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Web-based monitoring system using Wireless Sensor Networks for traditional vineyards and grape drying buildings

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ABSTRACT

The quality of grapes and the drying process has a momentous impact on the quality of the final products (raisins). South Azerbaijan is the most important region for grape growing and raisin producing. However, the majority of the vineyards in the region are traditional, and the drying process is carried out in conventional structures that are not convenient. To increase the quality and productivity, it is necessary to modernize agricultural practices with reasonable cost suitable and affordable to traditional farming and farmers. To do this, the harsh environments and severe climate conditions of the vineyards and the drying buildings should be observed periodically to collect data. Wireless Sensor Networks are a key technology that can provide precise information, can update information, and can be a valuable resource to farmers to determine appropriate management practices. Using this technology, farmers can make real-time decisions such as scheduling irrigation periods, preventing diseases, choosing the right time for harvesting and so on. In this project, a Wireless Sensor Network system was designed and developed for remote real-time monitoring and collection of micrometeorological parameter data in three distant vineyards. The system was also used for monitoring the SO_2 gas fumigation process and atmospheric parameters inside the drying structure. The system consists of a gateway and a series of peripheral wireless motes placed in the vineyards and inside the drying structure, which are equipped with agrometeorological sensors for environmental monitoring and for storing and transmitting data to the gateway. The gateway collects agrometeorological data and utilizes a wireless technology for data transmission and for communication between the motes and the central server (webpage). In addition, an on-line (real-time) warning system was embedded in the gateway to send alarm signals via SMS (Short Message Service). The devices were tested for software configuration functionality, hardware operation and data acquisition, energy consumption, and connectivity. Field experiment results demonstrated that the system represents a complete monitoring system, which provides efficient performance for developing information systems in precision viticulture.

1. Introduction

According to the FAOSAT, Iran was the ninth largest grape producer in the world in 2012 (2150000 MT). Additionally, in 2014 grape growing ranked second among horticultural products grown in Iran. The Azerbaijan provinces (South Azerbaijan) are the most important regions for grape growing in Iran, wherein more than 90% of the grape vineyards in these regions are traditional ones. Because of the cold weather and the environment of the region, the traditional vineyards are mainly in the form of large furrows. These specific furrows are called “Qana” in local Azerbaijani Turkish language and are a form of triangular prisms with a long base (approximately 25×2^2) two meters in height with a one-meter interval between every Qana (Fig. 1). Obviously, this particular kind of vineyard is not as productive as trellis ones, but they are more appropriate to the harsh environmental and climatic conditions of the region (extremely cold winters and extremely hot summers with -20 to 40 °C records). Additionally, the conversion of a traditional vineyard to a trellis one is costly and the majority of farmers cannot afford it, and so updates would require a nationally invested project. Instead, farmers could focus on utilizing suitable modern technologies to grow, tend, and monitor their vineyards to enhance efficiency and productivity.

Additionally, Iran is one of the largest raisin exporters in the world, ranking third (after Turkey and the USA) in the world and accounting for 27% of the world’s raisin exports. Compared to the other agricultural activities in the region, raisin producing has become of paramount importance for its economic values and for the size of the population involved in this kind of husbandry and commerce.

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Fig. 1. The traditional vineyard (Qanas).

Fig. 2. Drying structure.

Traditionally, raisins are produced naturally by sun-drying and hanging the grape bunches outdoor inside a structure (Karimi, 2015), as shown in Fig. 2. Drying the grapes in shade (inside the building) can preserve their natural flavor and color. First, the grapes are pretreated by immersion in 2% K_2CO_3 solution for ruining the natural wax coating and subsequently for increasing the drying speed (Karimi et al., 2011). The grapes are also fumigated with SO_2 gas to control postharvest gray mold rot (Botrytis) and other decay-causing fungi, to preserve the golden color of the raisins, to prevent the enzymatic browning, and to facilitate the drying process (Franck et al., 2005; Karimi et al., 2015; Karimi et al., 2017). According to the Codex standards of golden bleached raisins, the maximum limit applicable for sulfur dioxide is 1500 ppm (62,400 μmol m^{-3}). Since excessive sulfur dioxide fumigation is extremely dangerous to human health, the process should be closely monitored and controlled. Furthermore, as the grapes are dried in the shade, the drying process is sensitive and the drying grapes (raisins) can be spoiled and molded by excessive humidity. Hence, the humidity and temperature of the building should be monitored.

Additionally, pest and nuisance birds, insects, and animals can damage and depredate grape berries in vineyards, which can demolish the quality of grapes and raisins. By monitoring damage patterns and depredating species, it is possible to reduce damage or lower the cost of control by concentrating control methods in areas and seasons when damage is most severe.

Precision Agriculture (PA) is one of the most modern and strategic farming systems that integrates information technology with management to increase long-term, site-specific, and whole-farm production efficiency and productivity. Precision Viticulture (PV) as a specific area of PA in vineyards being used to improve productivity and quality. Grape quality and yield depend on agricultural practices, climate and soil characteristics, pests, and environmental diseases. Accordingly, using these variables, PV can provide a management strategy to enhance grape and raisin quality. Generally, PV can simultaneously improve the yield and quality of grapes and their by-products. PV practices are performed based on acquiring, transmitting, and processing agglomerative data coming from a large-scale, heterogeneous sensor network. In recent years, Wireless Sensor Network (WSN) technologies have been used efficiently to provide remote and real-time monitoring of high-quality production and processing systems. Therefore, WSNs can offer a more reliable and safe measuring process for grape and raisin production.

By monitoring environmental conditions through ubiquitous devices called sensor nodes (or motes), a WSN connects the physical and computational world. These networks include a number of motes and