of the inputs of the business are limited or fixed in the short term and that perfect competition conditions do not apply in the input or output markets does not change the basic structure of the algebraic expression above but makes it more complex. In the short term, resource constraints such as xI=kI or xI<k should be added to the constraints, and if prices can be affected by business production, relevant factor, and product demand functions should be substituted instead of fixed input and output prices.

The cost elements used in the study are defined in two classes, depending on their variable or fixed character, and are shown in Table 1.

Table 1. Fixed and variable costs in production (Aslan, 2013).

Variable Costs	**Fixed Costs**
Seed, Seedling	Fixed Capital Interest (Machine, building, etc.)
Fertilizer, Lime etc.	Depreciation of Fixed Capital (Machine, building, etc.)
Agricultural Control Medicine	Insurance
Fuel, oil, repair-maintenance Variable costs of the machine such as	Tax (Except income tax)
Temporary Worker Wage	Land Rent
Machine Rent	Permanent Labor Wages
Irrigation Fee	
Product Insurance	
Marketing Expenses	
Interest on Variable Costs (Revolving Fund Interest)	
Payments for Lump Sum Works	

3. PROPOSED METHOD AND DESIGNED SOFTWARE

The block diagram of the APRIS expert system is shown in Figure 3(a). It is designed to identify the problem and determine the requirements, analyze the system needs and functions in detail, create the database and knowledge base, perform coding for logical inference, interface design, test it with data obtained from the field, and solve the problem.

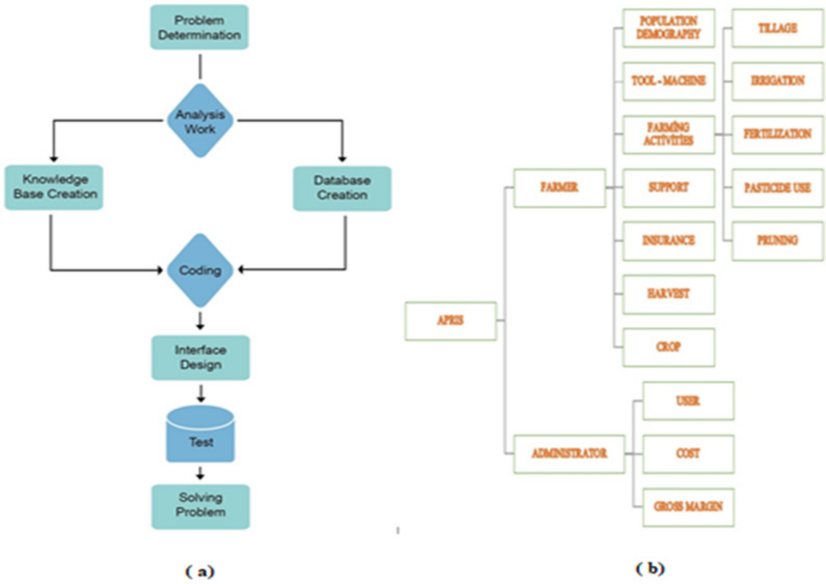

Figure 3. (a) Block diagram of the expert system, (b) APRIS modular structure

The defined problem is real-time analysis of apricot data for agricultural enterprises and farmers, making cost and gross profit calculations and planning production with the obtained digital data. A modular structure was planned to solve the problem at hand, and the requirements needed for each module were designed as seen in Figure 3(b). For the APRIS system, the Interface design stages are presented in Section 3.1, the design of the Information base and the created rules and database design are presented in Section 3.2, and the Data Analysis and Cost and Gross Profit Calculation are presented in Section 3.3.

3.1. APRIS Interface Design

In the developed system, the user interface allows the application to communicate with the user. If the user needs to control the developed knowledge base, he can add or remove new rules, run the rules in the knowledge base, and solve the problems with the results obtained by the logical inference engine. It also makes it easier for users, developers, and administrators to use.

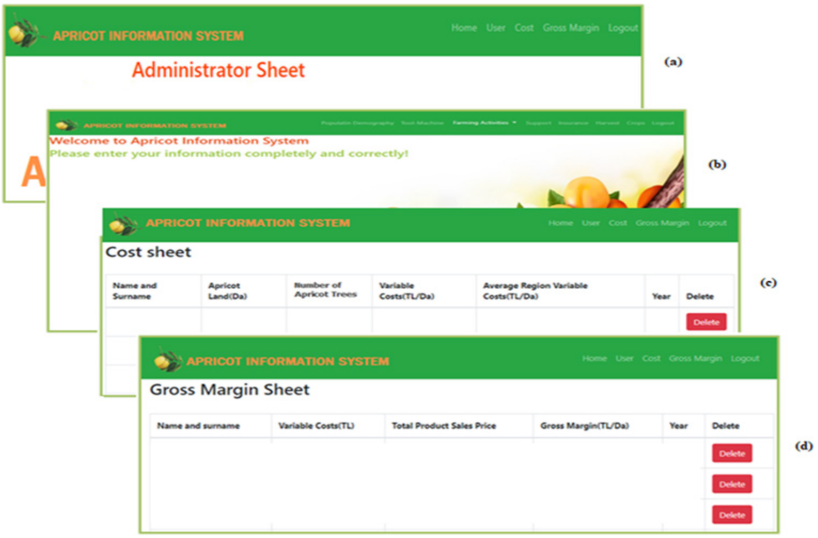

Figure 4. Data input interfaces of modules.

In the interface design, the Admin Module interface containing User, Cost, Gross Profit modules for Administrators and Developers in Figure 4(a), Figure 4(b) shows the User Module interface that enables enterprises or farmers to perform Population Demography, Tools - Machinery, Maintenance Operations, Support, Insurance, Harvest and Product user transactions, and Figure 4(c) shows Cost and Gross Profit Calculation, which is the subject of the study. The Cost Calculation Module interface, where the transactions take place, and the Gross Profit Calculation Module interfaces are designed in Figure 4(d). The design focused especially on making APRIS software easy to use and accessible for, who are its most important stakeholders. In this way, practical and fast access to information, efficiency, and complex tasks are ensured by avoiding designs that would tire the user and cause a loss of time.

3.2. APRIS Knowledge Base Design

Expert systems aim to accumulate the knowledge and experience of experts in a field in order to solve the problem in a real and fastest way. This collected information forms the knowledge base. APRIS knowledge base was prepared in line with the information obtained from KAEM staff and academicians of MTU

Faculty of Agriculture, Department of Agricultural Economics. APRIS knowledge base consists of 180 rules. Rule examples are prepared in Table 2, and the pseudo-code block representing these rules is presented in Table 3.

Table 2. APRIS knowledge base sample rules.

Rules created according to the IF…THEN..........…ELSE structure	
Rule 1 **If** irrigation is done; **And** if the irrigation type is drilling, **And** if the irrigation number is less than 6, **Then** the irrigation frequency should be 6.	**Rule 2** **If** irrigation is done; **And** if the irrigation type is drilling, **And** if the watering time is less than 6 hours, **Then** watering should be done at 6 o'clock.

Table 3. Knowledge base pseudocode.

```
choose irrigation type
If (irrigation type== drilling or Cooperative && irrigation quantity (<6 or >6)) then
Irrigation Quantity=6;
Irrigation Cost = (Irrigation Quantity * Labor Time / 8 * Labor Per Diem * Number of Workers) +
(Fuel Liter Price * Fuel Liter per Decare) + (Paid to the Cooperative) + (Electricity Fee) + (Other
Expenses);
Else If (irrigation type== (drilling or Cooperative) && irrigation hour (<6 or >6)) then
Watering Hour =6;
Irrigation Cost = (Irrigation Quantity * Labor Time / 8 * Labor Per Diem * Number of Workers) +
(Fuel Liter Price * Fuel Liter per Decare) + (Paid to the Cooperative) + (Electricity Fee) + (Other
Expenses);
Endif
```

Databases are areas where structured information or data is stored. It is possible to define a database simply as a system consisting of more than one table (relationship). The APRIS relational data model, which is the subject of the study, consists of 32 tables that provide modular design.

3.3. APRIS Cost and Gross Profit Calculation

In this section, cost and gross profit calculations, which are the main purpose of the article, were carried out by processing the information from the database and the rules in the knowledge base in the inference engine, which is the last stage of expert systems.

3.3.1. Apricot Cost Calculation

The cost of apricots was calculated by processing the data obtained from 15 farmers through a face-to-face survey and the rules created in the information base. The flow diagram of cost calculation is presented in Figure 5.

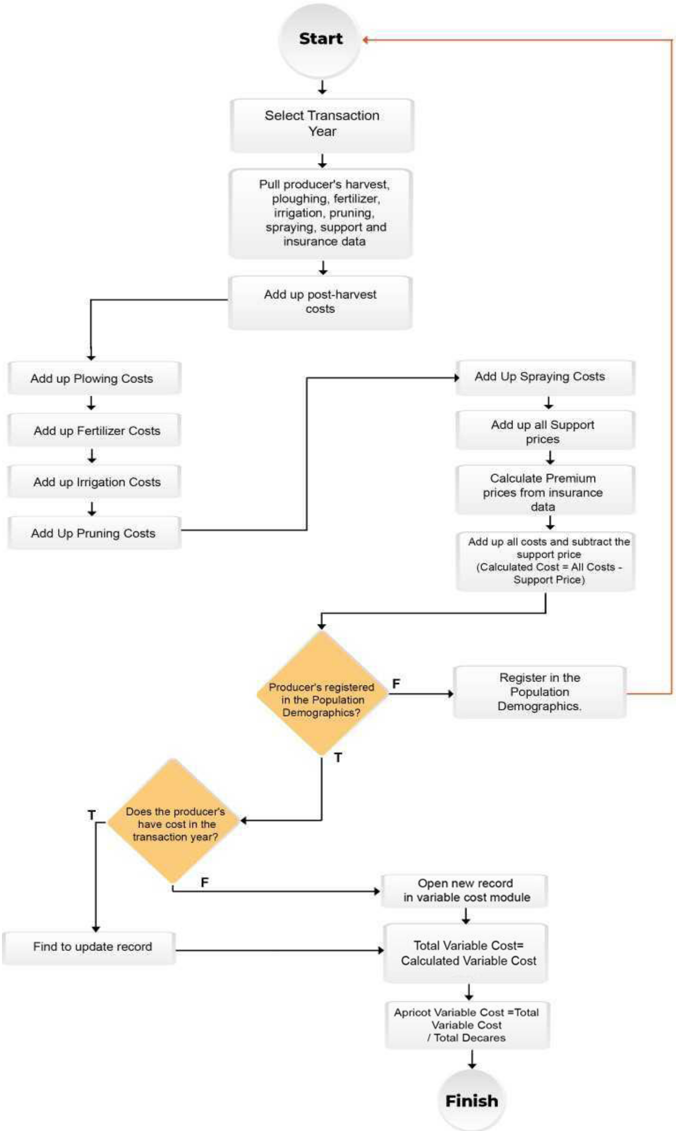

Figure 5. Variable costs calculation flow chart (Erkuş et al, 1995).

In Table 4, annual calculations were made for the apricot area (da), number of apricot trees, variable costs (₺/da), and average regional variable costs (₺/da) in the expert system cost calculation module. Farmers were included in the system, and the 2020 apricot variable cost was found to be 1126.36 (TL/da).

Table 4. Cost calculation results and comparison.

	Statistical Methods				Expert System Method (APRIS)			
	Apricot Land (Da)	Number of Trees	Variable Costs (TL/Da)	Average Region Variable Costs (TL/Da)	Apricot Land (Da)	Number of Trees	Variable Costs (TL/Da)	Average Region Variable Costs (TL/Da)
Farmer 1	15	250	780,43	1252,89	15	250	780,43	1126,36
Farmer 2	12	160	1452,11	1252,89	12	160	1452,11	1126,36
Farmer 3	10,5	120	924,55	1252,89	10,5	120	924,55	1126,36

In the study, fixed costs were not taken since the system calculates the gross profit. Variable expenses were used to find gross profit. Rental prices in the region were taken into account in the expenses incurred.

3.3.2. Gross Profit Calculation

The gross production value (GPV) of the enterprises was calculated with the apricot, seed, and wood sales information obtained from the farmers. The annual costs of these enterprises were subtracted from their annual GPV totals, and after this process, their gross profits were calculated by dividing them by the apricot land (da) of the enterprise. The main steps of calculating gross profit are explained in Figure 6.

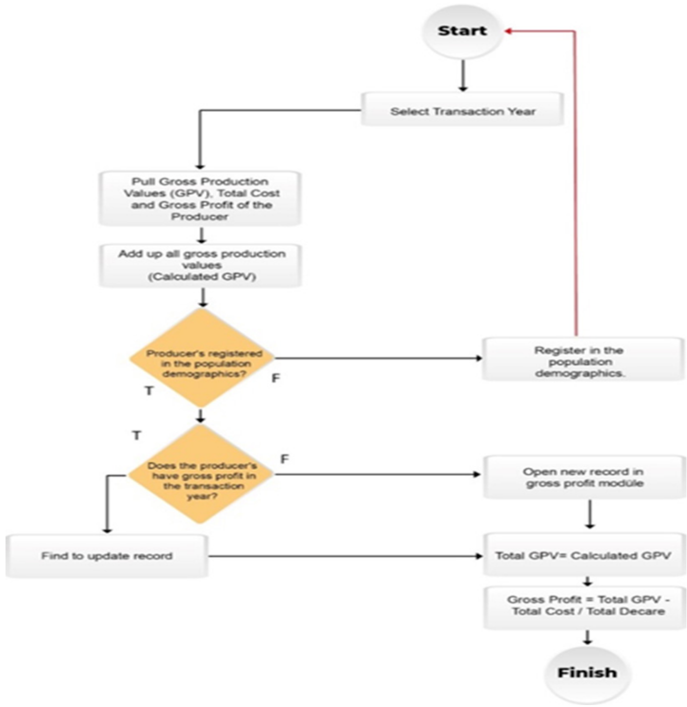

Figure 6. Gross profit calculation flow chart.

As seen in Table 5, the gross profit page is drawn from the data entered by farmers into the system; Name and surname, variable costs (₺), total product sales price gross profit (₺/da) are calculated and listed. Gross profits of businesses per decare are calculated on a business-by-business basis, as seen in the Gross Margin Column of Table 5.

Table 5. Gross profit calculation results and comparison.

	Statistical Methods			Expert System Method (APRIS)		
	Variable Costs (TL)	Total Product Sales Price	Gross Margin (TL/Da)	Variable Costs (TL)	Total Product Sales Price	Gross Margin (TL/Da)
Farmer 1	30087,91	4675	-473,48	30087,91	4675	-423,55
Farmer 2	9458,9	7210	-321,21	9458,9	7210	-281,11
Farmer 3	25586,28	16700	-260,12	25586,28	16700	-222,16

CONCLUSIONS

APRIS is a platform where farmers are authorized to access the system and enter their own data into the system in real-time. This study aims to reveal a structure in which producers can instantly monitor the recently increasing input costs and operate price mechanisms in cost calculations. It also provides up-to-date data flow to institutions making production planning. The module's feature will create an important platform for a system that can prepare reports on issues such as cost calculations of other agricultural products, yield calculations, determination of tree availability, and the effects of climate change. The designed APRIS expert system is an artificial intelligence-based application that can provide fast and accurate answers and provide solutions to problems that may arise with incorrect or incomplete data. The fact that the developed application has high reasoning power and a good memory prevents incorrect data entry and miscalculations.

Conflict of Interest

The authors declare that there is no conflict of interest.

Ethics

This study does not require ethics committee approval.

Author Contributions Rates

Design of Study: OŞ(%50), FT(%50)

Data Acquisition: OŞ(%75), FT(%25)

Data Analysis: OŞ(%75), FT(%25)

Writing Up: OŞ(%25), FT(%75)

Submission and Revision: OŞ(%25), FT(%75)

REFERENCES

Abraham, A., 2005. Rule-based Expert Systems. Editör: Peter H. Sydenham ve Richard Thorn, Handbook of Measuring System Design. John Wiley & Sons, Ltd. New Jersey. 909-919.

Angeli, C., 2010. Diagnostic Expert Systems: From Expert's Knowledge to Real-Time Systems. Advanced Knowledge Based Systems: Model, Applications & Research, 1(4), 50-73.

Aslan, A., 2013. Malatya İlinde Organik ve Konvansiyonel Kayısı Üretimi Yapan İşletmelerin Karşılaştırmalı Ekonomik Analizi, Kahramanmaraş Sütçü İmam Üniversitesi, Fen Bilimleri Enstitüsü, Tarım Ekonomisi Anabilim Dalı, Yüksek Lisans Tezi, Kahramanmaraş.

Babalık, A., 2000. Uzman Sistemlerin Tıpta Teşhis Amaçlı Kullanımı. Gazi Üniversitesi Fen Bilimleri Enstitüsü, Yüksek Lisans Tezi, Ankara.

Çaylı, A., Temizkan, Y., 2018. Kahramanmaraş Bölgesi İçin Seralarda Örtü Malzemesi ve Isı Tasarruf Önlemlerinin Isıtma Yüküne Etkisinin Uzman Sistem ile Belirlenmesi. Kahramanmaraş Sütçü İmam Üniversitesi Tarım ve Doğa Dergisi, 21(3), 312-322.

Çetinyokuş, T., Metin, D., Oktay Y., 2010. Personel Seçiminde Eşleşme Yöntemi Temeline Dayanan Bir Uzman Sistem Yaklaşımı. e-Journal of New World Sciences Academy, 5(4), 590-602.

Demirtaş, M.N., Öztürk, K., Yiğit T., Çolak, S., Şahin, S., 2011. Kayısı Yetiştiriciliği. EYYDB yayınları, Ankara.

Erkuş, A., Bülbül, M., Kıral, T., Açıl, A.F., Demirci, R., 1995. Tarım Ekonomisi. Ankara Üniversitesi Ziraat Fakültesi, Eğitim, Araştırma ve Geliştirme Vakfı Yayınları No: 5, Ankara.

Fielke, S., Taylor, B., Jakku, E., 2020. Digitalisation of agricultural knowledge and advice networks: A state-of-threat review. Agricultural Systems, 180, 102763.

Golanskı, P., Przemyslaw M., 2015. Use of the Expert Methods in Computer Based Maintenance Support of the M-28 Aircraft. Scientific Journal of Polish Naval Academy, 1-12.

Gutıerrez, S.A., Branch J.W., 2011. A Comparison Between Expert Systems and Autonomic Computing Plus Mobile Agent Approaches for Fault Management. Dyna, 78(168), 173-181.

Heiß, A., Paraforos, D.S., Sharipov, G.M., Griepentrog, H.W., 2021. Modeling and simulation of a multi-parametric fuzzy expert system for variable rate nitrogen application. Computers and Electronics in Agriculture, 182, 1-12.

Janssen, S.J.C., Porter, C.H., Moore, A., Athanasiadis, I.N., 2017. Towards a new generation of agricultural system data, models and knowledge products: information and communication technology. Agricultural Systems, 155, 200–212.

Kamilaris, A., Prenafeta-Boldú, F.X., 2018. Deep learning in agriculture: a survey. Computers and Electronics in Agriculture, 147, 70–90.

Klompenburg, T.V., Kassahun, A., Catal, C., 2020. Crop yield prediction using machine learning: A systematic literature review. Computers and Electronics in Agriculture, 177, 1-18.

Mostafa, M.A., Al-Qurishi, M., Al-Amri, A., Aksoy, M.S., Emam, A., 2022. Novel graphical family tree representation to develop an interactive expert system. Expert Systems, 39(10), 1-19.

Musleh, M.M., Abu Naser, S.S., 2000. Rule Based System for Diagnosing and Treating Potatoes Problems. International Journal of Academic Engineering Research (IJAER), 2(8), 1-9.

Negnevıtsky, M. (2005). Artificial Intelligence. 2nd Edition, Pearson Education, London.

Shahzadi, R., Tausif, M., Ferzund, J., Suryani, M.A., 2016. Internet of things based expert system for smart agriculture. Int. J. Adv. Computer Science Applications, 7(9), 341-350.

Tzounis, A., Katsoulas, N., Bartzanas, T., Kittas, C., 2017. Internet of things in agriculture, recent advances and future challenges. Biosystems Engineering, 164, 31–48.

Üstün, S., Baytorun, A.N., 2003. Sera projelerinin hazırlanmasına yönelik bir uzman sistemin oluşturulması. KSÜ Fen ve Mühendislik Dergisi, 6(1), 168-176.

Verdouw, C., Tekinerdogan, B., Beulens, A., Wolfert, S., 2021. Digital twins in smart farming. Agricultural Systems. 189, 1-19.

Zhai, Z., Martínez, J.F., Beltran, V., Martínez, N.L., 2020. Decision support systems for agriculture 4.0: Survey and challenges. Computers and Electronics in Agriculture, 170, 1-16.

Winstanley, T., Courvalin, P., 2011. Expert systems in clinical microbiology. Clinical microbiology reviews, 24(3), 515-556.