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Advantages and possibilities of application of precise systems in the agricultural production

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Abstract

A special area with the application in agriculture is the correct driving of tractors with the aim of minimizing overlap of passages, i.e. avoiding empty spaces. The use of markers is not possible when working with large heavy-duty machines, and in many cases due to poor additional processing, the marker cannot leave a good enough "record" on the ground. The aim of this research is to describe the development, working principles, application, and advantages of GPS in modern agricultural production, and to assess the cost-effectiveness of the global positioning system. The application of GPS relates to the finding of spatial and temporal data, where, for certain classes of applications, centimetre accuracy is required to determine the position. Different types of data need to be collected for effective management in this area. GPS-based guidance technology can be used in many agronomic operations. This technique can provide complete autonomous navigation.

Key words: guidance, precision agriculture, productivity, practical application

Introduction

The application of the GLOBAL POSITIONING SYSTEM (GPS) in agricultural production has been carried out intensively for the last twenty years. At the beginning, many were sceptical about achieving wider application, primarily because the price of the devices was high, and the accuracy was much lower than today (Kendall et al., 2017). In agriculture, positioning requirements are specific. In the meantime, the accuracy of guidance has been significantly improved, so that positioning can be applied very successfully to agricultural operations. It is of particular importance the fact that the prices of equipment and the use of guidance services are much lower now, and more and more users are finding an economic calculation for the application of GPS in agriculture.

This guidance system in agriculture first began to be applied in the USA, the EU, and Russia. Even today, this guidance system is mostly used in these countries, with an increasing tendency to spread to other countries.

The Global Positioning System (GPS) was developed by the US Department of Defence, primarily for military purposes. Despite its original purpose, the number of civilian applications based on the use of GPS systems has grown at an incredible rate. Applications of GPS systems are numerous, and can be divided into several basic categories and various research projects (Hunt & Daughtry, 2018).

The first systems of tracking passages were based on guidance towards the electromagnetic field, with the obligation to lay electrical lines. This was followed by the control of the electromagnetic headlight, but this system also had several shortcomings, and equipment was needed that would move across the width of the field during operation (Srbinovska et al., 2015).

An optical system based on an infrared light beam or a laser beam are known areas for guiding a combine harvester when harvesting stubble. In the meantime, these systems have been improved and can recognize a ridge, or row of plants, and have been used successfully for guidance in an inter-row cultivation. A big problem is that the sensors are sensitive to dirt-dust.

There are a number of divisions of systems and technologies that define the prerequisite for the application of precision agriculture: guidance technology (components and software for tractor control inside and between fields), recording technology (sensors mounted on stations, objects, air, or satellite platforms-spatial information collection) and response technology which is a category that uses the previous two (Rossi et al., 2014).

Thus, the GPS system consists of three basic components, i.e. space component, control component, and user component. The space component consists of GPS satellites in the Earth's orbit. The number and layout of satellites have changed over time.

The control component consists of satellite monitoring stations and ground receivers. Updates are performed continuously, which makes fine adjustments to the system. The newer generation of satellites is able to communicate and synchronize data with each other, so the accuracy of determining the position would not be significantly impaired even if the satellites worked for days independently of the control component on the Earth.

The user component consists of GPS receivers on the Earth. Receivers can be components included in other devices, such as a mobile phone, watch, etc., or stand-alone devices (Pongnumkul et al., 2015).

As in other areas of application and in agriculture, the application of GPS can determine three basic groups of tasks: the collection of data on spatial characteristics, the transformation and translation of spatial data, and the synthesis and application of management (Lindblom et al., 2017).

Large satellite distances, interference due to the passage of signals through the layers of the atmosphere, and other influences lead to the need for the improvement and increase of positioning accuracy.

In the meantime, dGPS (differential GPS) systems have been developed that correct the data, achieving absolute accuracy, i.e. relative, which is very important for the user in agriculture. Observation satellites, about 300 km from the ground, or earth stations are used for dGPS. The European Geostationary Navigation Overlay Service (EGNOS) system is available in Europe. EGNOS can be used free of charge.

Figure 1. The John Deere StarFire navigation system

In addition to EGNOS, other commercially available, higher-priced commercial systems are available, such as the John Deere StarFire Autotrac with an accuracy of ± 10 cm (Figure 1).

Results and Discussion

The implementation of precision systems and modern technologies in the agricultural production has become possible with the implementation of GPS systems. The plan of the European Union is to invest in the development of techniques and technologies in the agricultural production. The desire is to increase the level of application of science in agriculture through the application of new technical achievements, in order to respond to the challenges of increasing the volume of agricultural production by about 60% by 2050. This is in favour of reducing the number of active substances in plant protection from 1000 to about 250. Precise agriculture means better management of inputs such as mineral fertilizers, herbicides, seeds, and fuels used during processing, sowing, or pesticide application.

More precisely, it means that the inputs in agriculture are used in the right and better way, in the first place at the right time in the right quantities (Maličević et al., 2009). The concept of precision agriculture surpasses the application of uniform distribution of mineral fertilizers, pesticides, irrigation, seeds, etc. More precisely, production plots are divided into fields, into several zones in which, depending on the quality of land, terrain, and previous production, a variable amount of input will be applied. Zoning provides increased productivity and sustainability of production through improved input management. This type of production involves the use of various hardware and software, machine guides, soil sensors, and crops. By using sensors in the application of pesticides, the amount used on average can be reduced by 13% (Maličević et al, 2013a). The concept also has a positive effect on the protection of the environment, which is reflected in the excessive use of nitrogen and phosphorus fertilizers (Schieffer & Dillon, 2015).

High production costs and reduced yields reduce profit (Jugović & Maličević et al., 2019). Based on inaccurate estimates, excessive amounts of mineral fertilizers are dosed, which significantly increases production costs, and in some cases reduces yields due to the increased presence of a certain element that prevents the absorption of other microelements.

The implementation of precision agriculture has become possible due to the development of sensor technology used in combination with variable mapping procedures at the appropriate agrotechnical measure. A key feature for achieving precision is reflected in the application of positioning systems, primarily the Global Navigation Satellite System (GNSS). Controlled Traffic Farming (CTF) and the autopilot system are the most successful forms used.

The application of GPS is based on the collection and transformation of spatial and temporal data, where, for a particular application, centimetre accuracy is required to determine the position. This requires a complex technological and organizational infrastructure (Shepherd et al., 2020).

There must be a transition period in each subject, i.e. a period of getting employees used to a completely new system and concept. It is realized by installing an advanced system in a small number of tractors, and then permanent training is performed throughout the season in various agro-technical operations. After the first year, if the conditions are met, new systems are installed on the remaining drive and connection machines. The transition period on each property should not last less than 3 years, and preferably it should last 5 years.

The implementation of the guidance system usually takes place in two ways. The first method involves the installation in the tractor of the simplest guidance systems consisting of a monitor and an antenna. It is mostly used for fertilizer spreading and pesticide application, and can be transferred from one tractor to another.

Once the unit operators get used to such systems, more complex components are introduced, which are the automatic guidance of the tractor. The operator is dedicated to controlling the entire system, which works with an accuracy of 2.50 cm in combination with a corrective X-ray signal. The operator turns the unit on the headlands, at the beginning and end of the plot, switches the system on / off, and monitors the work. The next step involves collecting data from the field, and primarily refers to yield / yield data because it is the beginning of a further decision-making process.

Before deciding on the purchase and application of a walkway guidance system, the user should carefully consider all offers and, needless to say, assess the cost-effectiveness of the application. As in other cases, the assessment is not universal, as all influencing factors should be taken into account. For example, if you already have a tractor equipped with a GPS device, it is very likely that the purchase of additional guidance devices will pay off quickly. It is also necessary to consider how many wide-reaching machines and tools there are on which the guidance would be applied, and to estimate the savings on the basis of data in the literature. Special consideration should be given to the need to work at night and in poor visibility, where guidance is crucial. Two examples are given for creating the basis for the cost-effectiveness assessment:

The tractor cultivates 1000 ha per year. The cultivator has a working reach of 8 m, and the tractor is moving at a speed of 8 km per hour. The fold, based on experience, is without average 0.6 m. With guidance, based on the experiences of others, it is 0.2 m (Sedlar et al., 2019a). Counting only active work, without turning time on the headland, breaking with a larger fold will take 9 hours longer. More time for turning on the headland should be added to this, because it will be carried out more often, because the active working width is smaller. When the active length of work is calculated in both cases and the full intervention is taken into account, it is obtained that when working with a fold of 0.6 m, it really "covers" about 55 ha more than when working with a fold of 0.2 m. It is true that the resistance is lower then, because the land has already been cultivated, but the required amount of fuel for this unnecessary work can still be estimated.

It should be added that if the tractor worked at night, in two shifts, all the work would be done in less than half a month, while in the autumn period without night work it would take more than a month.

A comparison was made for the work on the distribution of mineral fertilizers and work on plant protection on an area of about 700 ha (1,500 acres) during the year, using foam marking and a GPS (Medlin & Lowenberg-DeBoer, 2000). When working with foam, the overlap is 10%, and when working with GPS 5%. It was determined, based on an analysis of all costs and payback time of only three years, that the purchase of an additional device with a light bar pays off, because the annual cost is lower by about $ 0.5 per acre. If the purchase of a GPS receiver is taken into account, the costs are higher by about 0.35 dollars per acre per year. This calculation would be different if we take into account the work on 1,500 ha, as well as the application of a GPS in other operations. It should also be taken into account that today the prices of GPS devices of the same configuration are much lower.

When using automatic guidance, the driver does not have to drive, so he can pay attention to more important things (sowing, spraying, and other applications). This results in less driver fatigue, more rational work due to the calculated trajectory, and unnecessary movement of the machine is lost. However, the use of the steering wheel is sometimes necessary if an obstacle appears or when it comes to the end of the field. Another item that is important to mention in automatic guidance is that it is easy to learn and use this system so that when using GPS guidance, you do not need much driver experience, so even drivers with insufficient experience can work as seasonal drivers.

Modern guidance technology is used to support the concept of precision agriculture, especially when fertilizing. The amount of discarded fertilizer is dosed via the location recognition system and the desired yield. During the operation, the computer controls the opening of the dispenser and the number of rotations of the disk or disks. Naturally, for this kind of work, spreaders must be equipped with an appropriate hydrostatic drive, dispensers, and a navigation system. One such device is shown in Figure 2.

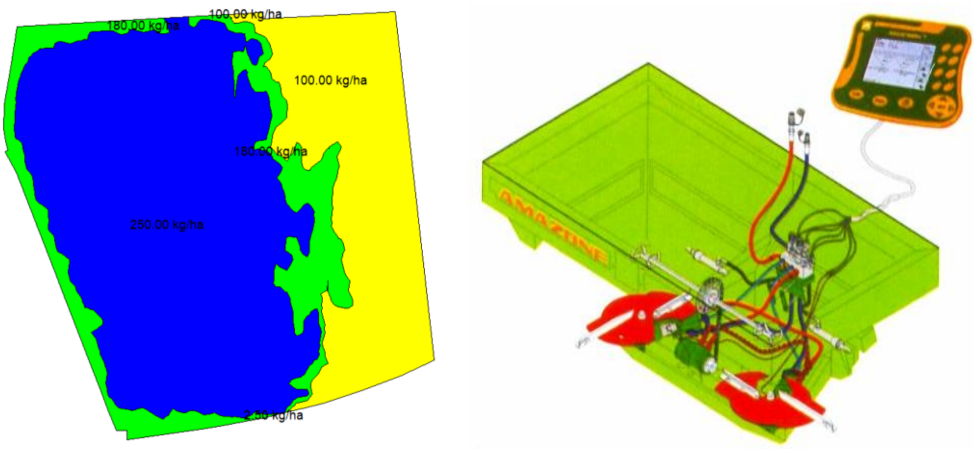

Figure 2. Fertilizer spreader equipped with a GPS system and a variable fertilization map

There is a continuous change in the rate of fertilization, and everything is realized on the basis of mapping the plot according to the content of the elements, i.e. yields from the previous year, planned crops, and land needs. The system receives information from the GPS and on the basis of the map it receives the recalculated fertilization norm. Afterwards, on the basis of the speed of movement and the type of fertilizer, it corrects the norm. By applying such a system, the reduction of fertilizer use goes up to 25%, and the yield increases up to 20%. The result is reflected in the economic effect and reduces production costs by 5.5% (Sedlar, 2019b).

In order to use these potentials for savings, it is necessary to start the process of introducing precision agriculture into everyday practice. There is no ideal uniform solution that can be applied to all users. This fact leaves a lot of room for manoeuvre to each user, because each of them can have a unique path, that is, to see their existing capabilities and start the process of introducing new technologies.

The Global Navigation Satellite System (GNSS) enables "precision", i.e. the application of variable norms of sowing, fertilization, and application of pesticides in accordance with the performed mapping (Maličević et al., 2013b). The success of the application of the mentioned variable standards (Variable Rate Application-VRA), which provide optimization of the application of seeds, fertilizers, or pesticides varies according to specific application factors, and is read through the measured yield by zones (yield sensors-mapping of yields by zones). For example, “section control” means turning off the seed drill, spreader, and sprayer sections outside the plot boundaries or on an already treated part of the plot (Maličević et al., 2019). Variable application of fertilization rates can be reduced by 10-25 €/ha (depending on the area). With this type of fertilization, it is possible to reduce the use of nitrogen by 10-15% without affecting the reduction of yield.

Levelling involves navigation in two planes, both horizontal and vertical. The use of a positioning system can also be useful for driving: in the ground levelling process, computerized navigation techniques help tractors to move within parallel rows (i.e. within a narrow part of the ground in parallel rows, leaving no space or overlapping between successive tracks).

The GPS system is becoming an increasingly valued technology thanks to the continuous research of its possible uses. One example is ground levelling shown in Figure 3 (especially in the case of large areas, where it would be impractical to frequently move the transmitter of the laser system due to its limited range).

Figure 3. Application of a GPS system in land levelling

Conclusion

In traditional agriculture, high production costs and reduced yields reduce profits. By implementing modern systems in the management of traction units, a much more precise quality of work is achieved. GPS guidance can reduce the consumption of seeds, chemicals, fertilizers, and fuel while increasing work efficiency and maximizing the performance of tractors, tools and driver productivity. This is supported by an enormous increase in inputs in the agricultural production. By applying modern technologies in this type of production, it is possible to reduce production costs, while at the same time a serious approach can increase yields, and thus profits. There is no single ideal solution for the introduction of precision agriculture that can be universally applied to every user, i.e. each user can and must have their own unique way of deployment. This is supported by the fact that there is a lot of wandering and wrong procurement of equipment caused by ignorance and incomplete information. The given recommendations are of a general character and can only serve as an aid in terms of understanding the tasks that need to be performed during the process of introducing modern technologies. It is important to start with the process of introduction of modern technologies with a less important sequence of exhaustive follow-up of recommendations.

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Предност и могућности примјене прецизних система у пољопривредној производњи

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Сажетак

Посебна област са примјеном у пољопривреди је правилно вођење трактора са циљем што мањег преклапања прохода, односно са избјегавањем празних мјеста. Коришћење маркера није могуће при раду машина великог радног захвата, а у многим случајевима због лоше допунске обраде, маркер не може да остави довољно добар „запис“ на земљишту. Циљ истраживања је описати развој, принцип рада, примјену и предности GPS-а у савременој пољопривредној производњи, те дати оцјену економичности примјене глобалног система за позиционирање. Примјена GPS-а своди се на проналажење просторних и временских података при чему се, за одређене класе апликација, захтијева центиметарска тачност у одређивању позиције. За ефикасно управљање у овој области потребно је прикупити и различите врсте података. Примјена система омогућава мање преклапање, тј. омогућава повећање коефицијента искориштења радног захвата. Технологија вођења заснована на GPS-у може да се користи у многим агротехничким операцијама. Том техником се може обезбједити потпуна аутономна навигација.

Кључне ријечи: навођење, прецизна пољопривреда, продуктивност, примјена у пракси

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