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Web-based intelligent system for predicting apricot yields using artificial neural networks

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ABSTRACT

This paper shows the use of artificial neural networks and the PDCA (Plan, Do, Check, Act) method for predicting the apricot yield per hectare. The goal of the paper is to determine the possibilities for using artificial neural networks to predict the apricot yield per hectare if the following items are used as input parameters: amount of fertilizer, length of shoots, thickness of shoots, beginning of the harvest and fruit mass. The goal of the paper also includes creation of a web-based application that displays final research results, obtained through neural networks. The PDCA method was used in order to ensure the control and continual improvement of the process. The results point to the possibility of successful application of the above mentioned methods, highlighting the limitations, advantages and shortcomings. Future work relates to the successful application of association rule mining in order to detect the relationship between the apricot yield and other parameters.

1. Introduction

The history of growing apricots covers at least 5000 years in China, where it actually originates from (He et al., 2007; Yuan et al., 2007). Apricots have been grown in Europe since the first century AD (Faust, 1989), over the territory of the former Roman empire, as a small fruit plant. The same author stands by the hypothesis that the first cultivars with larger fruit were created by selection in the seventeenth century in Hungary, from genotypes brought by the Turks.

Today, there is around 1.7 million apricot trees in Serbia and, from a production standpoint, it is currently in the ninth place. The average production, for the period 2007–2011, was 26,400 t (Republic Institute for Statistics, 2012), which places Serbia in the 26th place in the world and ninth in Europe. Average yield per tree is 15.8 kg.

The apricot yield per hectare depends on many factors, and prediction is based on planned production and the input parameters that influence it. Artificial neural networks represent one of the prediction methods used in this paper. This method has been used in numerous research studies in order to predict the grape drying process (Khazaei et al., 2013), water demand (Pulido-Calvo et al., 2003), soil water content (Givi et al., 2004; Wanakule and Aly, 2005), etc.

The analyses conducted by way of artificial neural networks point to the possibility of predicting selected parameters with considerable accuracy. According to Marinković et al. (2009), these analyses assume the existence of knowledge of various areas, such as agriculture, information technology and data mining. This has motivated us to apply this method to predict the apricot yield, with considerable enhancement by implementing the PDCA method. Besides, the motive behind the paper lies in the need and importance of creating an application that will enable agricultural producers to see the results of artificial neural networks with basic knowledge and skills in the area of information technologies, without additional specialization in this area.

There is a large number of research studies that deal with application of data mining technologies, in effort to predict yields of various cultures. Some of them are shown in the research done by Uno et al. (2014), Ehret et al. (2011), Kaul et al. (2005), Guo and Heru (2014), Farjam et al. (2014), Bejo et al. (2014), Stastny et al. (2011), Dahikar and Rode (2014), etc. The goal of using mentioned techniques is extracting useful information from large quantity of real data, according to McQueen et al. (1995) and Ramesh and Vardhan (2015).

According to Rub et al. (2008), the importance of using data mining techniques, especially artificial neural networks, rises with an increase of available data in agriculture which are nowadays

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received from sensors and GPS technology. Rossana et al. (2013) point to the fact that neural networks are largely used for "its capability to recognize pattern and the speed of its techniques to accurately solve complex processes in many applications" (Rossana et al., pp. 4). The importance of using these techniques, according to Raorane and Kulkarni (2013), is seen in the possibility of applying the results in the decisions that relate to storage, distribution, pricing, marketing, import-export, etc. The results received from the above mentioned technologies lead to the development, or so called, precision farming whose goal is to improve cropping efficiency, according to Drummond et al. (1998). Besides, according to Rub (2009), an adequate usage of the results obtained by the technique of artificial neural networks improves efficiency and therefore brings economic advantages. According to Medar and Rajpurohit (2014), target group for which the results of data mining pertain are producers, consultants and agriculture-related organizations. Target group for the research proposed here are agricultural producers who would use the results to predict future apricot yields based on the input parameters.

The application of neural networks, or any other technique for data mining in the case of apricots, was recorded in the research of Parpinelloa et al. (2007) and Gago et al. (2011). Artificial networks are applied to a wide spectrum of problems and research questions. Neural networks have the ability to learn, adapt and self-organize (Maind and Wankar, 2014; Sumathi and Surekha, 2010). They are based on the structure of a biological neural system and mimic all the characteristics of the natural system.

Parpinelloa et al. (2007) showed in their research the use of artificial neural networks in order to "analyse the headspace of apricot fruits to classify 10 different cultivars". The results point to the possibility of the successful use of artificial neural networks in this entire area with 90% of correct classifications of apricot cultivars. As in the above research, this paper also uses a technique of neural networks to predict apricot yield per hectare. Also, a similarity is apparent in the selection of the network architecture, that is, the application of one hidden layer.

Data-mining techniques were used in order to uncover knowledge that was hidden in multiple data from apricot databases (Gago et al., 2011). The above mentioned techniques were used in order to extract useful information from large amounts of data. Unlike the mentioned research, this paper predicts apricot yield using a technique of neural networks. In a similar way, patterns that relate to input and output parameters in an artificial neural network are discovered.

Many research studies deal with the application of artificial neural networks in agricultural prediction. However, some of them also use the PDCA (Plan, Do, Check, Act) method, in order to guarantee quality.

The four Deming phases (Deming, 1982) include Plan, Do, Check and Act.

This research was conducted according to the given phases. The Plan phase contains a detailed plan of the research, data gathering and selection of the appropriate architecture of an artificial neural network. The Do phase creates a tested and evaluated architecture of the neural network. In the Check phase, the neural network is tested with a questionnaire and the Act phase identifies the needs for creating a web-based system which is achieved during the improvement step. The use of the PDCA method in order to secure quality during the application of a data-mining model is shown by Blagojevic and Micic (2013).

In comparison to the studies presented above, the approach suggested in this paper is different because it includes the PDCA method in order to ensure the control and continual improvement of the process. Besides, the need for the software that would provide the results of prediction of artificial neural networks is taken into account, the software that could be used without specific knowledge of information technologies. In that regard, the research presented in this paper gives the advantage to the end users of the system, and those are agricultural producers.

1.1. Purpose, goals and tasks

Bearing in mind the importance of the predictions of apricot yield per hectare for the upcoming period, the purpose of the research relates to enabling end users to gain insight into the potential yield per hectare, based on input parameters.

The research objectives are the following:

1. Identifying features of neural networks in order to obtain predictions of apricot yield per hectare;
2. Enabling end users (agricultural manufacturers and other interested parties) to make predictions of apricot yield per hectare based on input parameters.

The research tasks are as follows:

1. Gathering and selection of data (P-Plan)
2. Data pre-processing to clean and prepare data (D-Do)
3. Modelling of neural networks (D-Do)
   - Creating a model (determination of inputs, outputs and network parameters)
   - Evaluation of the network
4. Testing the network through DMX (data-mining extensions) queries (C-Check)
5. Creating a web-based application
6. System upgrade

The remainder of this paper is structured as follows: materials and methods are presented in Section 2, Section 3 highlights the results and Section 4 presents the conclusions.

2. Materials and methods

2.1. Objectives, materials and data

2.1.1. Objectives

The testing was undertaken in an apricot orchard (a cultivar in question is a Hungarian cultivar Magyar Kajszi), located in the village of Milicevci, 9 km north from Cacak, Serbia (43°57′N, 20°19′E, at an altitude of 379 m). The orchard covers 1.60 ha and was established in 1960. The testing was undertaken in the period 2010–2014. It was grafted on *Prunus domestica* rootstock.

The orchard was planted on a slightly inclined terrain with eastern exposition. The direction of the span is east–west, the distance between the trees is 6 m × 6 m, and the growth form is the so-called free growth. The distance between the trees is greater than today's recommended planting distances, but that was the distance used at the time the orchard was planted.

The usual agro and pomotechnical measures, typical of apricots as nut fruit, were implemented. Grass between the trees was cut several times and weeds were destroyed mechanically using a rotary tiller with a sensor. Basic fertilization was undertaken in the autumn, mid-November, with NPK (Nitrogen (N), Phosphorus (P), and Potassium (K)) fertilizer, with the formulation 8:16:24, in amounts of 400–500 kg/ha. Supplemental feeding was undertaken twice: just before the flowers bloomed and at the beginning of May, with KAN (Koch Advanced Nitrogen), in a total amount of 400 kg/ha. Foliation was carried out just before the harvest with KNO_3, in a concentration of 0,5%. There was no irrigation. The trees were pruned only once, during the harvest, in the first half of August. The trees were protected from disease and vermin by using chem-