Opportunities for precision agriculture in Serbia

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Abstract. *The aim of this paper is to analyze the factors leading to low adoption rate of precision farming in Serbia and to describe steps being taken by BioSense institute to increase it. The majority of the arable land in Serbia is grown by small family owned and operated farms most of which are in the range of 2 to 5 ha making them highly unsustainable. Only 16% of the arable land is managed by agricultural companies and cooperatives. We believe that the adoption of advanced technologies with the currently available precision farming solutions is low among the small farmers due to the small size of the agricultural fields and their inability to invest in technologies. Therefore BioSense institute aims to develop low cost, easy to use precision farming solutions that can be applied anywhere regardless of size, the type and age of agricultural machinery used by the farmers and make IT an important tool to drive small farms towards sustainability. With the new applications developed by BioSense all farmers, even small, can benefit from the diffusion of IT into agriculture making precision farming widely accepted in the years to come. In the framework of the "Digital Agriculture of Serbia" program, several technologies are being developed in the areas of nano and microelectronic in-situ sensors, robotic platforms, genotyping/phenotypic, remote sensing (UAS, satellites), internet of things (IoT), and big data analytics as a means to create new information and extract new knowledge that is not otherwise available. A web-based and android-based digital platform named "AgroSense" was recently released for public use and got widely accepted with a large number of large, medium and small farmers registering to the system. The platform brings the benefits of IT to the end users providing free and paid tools (for advanced users) for better decision making. It is also an excellent tool for big data collection that will create new agronomic knowledge. We foresee a great potential for advancing and modernizing farming in Serbia leading towards a more sustainable and environmentally friendly agriculture.*

Keywords.
Presision Agriculture, Smart Farming Technologies, adoption.

Introduction

Precision Agriculture (PA) is described as the management of spatial and temporal variability of the fields using ICT (information, Computers and Technology (Gemtos et al., 2013). The use of PA can actively contribute to food security and safety, support sustainable farming and trigger societal changes. On the other hand, it requires new skills to be learned (Schrijver et al., 2016). However, the adoption and diffusion of technological innovations is low even in developed countries with significant barriers existing in both the users and technology developers sides (Long et al., 2016). One of the main barriers is the high cost of adopting new technologies (Gruèr and Wreford, 2017) and lack of financial capacity to implement such equipment is an important factor that restrains adoption. In addition, the anticipated financial benefits have been identified as important drivers of the adoption (Rochecouste et al., 2015). According to the results of a study conducted by Wageningen University and Research, adoption rate of precision agriculture applications is low in the Netherlands mainly because (1) the applications are complex, (2) cost-benefit for farmers is sometimes small, and (3) there is lack of models for data use and protection (Wal et al., 2017).

Agriculture in Serbia

Agriculture is the most important export sector for the economy of the Republic of Serbia representing 19.4% of the total value of exports, engaging more than one third of the working population (Vehapi and Saotic, 2015).

According to the official statistical data, the agricultural land covers total area of 3.86 million ha 89% of which is cultivated. The 73% of the total utilized agricultural land is used for arable crops 68% of which cultivated with cereals (census of agriculture 2012). In the period from 2007 to 2016 cereals were the dominant crops occupying the 43.8% of the total crop production (Statistical Office of the Republic of Serbia, 2017). Maize and wheat are the most predominant crops covering 39% and 24% of the total arable land respectively followed by sunflower and soybeans (Table 1).

Table 1. Use of agricultural land in Serbia.

Crop	Year	Harvested area (ha)
Maize	2016	1,010,097
Wheat	2016	595,118
Sunflower seed	2016	200,299
Soybeans	2016	182,362
Barley	2016	91,530
Sugar beet	2016	49,237
Potatoes	2016	40,105

Source: FAOSTAT (http://www.fao.org/faostat)

According to the latest census of agriculture in Serbia (Census of Agriculture, 2012), the total number of agricultural holdings is 631,552 with only 3,000 (0.5%) belonging to legal entities and agricultural companies. Therefore, the majority of the arable land is grown by small family owned and operated farms most of which (78% of the total) are utilizing less than 5 ha of agricultural land; the average utilized area per holding was 5.4 ha, which is likely not sustainable. Another interesting outcome of the latest census was the age of the agricultural population in Serbia with the average age of the farmers of the family agricultural holdings reaching 59 years.

Yields for the main crops grown in Serbia have increased during the last decade indicating that farmers started using more advanced farming techniques and better cultivars. However in the years with unfavorable weather conditions, severe drought in 2007, 2012 and 2015, yield was greatly affected (figure 1). Maize production was more susceptible to drought during summer compared to sunflower and soybeans.

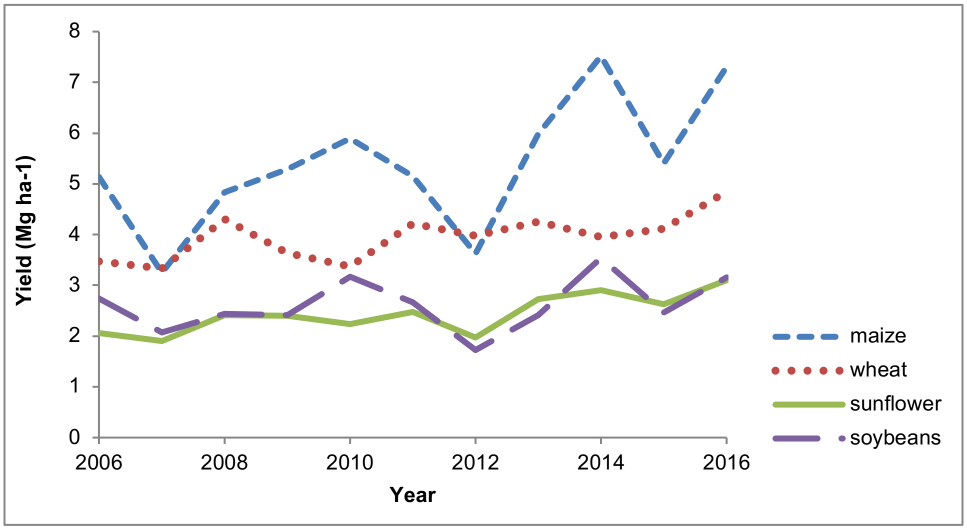


Figure 1. Yield trends since 2006 for the main crops grown in Serbia (maize, wheat, sunflower and soybeans). Source: FAOSTAT

In 2016 the average grain maize yield in the republic of Serbia was 7.3 Mg ha-1 (FAOSTAT) while the selling price was € 0.13 kg-1 (Chamber of Commerce and Industry of Serbia) providing gross income of € 930.2 ha-1. According to the calculations, the total cost of maize production following the conventional growing practices in 2016 was €639.2 ha-1 leaving a net income of €291ha-1. The same economic analysis was performed for Krivaja DOO, a farm collaborating closely with BioSense institute, testing and disseminating the advantages and benefits of digital technologies in agriculture in Serbia. In 2014 the farm started adopting and using precision agriculture technologies for decision making such as yield mapping, targeted soil sampling and remote sensing for management zones delineation and prescription maps creation with the final goal to perform variable rate fertilization and variable rate sowing. Unfortunately in 2016 the farm didn’t perform any variable rate applications (VRA), therefore the comparison between conventional (the average inputs and yields in Serbia) and precision farming applications in Serbia (data from Krivaja DOO for the year 2016 does not include VRA. However, the rest of the technologies were used for decision making on field level leading to better management. According to the calculations, the net income for Krivaja for maize production in 2016 was €666.8 ha-1, significantly higher than the average income from conventional management of maize in Serbia mainly because of the considerably higher yield achieved (Table 2). The high yields were the result of the combination of the utilization of high quality inputs, better farming practices and smart farming technologies.

Table 2. Cost analysis of the inputs and yields of maize crop from conventional management in Serbia (average) and from Krivaja DOO for the year2016.

operation / material	unit	conventional management*	precision farming**
soil preparation	€ ha^{-1}	98.7	190.0
sowing	€ ha^{-1}	22.0	21.9
fertilizer application	€ ha^{-1}	17.2	24.7
plant protection	€ ha^{-1}	75.5	48.8
harvest	€ ha^{-1}	99.9	95.2
cost of operations	€ ha^{-1}	313.2	380.6
Seed	€ ha^{-1}	78.1	139.0
fertilizer	€ ha^{-1}	186.9	189.7
pesticide	€ ha^{-1}	61.0	51.1
cost of materials	€ ha^{-1}	326.0	379.8
total cost	€ ha^{-1}	639.2	760.4
average yield	Mg ha^{-1}	7.3	11.2
gross income	€ ha^{-1}	930.2	1427.2
net income (before taxes and contributions)	€ ha^{-1}	291.0	666.8

*Data for conventional management were obtained from the analysis of the Cooperative Union of Vojvodina for 2013 (22nd meeting of the Steering Committee) and adjusted for 2016.

**Data for precision farming were obtained from the records of Krivaja DOO for the year 2016 from 20 fields covering total area of 1091 ha. The inputs were applied conventionally. The management decisions were based on precision farming technologies. Navigation during sowing and for other farming practices was based on RTK GPS

The comparison of the cost analysis for wheat (Table 3), sunflower (Table 4) and soybean (Table 5) crop yielded similar results with the comparison in maize.

Table 3. Cost analysis of the inputs and yields of wheat crop from conventional management in Serbia (average) and from Krivaja DOO for the year2016.

operation / material	unit	conventional management*	precision farming**
soil preparation	€ ha^{-1}	107.7	175.7
sowing	€ ha^{-1}	17.2	18.2
fertilizer application	€ ha^{-1}	27.9	18.5
plant protection	€ ha^{-1}	42.6	78.9
harvest	€ ha^{-1}	89.7	92.9
cost of operations	€ ha^{-1}	285.1	384.2
Seed	€ ha^{-1}	101.3	89.5
fertilizer	€ ha^{-1}	177.2	196.3
pesticide	€ ha^{-1}	19.4	103.0
cost of materials	€ ha^{-1}	297.9	388.8
total cost	€ ha^{-1}	583.0	773.0
average yield	Mg ha^{-1}	4.8	8.1
gross income	€ ha^{-1}	616.0	1029.4
net income (before	€ ha^{-1}	33.0	256.4

*Data for conventional management were obtained from the analysis of the Cooperative Union of Vojvodina for 2013 (22nd meeting of the Steering Committee) and adjusted for 2016.

**Data for precision farming were obtained from the records of Krivaja DOO for the year 2016 from 15 fields covering total area of 1088 ha. The inputs were applied conventionally. The management decisions were based on precision farming technologies. Navigation during sowing and for other farming practices was based on RTK GPS.

Table 4. Cost analysis of the inputs and yields of sunflower crop from conventional management in Serbia (average) and from Krivaja DOO for the year2016.

operation / material	unit	conventional management*	precision farming**
soil preparation	€ ha^{-1}	102.1	155.4
sowing	€ ha^{-1}	22.0	20.9
fertilizer application	€ ha^{-1}	34.6	23.8
plant protection	€ ha^{-1}	57.3	55.8
harvest	€ ha^{-1}	76.7	76.9
cost of operations	€ ha^{-1}	292.7	332.8
Seed	€ ha^{-1}	60.8	88.0
fertilizer	€ ha^{-1}	176.5	152.6
pesticide	€ ha^{-1}	73.0	57.1
cost of materials	€ ha^{-1}	310.3	297.7
total cost	€ ha^{-1}	602.9	630.5
average yield	Mg ha^{-1}	3.101	3.5
gross income	€ ha^{-1}	802.9	916.5
net income (before	€ ha^{-1}	199.9	286.0

*Data for conventional management were obtained from the analysis of the Cooperative Union of Vojvodina for 2013 (22nd meeting of the Steering Committee) and adjusted for 2016.

**Data for precision farming were obtained from the records of Krivaja DOO for the year 2016 from 28 fields covering total area of 1018 ha. The inputs were applied conventionally. The management decisions were based on precision farming technologies. Navigation during sowing and for other farming practices was based on RTK GPS.

Table 5. Cost analysis of the inputs and yields of soybean crop from conventional management in Serbia (average) and from Krivaja DOO for the year2016.

operation / material	unit	conventional management*	precision farming**
soil preparation	€ ha^{-1}	89.1	204.9
sowing	€ ha^{-1}	27.1	24.2
fertilizer application	€ ha^{-1}	14.6	24.9
plant protection	€ ha^{-1}	75.5	78.0
harvest	€ ha^{-1}	93.1	88.6
cost of operations	€ ha^{-1}	299.3	420.6
Seed	€ ha^{-1}	87.3	57.8
fertilizer	€ ha^{-1}	127.9	141.8
pesticide	€ ha^{-1}	95.3	67.1
cost of materials	€ ha^{-1}	310.5	266.7
total cost	€ ha^{-1}	609.8	687.3
average yield	Mg ha^{-1}	3.161	4.2
gross income	€ ha^{-1}	1004.1	1346.8
net income (before taxes and contributions)	€ ha^{-1}	394.3	659.5

*Data for conventional management were obtained from the analysis of the Cooperative Union of Vojvodina for 2013 (22nd meeting of the Steering Committee) and adjusted for 2016.

**Data for precision farming were obtained from the records of Krivaja DOO for the year 2016 from 3 fields covering total area of 67 ha. The inputs were applied conventionally. The management decisions were based on precision farming technologies. Navigation during sowing and for other farming practices was based on RTK GPS.

Why adoption of advanced technologies in agriculture in Serbia is low

A detailed survey was performed by BioSense in an effort to study the reasons for the low adoption rate of the advanced technologies in Serbian agriculture. The results were compared with other countries across Europe in the framework of SmartAkis project funded by the European Union (Horizon H2020, Project ID: 696294). A total of 36 farmers involved in the most dominant cropping systems in Serbia were interviewed; 44% of the interviewed farmers were growing arable crops, 28% orchards and 28% vineyards. According to the results, only 14% of the interviewed farmers were adopters of smart farming technologies. Compared to the other countries participating in the analysis (France, Germany, Greece, Spain, Netherlands and United Kingdom) this was the lowest adoption rate with the second country from the end presenting almost double rate of adoption. In addition, 92% of the interviewed farmers agreed that the infusion of technology in agriculture can improve farming and 36% that smart farming technologies can increase income. This seems more likely in Serbia compared to developed countries since the yields are quite low due to insufficient management using low quality and quantity of inputs leaving a larger margin for improvement. Furthermore, 81% of the farmers recognized the cost of the equipment as the most important factor for not adopting smart farming technologies, while 94% would adopt SFT if supported though subsidies.

In the same study the interviewees were also questioned what technologies are most important and show higher potential for adoption. Five main categories of smart technologies in agriculture were included (1) robots and autonomous machines, (2) UAVs and aerial images, (3) wireless systems and connected tools (soil sensors, meteorological stations, etc.), (4) GPS for guidance and mapping connected to sensors, (5) agricultural applications.

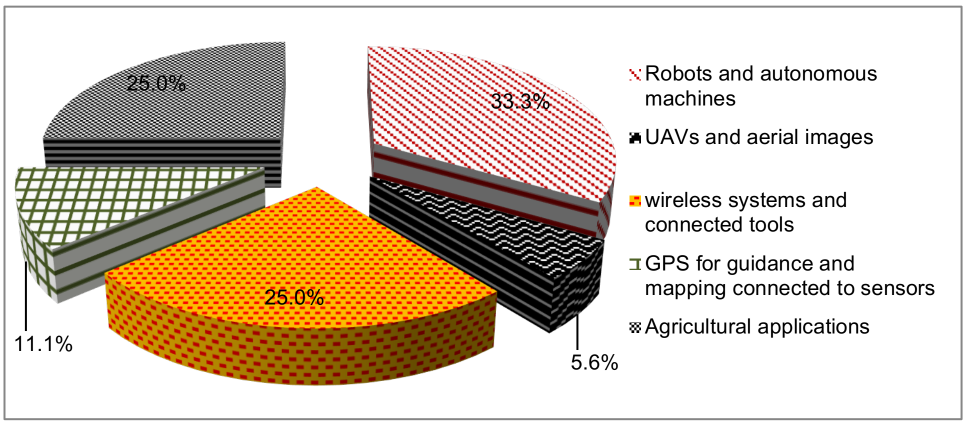


Figure 2. Farmers' perspective of usefulness of the five main categories of smart farming technologies that are currently available. The results were attained from detailed survey conducted by BioSense institute in a sample of 36 farmers in Serbia.

According to the farmers' perspective, robots and autonomous machines would be the most useful smart farming technologies followed by sensors connected wirelessly sending data and agricultural phone applications. Only 5.6 % of the farmers found UAVs and remote sensing data from satellite and aerial images useful. In addition only a few farmers, 11.1% of the interviewees, find GPS, mapping systems and crop sensors useful. These results are contradictory to the market trend in smart farming technologies that mainly support mapping and variable rate applications technologies based on remote sensing.

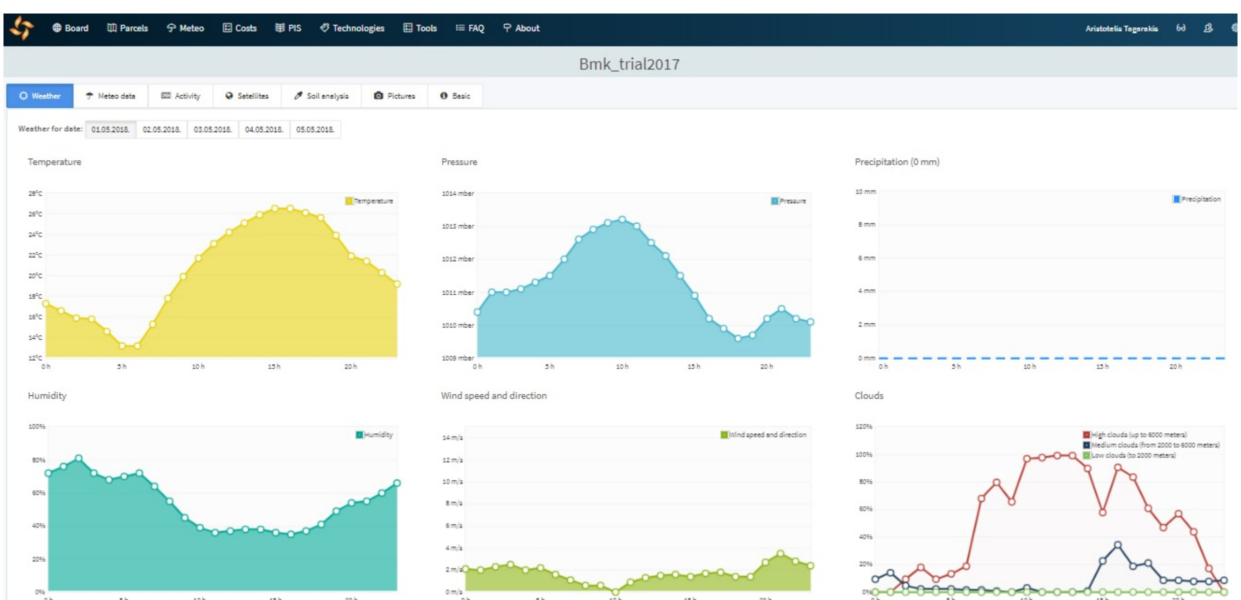
Actions undertaken by BioSense institute to increase adoption of advanced technologies in agriculture

During the last years BioSense Institute has taken actions to increase awareness and adoption of PA and digital agriculture technologies in Serbia. BioSense is a research and development institute for Information Technology in Biosystems with vision to generate, apply, and disseminate ICT solutions for agrifood and related biosystems. It is highly active in six main research areas (1) Nano and microelectronics, (2) communications and signal processing, (3) remote sensing, (4) knowledge discovery and big data analytics, (5) robotics and (6) biosystems. The institute aims to develop low cost, easy to use precision farming solutions that can be applied anywhere regardless the size, the type and age of agricultural machinery used by the farmers and make IT an important tool to drive small farms towards sustainability.

With the new applications developed by BioSense all farmers, even small, can benefit from the diffusion of IT into agriculture. In the framework of the “Digital Agriculture of Serbia” program, several technologies are being developed in the areas of nano and microelectronic in-situ sensors, robotic platforms, genotyping/phenotypic, remote sensing (UAS, satellites), internet of things (IoT), and big data analytics as a mean to create new information and extract new knowledge, not otherwise available.

AgroSense digital platform

A web-based and android-based digital platform named “AgroSense” was released in October 2017 for public use and got widely accepted with a large number of large, medium and small farmers registering to the system (over 8000 users). This digital platform gives support to farmers and agricultural companies in a way to follow the status of the crops and to plan agricultural activities. It consists of AgroSense web application aimed to work on computer and AgroSense Android application which changes a common smart phone into a useful tool for agriculture. The platform brings the benefits of IT to the end users providing free tools for record keeping and for better decision making based on remote sensing to all users. More specifically the tools provided free in “AgroSense” are (1) diary of agricultural activities, (2) weather forecast for each registered field using data from 30 meteorological stations across Serbia, (3) 8 different vegetation indices derived from sentinel satellite images, (4) review of soil analysis, (5) information regarding smart technologies used in agriculture, (6) information regarding diseases and pathogens around each registered field. In addition, for paying users it provides advanced services such as (1) historical data from weather stations, (2) soil properties and soil fertility maps, (3) aerial images, (4) management zones delineation, and (5) ability to connect any sensor in the field and automatically record, log and upload the sensor readings making them available for display in real time. It is also an excellent tool for big data collection that will create new agronomic knowledge. Work is ongoing to advance the platform to provide yield predictions and prescriptions for variable rate applications, and crop rotation and cultivar selection suggestions based on profit versus risk assessment.



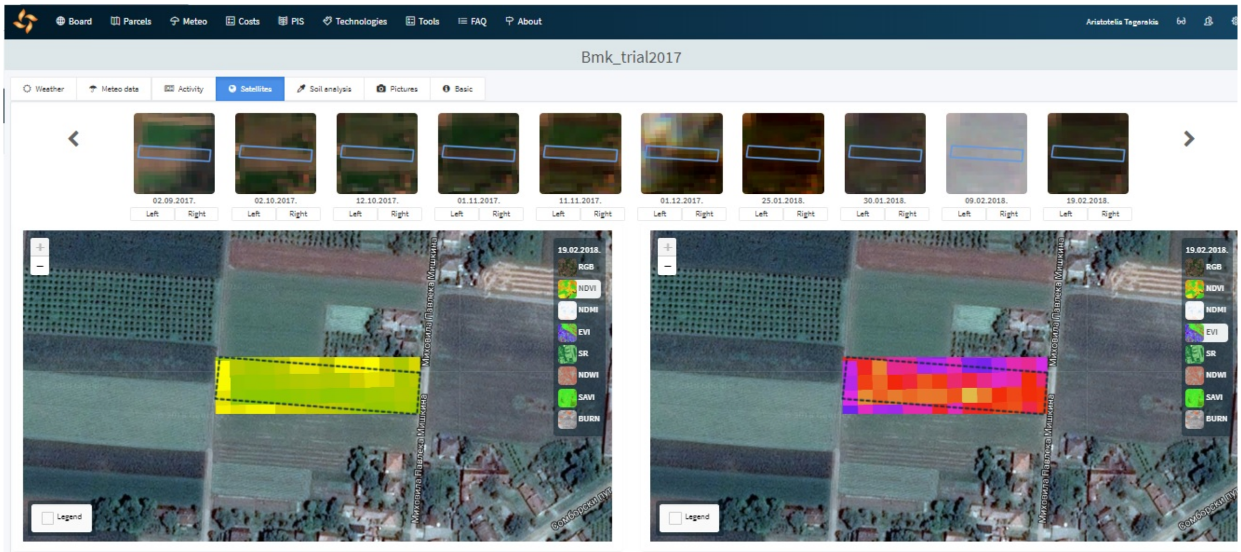


Figure 3. Agrosense platform for digital agriculture of Serbia.

Sensors development

In addition, the efforts of BioSense institute are focused on the development of low cost sensors, applications and solutions that would be affordable by all farmers. An active proximal crop sensor capable of estimating the crop vigor, biomass and nutrient status has already been developed and is expected to be available in the market soon. The “Plant-O-Meter” senses the reflectance of its own specific multispectral light source from the plant canopy in four bands (blue, green, red and near infra-red). The novelty of the sensor is that it uses the processing power and the GPS receiver of any android smart phone device for the canopy reflectance measurements. The android application is used to log, geo-reference, save the measurements and send the data to the cloud. It provides the possibility to calculate over 16 different vegetation indices. Because of the limited electronics needed, the cost will be considerably lower than any other commercial handheld crop sensor available on the market. Therefore the expectation is to be affordable even for small farmers.

Figure 4. Plant-O-Meter active proximal crop sensor developed by BioSense.

Research is also ongoing in the area of wireless connection on farm level developing modules based on long range (LORA) wireless system that provides the capacity to transfer data free of charge within a range of 15 km. The final goal is to connect all the sensors and systems in the farm and send the data to the cloud in real time to be accessible anywhere. There is also an array of sensors being developed such as soil moisture sensors with the ability to connect to the wireless system and soil fertility sensors. The main goal is to make all sensors reliable and low cost to be useful and affordable for every farmer.

Big data analytics

The institute is also active in “Big Data” analysis striving to develop decision models that can assess the risks and benefits of each management practice such as cultivar selection according to the local properties and climate conditions and was the winner of “Syngenta challenge” in 2017. Seed selection is one of the most important management decisions that cannot be compensated by any practices later in the season. Scientists from the department of remote sensing and GIS at BioSense institute developed a tool for selection of an optimal portfolio of varieties to be sown (Marko et al., 2016; Marko et al., 2017). This method was the winning solution for Syngenta Crop Challenge 2017 and will be part of AgroSense platform. The system will be expanded and include the main crops grown in Serbia. In the end this decision support system will recommend what crop and which variety to grow in each field of the farm.

Dissemination

Even though the technology and the solution are available on the market and some of the solutions are free of charge, the adoption is still low. To that end BioSense has adopted the concept of digital farm for demonstration of the innovative technologies in Agriculture to familiarize farmers with the advanced technologies and sensors used for digital agriculture. To that end a pioneer farm, in the adoption of precision agriculture, was selected to host the demonstration events and become a digital farm powered by BioSense. The farm, Krivaja DOO, is farming 4,000 ha out of which 2,000 ha are managed using precision agriculture and variable rate technologies. In the demonstration events, all the commercial precision farming equipment used by the farm and the sensors and innovative technologies developed by BioSense are available for preview.

Discussion

The average yields in all crops grown in Serbia are quite low mainly because of the inability of small farmers to invest in fertilizers, agrochemicals and certified seeds. It is common practice among small holders to store seed in order to use it the following year for sowing. In addition these small producers use minimal inputs for soil preparation, fertilization and crop protection and usually the quality of the fertilizers and agrochemicals is very low to minimize the cost. This is evident form the comparison of the costs of inputs and net income of the average production for Serbia and Krivaja DOO which is farming using advanced techniques and technologies for the main arable crops grown in Serbia. Even though the cost of inputs is higher, the yields were significantly higher compared to the yields achieved using the conventional practices providing higher net income. This is evidence that the potential yields of the crop production in Serbia are considerably higher than the ones currently achieved.

Current adoption of precision Agriculture technologies in Serbia is still quite low mainly due to the small land size of the majority of the agricultural households which makes them highly unsustainable and unable to invest in technology. Also the majority of the farmers are aged with the mean age of the farmers’ population at 59 years. This means that the majority of the agricultural producers is less familiar with technology and is therefore less willing to learn using advanced systems and technologies and less likely to invest in advanced systems.

However, the new applications developed by BioSense institute have received wide acceptance by all farmers in Serbia irrespective of the age and the size. All farmers, even small can benefit from the infusion of digital agriculture using the free applications in AgroSense platform for better distribution of the inputs and better crop management. In the future AgroSense will provide more tools and our expectation are that large farms will become premium users and will engage in precision agriculture using variable rate prescriptions, weather and yield forecasts and other decision support tools for more precise and efficient management.

In addition, the new role of Krivaja DOO as digital farm, powered by BioSense, for demonstration of smart farming tools and equipment for precision agriculture management, has already attracted the attention of farmers in Serbia who visited the events and had a first insight of the use and the properties of the new technologies in agriculture.

We foresee a great potential for advancing and modernizing farming in Serbia leading towards a more sustainable and environmentally friendly agriculture.

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