Precision Viticulture Using Wireless Sensor Network

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Abstract—This Viticulture has always, by definition, been a "precision" production: detailed knowledge of not only individual vineyards, but also each grapevine individually, provided detailed programming of work operations and production factors adapted for each parcel individually or, better said, for each part of a single parcel. The spatial variability of a particular vineyard can be due to any difference in any element or property for each of the natural, biological, agronomic factors which influence vine performance and the expression of grape and wine characters. This research is aimed at developing methods to quantify temporal variability observed within vineyards and to use data processing tools to assist wine producers and viticulturists to control, analyse and make decisions from so-provided information. Combining the technologies and methodologies will allow wine growers to improve and optimize production systems by taking into account technical and economic aspects of management as well as environmental issues at an intra-parcel (sub-block) level.

Keywords—precision agriculture, precision viticulture, wireless sensor network, grapevines, viticulture, water, moisture, smart irrigation, IoT, sensing agriculture

I. INTRODUCTION

In the time of increasing demand for food, precision agriculture provides higher yields with a lower input cost and leads to a reduction in environmental pollution and labor. Modern day food production and precision agriculture are expected to dramatically increase the usage of the latest computer and electronic technologies. In accordance to this, decision support systems have been developed in the last decades in order to provide expert knowledge needed for farmers in their agricultural management [1].

Agriculture has been primary economic activity for the people of developing nations. The green-house based agriculture system enhanced by Internet of Things - IoT for monitoring and controlling would provide better yield as well as quality as per required by the market. The use of Wireless Sensor Nodes (WSN), actuators, remote database server/cloud computing, remote access through user application integrated as part of IoT, will enable the efficient utilization of resources available [2].

Agricultural systems are inherently characterized by spatial and temporal variability making yield maximization with minimal inputs a complex task. Thus the farming technologies followed in all parts of world need to be constantly updated to meet these challenges. The concept of precision agriculture has been around for some time now. A new approach of collecting real time data from the environment could represent an important step towards high quality and sustainable agriculture. Precision agriculture is an agricultural system that can contribute to the sustainable agriculture concepts [3].

Research in viticulture and winemaking sector are increasingly focused on the agronomic and technological innovations, aimed to improve quality of grapes and wine, with efficient management of water while minimizing negative impact on the environment. The effective management of the water regime and controlled water deficits are fundamental factors for the production of high quality grapes and wines, along with efficient management of viticulture and wine production.

In a context of growing competition on international markets, it becomes of utmost importance to achieve higher quality standards in the vineyard. This has led to a radical renewal of viticulture and a review of agricultural techniques, with the aim of maximizing quality and sustainability through the reduction and more efficient use of production inputs such as energy, fertilizers and chemicals, and minimizing input costs while ensuring the preservation of the environment [4].

With the increasing need for mechanization of labor operations and with the decreasing availability of manpower, there was a tendency to simplify the work on maintaining vineyards by standardizing the application of different
production inputs - factors of production and agrotechnical measures. This approach, which leads to the harmonization of agrotechnical measures, is based on the assumption that the vineyard should be viewed as a homogeneous individual by the characteristics of the soil and climate, and not as a set of different soil and micro-climate conditions. The result of this is the use of factors of production irrespective of the real needs of the vine, which leads to a deficient or over-application of them, with obvious consequences in terms of profitability and production efficiency, as well as environmental aspects.

In contrast, there are increasing signs of opposite tendencies that result primarily from:

- a significant increase in interest in "sustainable" wine-growing products that are well-suited to the application of locally specific agro-technical measures;
- reduction of costs of production inputs (factors) due to very precise programming of their application;
- differentiation of production, bringing to full expression its specificities by improving the inherent quality of the product, which is achieved through careful and precise programming of vineyard maintenance.

A. Precision Viticulture

In the last decade, wireless technologies have been increasingly applied in precision agriculture. Wireless monitoring systems in particular have been used in precision viticulture in order to understand vineyard variability, and therefore suggest appropriate management practices for improving the quality of the wines.

According to International Organisation of Vine and Wine, Precision Viticulture (PV) is a cyclic management approach to field operations based on information and technology tools that uses multiple sources of vineyard-related data to support site-specific decision making with the aim to optimize production processes.

PV privileges a range of information technologies for understanding variability in their production systems and to quantify and map variability within-vineyard in order to target management according to the real needs of each part of the field (site-specific management). A number of tools, such as soil proximal (ground) or weather sensors, remote sensing (satellite, airborne or drone-UAVs remote sensing), global navigation satellite system (GNSS), geographical information systems (GIS) and robotics can be used.

The spatial variability of a particular vineyard can be due to any difference in any element or property for each of the natural, biological, agronomic factors which influence vine performance and the expression of grape and wine characters. These factors may be present naturally or due to human activity [5].

Several authors have studied precision viticulture in different [4-19]. They reported about several benefits of precision viticulture: reduction of fertilizer costs, reduction of pesticide application costs, minimization of environmental pollution, increase of product yield, more accurate information management due to more efficient information production, operating records required for sales and after sales production periods [20].

Since the production methods and used techniques mainly in viticulture sector of Montenegro employ traditional approaches there is plenty of room for improvement. This particularly holds for application of biosensing technology and state-of-the-art concepts backed up with ICT solutions such as wireless sensor networks, low cost sensing devices and remote sensing. The introduction of this framework in Montenegro could lead to faster economic development, better and more intelligent utilization of the resources, high-quality food production and protection of the environment.

This research is aimed at developing methods to quantify temporal variability observed within vineyards and to use data processing tools to assist wine producers and viticulturists to control, analyse and make decisions from so-provided information. Combining the technologies and methodologies will allow wine growers to improve and optimize production systems by taking into account technical and economic aspects of management as well as environmental issues at an intra-parcel (sub-block) level [21].

II. MATERIALS AND METHODS

A. Field data

Locality Ćemovsko field where are vineyards situated, belong to Podgorica subregion. This subregion is characterized by a Mediterranean climate, modified by the influence of lateral high mountains. It covers 2.300 ha with around 11.5 million grapevines.

The intensity of insolation at the site of Ćemovsko field is very favorable for the growth of vines, with an average duration of sunshine around 2506 hours per year, and around 1793.9 hours during the growing season. Extremely low and high temperatures which would cause damage to the vines and thus hinder its cultivation do not appear. During the winter months the temperature rarely reaches -7°C and 39.2°C in summer. Annual precipitation is around 1482 mm. Disposition of annual rainfall is quite unfavorable. During the growing season around 42% or 626.5 mm of rainfall fall, while for the three hottest months (June, July, and August) fall around 111 mm, what is 7.4 % of total annual rainfall.

Dynamic movement i.e. winds are most intense from the north direction, with a share of 23%. Climatic conditions for growing vines in Ćemovsko field are favorable, except for the annual distribution of rainfall, which is uneven, especially in the summer when the requirements of the vines are increased, especially at the stage of development of green berries. In the period of berries growth, when the vine has the largest need for water, there is a deficit of rainfall. Therefore, successful viticulture at Ćemovsko field can not be achieved without the use of irrigation.

The soil of Ćemovsko field is formed at the conglomerate of fluvioglacial sediments. The sediments consist mainly of
lime or dolomite stone, gravel and sand. The land is characterized by a high content of the skeleton. The content of the skeleton over the entire depth of the profile up to the depth of 130 cm is 80% and the fraction smaller than 2 mm (small land) is 20%. The highest content of the skeleton consists of particles of diameter 0.5-2 cm. It is a high content of skeleton of 2-5 cm in diameter, and fraction of 0.2-0.5 cm is only 8%.

B. Wireless Sensor Network (WSN)

The advent of precision irrigation methods has played a major role in reducing the quantity of water required in agricultural and horticultural crops, but there is a need for new methods of automated and accurate irrigation scheduling and control. The early adopters found precision agriculture to be unprofitable and the instances in which it was implemented were few and far between. Further, the high initial investment in the form of electronic equipment for sensing and communication meant that only large farms could afford it. The technologies used are Remote Sensing (RS), Global Positioning System (GPS) and Geographical Information System (GIS) and Wireless Sensor Network (WSN).

Wireless sensor networks is a network of small sensing devices known as sensor nodes or motes, arranged in a distributed manner, which collaborate with each other to gather, process and communicate over wireless channel about some physical phenomena. The sensor motes are typically low-power consumption, low cost, water’s waste reduced, manpower reduced and reliable data communication between sensors nodes.

Low-power consumption: the main challenge is to design a low-power hardware component. Thus, the overall system should take into account the power consumption which should be minimized as much possible as it can be at every block of the system design. Moreover, the system uses a battery that requires low-power consumption. It provides a service life of several weeks.

Low cost: since there is a large number of nodes and because application is oriented to agriculture, nodes must be as cheap as possible. The easy deployment and low maintenance cost make WSNs a cost effective solution for monitoring. WSNs are designed to run unattended for years, thus, greatly reducing human resources for maintenance and repairing. Moreover, wireless modules do not need any cable to work.

Water’s waste reduced: to have an effective irrigation system it is necessary to obtain as much water to the plants, or into the soil, as possible. It may seem easy to do, but in fact, water loss from these systems can be up to 50% because of the evaporation cycle. On hot and sunny days, a good portion of water may never make it to the ground. Therefore the irrigation system should be able to detect when the plants are in need for water to open valves for irrigation.

Manpower reduced: it reduces effectively manpower requirement. Farmer can remotely control his system without going to his farm. The irrigation is automatically released by opening and closing the valve without the intervention of the farmer. Sensor nodes are small in size and weight and require no wiring which means that they are easy to install in most locations and applications.

Low data rate: for the transmission of sensor data, it is not necessary high-transmission rates. A few kilobits per second will be sufficient. This also enables lower-power consumption and lower bit error rate while transmitting. The use of this device will not only reduce the overall monitoring system cost in terms of labor cost, but also provides flexibility in terms of distance or location. Lower bit rate means lower transmission errors therefor larger transmission distance [22].

C. Node deployment and network architecture

In collaboration with DunavNET company, LoRa devices for monitoring soil moisture (Figure1, Figure2) were installed at the 20 different fields in the vineyard, covering 20 grape varieties (Figure3). Devices are energy independent, each equipped with solar panel. Soil moisture sensors were placed at two depths, 25 and 50 cm, for measuring soil moisture at the root zone.

Figure 1. Node with solar panel installed in the vineyard

Figure 2. Sensor node with moisture measurement
Measurements are made every 5 minutes and send the average value every 15-30 minutes. All devices are connected to the LoRa network established at the Čemovsko field by placing one LoRa gateway in the central part of the field. Communication is based on well-known LoRa protocol which operates on radio frequency 867-869 MHz. An antenna is 4 DB so that devices in 3 km of diameter can send the measurements. For internet connectivity, GSM router is used, able to provide internet connection through two different GSM networks. Measurements sent from devices to LoRa gateway are transferred to LoRa server, Lora adapter, Azure IoT hub and finally to agroNET platform that uses Microsoft Azure as an underlying platform.

In Figure 4, it is shown the architecture of implemented system.

After device installation, field water capacity is defined for each field and accordingly the minimum amount of available water needed for the plants (Figure 5).

III. RESULTS AND DISCUSSION

The current irrigation practice is based on experience and visual inspection of the vineyard. Based on this, the plants are irrigated every fifth day thus providing 50 litters of water. However, this doesn’t consider different mechanical soil’ composition and accordingly specific water need resulting in over or under irrigation. In case of under irrigation, the plants are suffering due to water stress. On the other side, over irrigation results in soil degradation.

By implementing the system for irrigation optimization, different water needs as well as different water constant are demonstrating through the Čemovsko field. Field water capacity comes in the range of 19,4% (Bunar 12, variety Kratosija) and 32,8% (Pista, variety Kratosija) while lento...
capillary water that indicates the minimum soil moisture for each field comes in the range of 12.6% and 21.3%. Throughout 2018 it was shown that irrigation at most of the fields was done before it was really needed as at the time when irrigation was done there were enough available water for the plants.

At the micro-location Pista (Kratošija variety) the limit value of soil moisture is 23.2%, while at the micro-location Dinoš (Petit Verdot variety) limit value 17.9% (lower for 5.3%). The obtained results indicate evident differences in water demand at these two localities. At the micro-locality Dinoš it is necessary to add about 30% less water than it is needed at the micro-locality Pista.

Monitoring data on the web application we have created an insight into the moisture movement of soil and the needs of the vineyard for irrigation. At Bunar 17 part of the field, for different grape varieties, soil moisture trend was very similar. During July and August, irrigation was done at the 5 days interval but according to measured data, it was shown that irrigation was done earlier than it was necessary.

On certain micro locations we reduced the irrigation for the harvest period in order to accumulate high content of sugar in grape.

IV. CONCLUSION

In the past 50 years, world agriculture has experienced enormous changes. Industrialized countries have created a modernized agricultural system with high productivity and advanced technology. Rapid socio-economic changes in some developing countries are creating new opportunities for application of precision agriculture [3].

Given the fact that the company ‘13. jul Plantaže’ its production of grapes and wine mostly based on autochthonous grapevine varieties, primarily on Vranac variety, with this practice the needs and requirements of Vranac variety for water and nutrients in different phenological stages of its growth and development in Cemovsko field will be recognized. The introduction of this technology in viticulture and wine production of our company and also in the viticulture and winemaking sector in Montenegro, will cause the rapid economic development, more and better use of resources, competitive and cost-effective production, better knowledge of agrobiological and oenological potential of grapevine, better quality of grapes and wines with the protection and preservation of the environment.

Bearing in mind the issue of climate change is increasingly prominent, for now, it is not yet possible to use an automatic irrigation method. However, by combining the received data from sensors, climate and soil data, knowledge of the requirements and the physiology of the vine, we have the ability to make the decision when it is necessary to start irrigation to reap the benefits of precision irrigation.

Precision irrigation system with robust components such as, sensing agricultural parameters, identification of sensing location and data gathering, transferring data from crop field to control station for decision making and actuation and control decision based on sensed data will find application in future agriculture [3]. To complete the control of a whole farm, we will try to implements this nodes and other methods of precision agriculture using wireless sensor network in the entire production (vineyards, fruit collections, machinery, protection).

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