Reduction of environmental pollution by using RTK-navigation in soil cultivation

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Abstract: The concept of precision farming is wide, and it represents the efficiency which is achieved with the help of precision. For the navigation of field machines, the RTK (Real Time Kinematic) navigation is needed. In order to verify the positive effects in practice, RTK navigation system equipped with Fentd 828 was applied to test the width of overlap, and fuel and time that could be saved compared with manual driving. The experiment was conducted on two areas of land size of 172 m × 58 m with two working machines width 3 m and 6 m. Results indicated that 15.7% of the time and 8.66% of the fuel were saved on a working machine of 3 meters width, and 12.6% of the time and 8.28% of the fuel were saved on a working machine of 6 m width. The width of the overlap represent 10% of the working width of the machine, and with the method of turning, which RTK navigation allows, additional time was saved. Ecological footprint, CO_2 emissions and global warming potential (GWP) was estimated under different guiding systems. The largest footprint was related to manual tillage with 3 m width working machine, while estimation on CO_2 (kg) emissions and GWP obtained the same result. The use of precision agriculture technologies allows better planning and analyzing of working procedures. The air, water and soil pollution are less intensive.

Keywords: precision farming, RTK technology, ecological footprint, environmental pollution, tillage
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1 Introduction

Precision farming is becoming increasingly important in all agricultural sectors. It describes the efficiency that can be achieved with precision. The field of precision farming is wide. One part of precision farming is so called 'digital farming'. In practice digital farming uses modern technologies such as sensors, robotics, and data analysis for shifting from tedious operations to continuously automated processes. Agricultural robotics is important in autonomous weed control, soil tillage and harvesting[1]. Nowadays, production conditions are changing and plants need nutrients in different quantities and qualities. Technique for precision farming (satellites, receivers ...) allows farmers to adapt the working parameters of agricultural machines (large and small) for each square meter according to changing conditions and requirements. The use of precision farming technologies is an acquisition for farmers, consumers, the environment and nature. Using these technologies, farmers can better plan plant production, simplify document working processes, preserve nature and natural resources, and enable reverse traceability of agricultural products which is important for consumer safety. Machines will inevitably become smarter and fully autonomous. To achieve these developments and gain the associated benefits, it is needed to determine how intelligent these machines need to be, and to define their appropriate behaviour. Increases in labour costs, progressively decreasing cost of powerful computers, electronics and sensors, and the demand for less arduous work, better quality of life and higher quality produce are all promoting the economic feasibility of advanced agricultural systems[2].

Agriculture technologies using navigation systems during field operations are more and more popular in all fields of agriculture. Machines without satellite navigation in fields have a tendency to pass-to-pass errors, resulting in waste of fuel and pesticides, longer working times and also environmental damages. The main positive factors for satellite navigation are: 1) savings at soil tillage, due to fewer paths needed for surface treatment, fewer fuel consumption and reduced machine hours; 2) precision: using the RTK (real time kinematic), the most precise autonomous tractor management system in the field, accuracy can be increased to 1-2 cm, thereby reducing overlapping by 33%; 3) driver relieving: using automatic steering, the driver's load can be decreased, and driver can focuses his attention to improved work control. With the help of RTK, it is capable to control the processing paths year after year in order to reduce compaction and maintain the structure of the soil[3].

Slaughter et al.[4] analyzed robotic weed control systems. They reported that technology may also provide a benefit of reducing agriculture's current dependency on herbicides, improving its sustainability and reducing its environmental impact. Weeds compete with crop plants for moisture, nutrients and sunlight. If

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weeds are not controlled, the quality of crop yields could be lower. A number of studies have documented the yield loss associated with weed competition. Monaco et. al.[5] reported 71%, 67%, 48%, and 48% yield reductions in direct-seeded tomato when jimsonweed (*Datura stramonium* L.), tall morning glory (*Ipomoea* L.), common cocklebur (*Xanthium strumarium* L.), and large crabgrass (*Digitaria sanguinalis* L. Scop.), respectively, were present in the row at a density of 11 weed plants/m^2. Total weed shoot weight increased and individual weed weights decreased with increasing densities. Tomato fruit quality, as measured by soluble solids, acidity, and colour, was not influenced by the various weeds and densities.

Jin et al.[6] designed an electric seeder for small-size vegetable seeds based on the power drive and the optical fiber. When the seeder worked at the speeds of 3 km/h and 4 km/h, the relative error of the monitoring precision of the system was less than 6%. This system can be upgraded with the real-time monitoring requirements of the seed metering device. Using modern navigation technology would improve the quality of the sowing work and reduce the relative error.

Kviz et al.[7] measured real pass-to-pass errors (omissions and overlaps) in a field on different tractor-implement units with and without guidance system utilization. The outcomes from measurements revealed that there was a statistically significant difference between the total area treated by machinery without any guidance system and machinery using precise guidance systems. Better accuracy of machinery passes in fields with guidance systems could help with energy and material savings. The fuel, seeding material or chemicals can be saved up to 6% from a single field operation.

Lopotz[8] presented data on Feldtag 2013 which showed that by using the automatic guiding system for sowing, fertilization and spraying, costs can be reduced by 2%-2.5%, or even by 6.5%-9.5% at soil tillage on the field (chisel). Lopotz compared the savings generated by manual driving and RTK system in different crop production: silage maize, rape, sugar beet, wheat and potatoes. The savings in production with the GPS system is around 13 €/hm^2 for silage maize, 22 €/hm^2 for sugarcane, 22 €/hm^2 for sugar beet and 23 €/hm^2 for cereals. The highest hectare savings of 61 €/hm^2 was obtained in the production of potatoes. Using an accuracy of 0.30 m, it can be saved 4-5 €/hm^2, with an accuracy of 0.15 m the saving can be increased to 9-12 €/hm^2, and with the RTK system the saving can reach 20-23 €/hm^2.

In Austria, at the Universität für Bodenkultur Wien, interesting experiment was made using a 5 m working connection. The actual width at the processing without the GPS system was 4.7 m, which means that the overlap on average was 0.30 m. With the GPS help, the actual width of the machining was 4.93 m, with the automatic guiding the actual width was also 4.93 m. On working surface of 1 hm^2, they had to make 9.02 turnings on manual driving, 8.6 turnings with GPS help, and 8.59 turnings with GPS-automatic driving. They also examined the fuel consumption during soil tillage. In the case of manual driving, 19.04 L was required for tillage and an additional 0.94 L for turning at the end of the plot. When hand-driven using the GPS system was applied, 16.79 L were used for the soil tillage of the plot, and additional 1.23 L for turning. In the third system with autonomous guiding, the actual tillage required 15.52 L of fuel and additional 2.66 L of fuel for turning. Thus, the smallest total consumption was achieved in the manual guiding system using the GPS system[9].

Holpp et al.[10] carried out an experiment in Switzerland where three systems with accuracy of 0.30 m, 0.15 m and 0.05 m, respectively, were compared. All precision systems were used on plots with different sizes (1 hm^2, 2 hm^2, 5 hm^2 and 10 hm^2), and at different working width of machine (3 m, 4 m, and 6 m). System with the highest accuracy has the most time saving, and time savings were reduced with the increase of working width. The greatest savings were found out with a lower working width (3 m). Individual parameters (precision, number of passages, time and fuel) were reduced by using GPS help. The more accurate the system was, the greater the savings. Reckleben[11] compared the savings of automatic and manual guiding, calculated the savings for each agricultural task. For more precise results he also presented actual savings per 100 hm^2, 300 hm^2, 500 hm^2 and 1000 hm^2. When dealing with a chisel, they saved 25 €/hm^2 for soil tillage, 115 €/hm^2 for fertilizing and 160 €/hm^2 for supplying plants. More interesting results were savings regarding the machining surface. They saved €1464 on a 100 hm^2 area, €4392 on 300 hm^2, €7320 on 500 hm^2 and €14640 on 1000 hm^2, respectively.

Zhang et. al.[12] made a system for controlling the relative soil moisture, which can be very well maintained. When the soil moisture curve changes from declining trend to rising, the fuzzy control system certainly makes an accurate control decision and responds quickly to open the solenoid valve for watering. Then the soil moisture rapidly increases to a certain extent. Fuzzy control system has a good adaptability to the change of soil moisture. Soil moisture is important in soil tillage, because the quantity of energy for soil tillage is lower at the optimal moister and environmental pollution is lower. To establish an efficient method for sensing soil moisture Gao et al.[13] made analysis of the spatial and temporal variations of moisture in a paddy soil profile. The results showed that soil layers at shallow depths undergo more extensive changes in the coefficients of variation. Moisture perception is most sensitive within a depth range of 0-60 cm. These findings provided a clear picture of the importance of understanding soil moisture and the impact on soil cultivation. Regular monitoring of moisture and weather events can make cultivation of soil more energy efficient.

Li et al.[14] made a study of visual navigation during cotton field management period. They investigated image detection algorithm of visual navigation route. Such a detection algorithm has the advantage of high accuracy, strong robustness and fast speed, and is simultaneously less vulnerable to interference from external environment, which can meet the actual operation requirements of agricultural machinery.

Stajnko et al.[15] made study of the intensification of vegetable production, economic activities and influences on the ecosystem. Tomato (*Solanum lycopersicum* L.) production for fresh consumption grown under greenhouse was used for estimating ecological footprint and CO_2 emissions. The reduction of food miles by introducing local production in Slovenia and the impact of alternative heating systems are very important for ecosystem.

The aim of this experiment was to check the savings of time and fuel, which consequently influences the reduction of variable production costs. In order to save time, various ways of turning the tractor enabled by RTK technology was tested. The purpose is also to determine the human accuracy of driving the tractor in the field and compare it with the use of RTK precision (±2 cm). With RTK-technology less energy for the production was spent, the working efficiency is higher and the environment is less damage. Multiple hypotheses were set in this experiment. The first hypothesis is that using autonomous control with RTK navigation can save up to 10% of time and fuel. The second hypothesis is that manual driving is 20% less accurate comparing with RTK guiding and that the width of the overlap decreases with increasing the working width of the connection. An additional time saving is achieved by turning the tractor.SPI was applied on Web to enable calculation software on ecological footprints and CO_2 emissions in the experiment with soil tillage.

2 Materials and methods

The Slovenian national network signal is the GNSS (Global Navigation Satellite System) network, which is made from 16 uniformly distributed permanent stations throughout the country (Figure 1). The stations are arranged in such a way that the distance between them is less than 70 km. The network allows various location services. However, it is better establishing locations on the basis of the GPS signal, which will in the future be upgraded to the Galileo European navigation system. Galileo is the global navigation satellite system (GNSS) that went live in 2016. Created was by the European Union (EU) through the European GNSS Agency (GSA). As of July 2018, 26 of the planned 30 active satellites are in orbit. In September 2003, China joined the Galileo project. The system is of key importance for all data and registries which are defined in space[16].

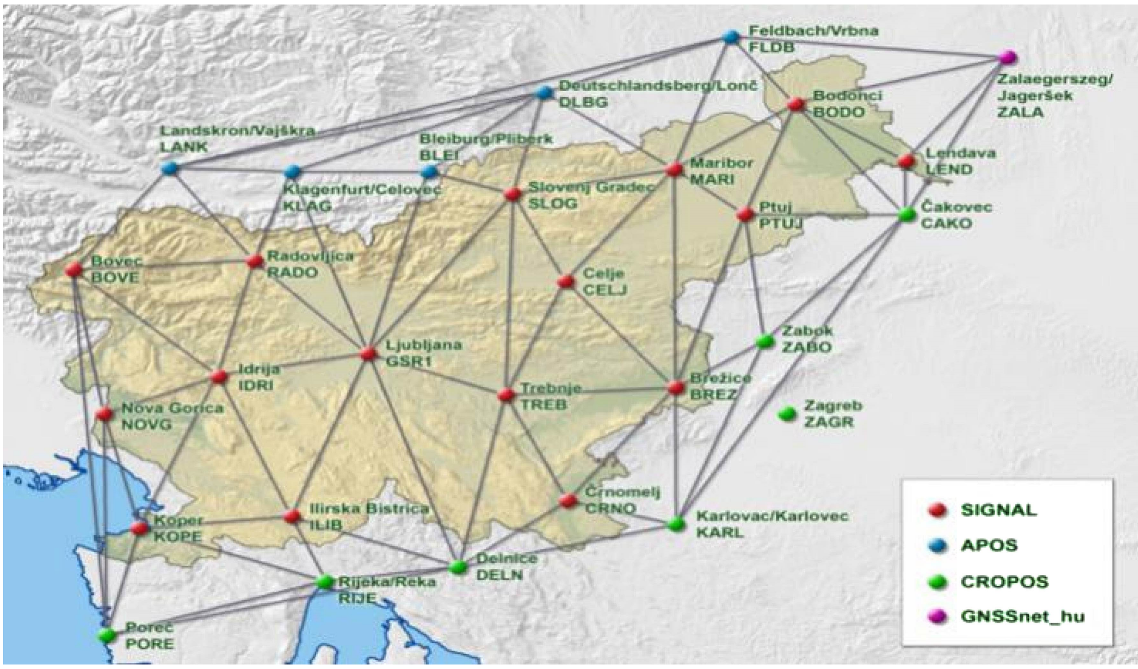

Figure 1 Stations of the National network Signal. (GNSS Map)

2.1 Study site

The field part of the experiment was held in Sebeborci in the municipality of Moravske Toplice (lat. 46.708320, long. 16.197880). The farm is under the home-name "Kerchmar Tabla" and has a total area of 5.73 hm^2. The soils are sandy-loamy and easy to tillage. The previous crop in the rotation was corn for silage, so there was only little crop residue in the field. The parcel is not rectangular shape, so for the purpose of the experiment two identical smaller parcels with dimensions of 58 m × 172 m was divided, represented an area of 1 hm^2 for each of them (Figure 2).

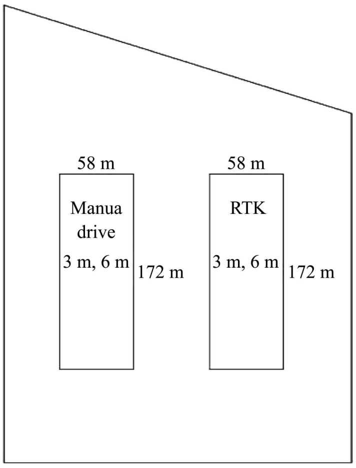

Figure 2 Design of the experiment field

During the first experiment in field, tractor was guided with RTK navigation and soil was cultivated with a 3 m chisel. This operation was conducted 3 times to collect enough data for the statistical treatment. The next experiment was followed by a fine prefabricated device i.e. a cultivator with working width of 6 meters, also conducted triplicates. When guiding with RTK, it is first tillage the plot with a working connection of 3 m and later with a 6 m working connection. At the end of passing, tractor was turned semi-circular to each second and third row.

On the second plot, manual guiding was carried out, in which the first parcel was cultivated with a working connection of 3 m (3 times) and then with a working connection of 6 m (3 times). At the end of passing tractor was turned by corrections classical in every row.

With the help of the tractor computer, basic information on the consumption, tillage time and distance travelled were obtained. The data were carefully collected for all experiments. With the help of traffic lines recorded by tractor navigation, the number of necessary paths to the plot was counted in the GPS Visualizer web application[17]. GPS-visualizer is a free web-based tool that is used to create maps and profiles using geographic information. The input data can be in different formats and from different sources. The web-based tool is versatile as it is compatible with many navigation devices. The information from navigation was removed and the route was mapped. The titles were inserted and the coordinates were simply entered. The necessary data were obtained with the help of Geoservis doo, which recorded the exact location of tractor on the day of the experiment. The data obtained in the form of the NMEA record of the locations was first processed in the Notebook, where the sections of both smaller parcels were cut out from the data set. The edited data were then displayed using the GPS-visualizer.

The cruising speed during the experiment on field was set at 10 km/h with the help of cruise control. The set operating speed was optimal for both connections under given conditions.

At a working connection of 6 m, the overlap for each stroke was set at 20 cm, and this overlap was set at 10 cm for a 3 m working connection. The setting of a small overlay is sensible because the aligned working surface was expected to reach.

2.2 Machines used in the experiment

In the experiment, Fendt Vario 828, a 6-cylinder engine of 6065 cm^3 and a rated power of 203 kW (EG 97/68), was applied. The engine is equipped with the SCR (Selective Catalytic Reduction) system, in which the exhaust gases are subsequently treated with AdBlue (32% urea solution), which change the NOx nitric oxide into non-toxic nitrogen and water. A non-stop welding gearbox is installed on the tractor, which has hydrostatically driven unit with distributed power transmission.

In the experiment, the Kverneland TLG coupler pre-cultivator was used, with a working width of 6 m. The total weight of the connection is 2590 kg, and for optimum performance the minimum working power of the tractor required 100 kW. The cultivator consists of 4 working areas.

The Cenius 3001 chisel from Amazon with a working width of 3 m are optimal for rapidly tillage of the soil with intensive mixing of crop residues. The grip was widely used, as it enabled soil tillage from a 5 cm to 28 cm.

These work connections, which were used, are very important in conserving soil tillage. Compared to conventional soil tillage, the use of chisel is environmentally friendly as they release less CO_2 into the atmosphere due to the C soil mineralization. Chivenge et al.[18] suggested that soil tillage disturbance is the dominant factor reducing C stabilization in a clayey soil, probably by reducing C stabilization within micro aggregates. In conclusion, developing viable conservation agriculture practices to optimize soil organic carbon (SOC) contents and long-term agroecosystem sustainability should prioritize the maintenance of C inputs (*e.g.* residue retention) to coarse textured soils, but should focus on the reduction of SOC decomposition (*e.g.* through reduced tillage) in fine textured soils.

2.3 Ecological footprint

The ecological footprint of each production operation was estimated by including environmental impacts related to fossil-C (kg CO_2/hm^2), air, water, soil, non-renewable, renewable, and area resources. Calculation of fossil-C assumed sedimentation of carbon to ocean beds, which requires about 500 m² of sea ground per year to put 1 kg of carbon back into the long-term (fossil) storage on the sea bed. CO_2 (kg) emissions are calculated from the "Area for fossil carbon," where the extracted fossil carbon and carbon-based materials are assumed to be oxidized to CO_2 over the life cycle and finally end up as C sedimention in the oceans. GWP potentials are calculated on the basis of GWP factors, where material flows of GWP are calculated by multiplying the GWP factor of the components. The sum of CO_2 life-cycle-emissions and other GWP-relevant impacts is the total GWP estimated in kg of CO_2 equivalent. Global Warming Potentials (GWPs) are a quantified measurement of the globally averaged relative radiative forcing impacts of a particular greenhouse gas. It is defined as the cumulative radiative forcing – both direct and indirect effects – integrated over a period of time from the emission of a unit mass of gas relative to some reference gas (IPCC 1996)[19].

2.4 Statistical analysis

The data that needed to calculate the savings was obtained through tractor board computer measurements. This information was firstly collected in the Microsoft Excel table and then calculated the differences between manual and RTK guiding. In the following chapter, the data was processed in the picture of the tractor's driving paths at the time of the experiment.

IBM SPSS Statistics, version 21 was used to calculate Paired sample *T*-test at 95% confidence interval.

3 Results and discussion

From Table 1 it is clear that 26 min and 26 s were spent to tillage the field using automatic guiding, while 31 minutes and 22 s were spent on manual guiding. In automatic guiding, turning time was 3 min and 28 s, and for manual guiding, 6 minutes and 57 s. With the help of RTK 3456 m in 20 rounds was recorded and 9.5 L of fuel were spent. In a manual run, 3822 m was carried out in 22 rounds and spent 9.5 L of fuel. Differences between treatments are statistically significant, which confirmed the hypotheses of this research. With the RTK guiding, the tillage in the spot spent 15.7% less time and 8.66% less fuel.

Table 1 Average measurements of working connection Amazone Cenius 3001 (3 m width)

	RTK	Manual drive	Difference/%	*p*-value
Total time (min:s)	26:26	31:22	15.7	0.001
Time of treatment/(min:s)	21:58	24:25	10.04	0.001
Turning time/(min:s)	3:28	6:57	50.12	0.002
Distance traveled/m	3456	3822	9.58	0.001
Fuel consumption/L	9.5	10.4	8.66	0.042
Procession_number	20	22	10	0.005

Landerl[9] compared three different control systems in the study. While comparing with manual guiding, RTK consumed 4.5% less fuel and 8.96% less time. Their savings are somewhat smaller, but still significant. It is anticipate that the more saving in this research results from the higher turning speed.

Table 2 Average measurements of working cultivator Kverneland TLG (6 m width)

	RTK	Manual drive	Difference/%	*p*-value
Total time/(min:s)	13:46	15:45	12,6	0,001
Time of treatment/(min:s)	10:54	12:15	11,03	0,004
Turning time/(min:s)	2:52	3:30	18,1	0,002
Distance traveled/m	1712	1916	10,65	0,001
Fuel consumption/L	5,4	5,9	8,28	0,042
Procession_number	10	11	10	0,005

The total time for tillage with automatic guiding was 13 min and 46 s. The turning took 2 min and 52 s. In the case of manual guiding, 15 minutes and 45 s were spent to tillage the plot, while 3 min and 30 s were spent for turning. When tillage the entire parcel in RTK mode, 12.6% less time were spent. Altogether, with the help of automatic guiding, a total distance of 1712 m was carried out, while 1916 m was used for manual guiding. The difference between RTK and manual guiding is 10.6%. When tillage the entire parcel, 5.4 L of fuel in 10 passages was recorded for RTK mode and 5.9 L of fuel in 11 passages was recorded for manual guiding. This saved 8.28% of the fuel. Brückner[20] transported 1923 meters without the navigation, and 1681 m with the help of RTK navigation using a working connection of 6 m wide for tillage 1 hm^2. This represents a 12.6% difference in the distance travelled, which is similar to this research.

During the observation of the driving lines during manual guiding, it is noticed that the lines were not completely parallel as at RTK mode. The lines were approaching to each other somewhere, and moved apart elsewhere. In the case of a 3 m working connection 22 rounds was needed to tillage the plot, which represents additional 2 rounds in comparison with RTK. For tillage with a 6 meter working connection, it took 11 turns, one turn more than with RTK. From the number of necessary roundabouts, data overlapping or precision of manual guiding were obtained. At both working connections (3 m and 6 m), 10% wider bends were needed on the experimental plot. When hand guided, tillage in this study covered about 10% more of the working width of the connection. At a 3 m connection the covering was on average 30 cm, and at a 6 m working connection it was 60 cm. Lopotz[8] states that the overlap for manual guiding is between 6.5%-9.5%, and data from this study is completely comparable to this survey. However, it is also need to know that overlapping is largely dependent on the driver's ability in manual driving.

When plotting the parcel with RTK, this study first treated each 2nd or 3rd row, depending on the width of the working connection. In the next step, each 2nd or 3rd row was reprocessed. Such S-shaped turning was repeated during the tillage of the entire parcel. The positive feature of such turning is to reduce tillage time or to increase agility at the end of the parcel. At the 3 m working connection, for turning at the end of the parcel 3 min and 28 s was spent, and with a working connection of 6 m, it was 2 min and 52 s. Another advantage is the smaller compaction of soil, since at the end of the parcel only a semi-circular turn is needed. It is also very important that RTK navigation by enabling turning modes greatly relieve drivers

In the case of manual guiding, it was necessary to drive a parallel line at both working connections until the entire surface was cultivated. In order to continue the line along the previously processed line, a reverse at the end of the plot was made. With this turning method, 6 min and 57 s were spent to process the plot with a working connection of 3 m, which is 3 m and 28 s more than with RTK. With a working connection of 6 m, 3 min and 30 s were spent to rotate, which is 38 s more than with RTK for one passing. When comparing the turning time at manual guiding and the RTK system, 50.12% of the time was saved at a working connection of 3 m, while at a work connection of 6 m it was 18.1% more. The reason for the lower percentage of time saving at the 6 meter working connection is a smaller number of passings on the plot and easier maneuvering at the end of the plot, as there was more space to the next machining line to make a faster turning.

Table 3 Footprint, CO_2 emissions and GWP under different processing types

Processing type	Footprint/$m^2 \cdot kg^{-1}$	CO_2/kg	GWP/kg CO_2eq
RTK tillage 3 m	10718.7	48.9	85.2
Manual tillage 3 m	12745.1	58.1	101.3
RTK tillage 6 m	5494.1	25.1	43.6
Manual tillage 6 m	6307.3	28.8	50.1

The ecological footprints of the assessed field operations are presented in Table 3. It represents annual amount of biologically productive land that necessary to assimilate the emissions produced in all processes needed for tillage of 1 ha field area (m^2/kg). The largest footprint is related to manual tillage with 3 m chisel (12745.1 m^2/kg). RTK tillage with the same chisel has a 15.9% lower footprint (10718.7 m^2/kg) than manual guiding tillage. 12.9% lower ecological footprint was estimated at RTK tillage with 6 m width chisel comparing with the manual driving. The maximum amount of CO_2 is released while hand driving with a 3 m connection. At the RTK soil tillage 11.9% less CO_2 was released. In the case of pre-cultivated soil tillage with the cultivator, only half of the CO_2 is released than in the basic tillage. The same is with global warming potential (GWP). In the soil tillage and production in agriculture, a lot of carbon is released in the atmosphere, which can be confirmed by related research. Bravo[21] studied the Chilean sweet cherry production. The average carbon footprint of the Chilean sweet cherry production is 0.41 kg CO_2-eq/kg of harvested fruit. Diesel and fertilizers are the most important contributors to the carbon footprint of sweet cherry cultivation[21]. Gan et al.[22] found that integrating improved farming practices (that is, fertilizing crops based on soil tests, reducing summer fallow frequencies and rotating cereals with grain legumes) lowers wheat carbon footprint effectively, obtained an average of 256 kg CO_2 eq/hm^2 less per year. For each kg of wheat grain produced, a net 0.027-0.377 kg CO_2 eq is sequestered into the soil. With the suite of improved farming practices, wheat takes up more CO_2 from the atmosphere than actually emitted during its production[22]. Environmental impact of food production is very important, and carbon footprint served as an indicator to guide farmland management. Zhang et al.[15] established a method and estimated the carbon footprint of grain production in China based on life cycle analysis (LCA). The results showed that grain production has a highest carbon footprint in 2013. These footprints are higher than that of some other countries, such as the United States, Canada and India. The most important factors governing carbon emissions were the application of nitrogen fertiliser (8%-49%), straw burning (0-70%), energy consumption by machinery (6%-40%), energy consumption for irrigation (0-44%) and CH_4 emissions from rice paddies (15%-73%). The most important carbon sequestration factors included returning of crop straw (41%-90%), chemical nitrogen fertiliser application (10%-59%) and no-till farming practices (0-10%)[23].

The introduction of regional production (250 km) could reduce the ecological footprint of transport by up to 83.33% in comparison with transcontinental transport (1500 km). Using alternative heating with geothermal energy might additionally reduce the impact of heating substantially. For the lower heating requirement of PE tunnel production, fossil fuels might be successfully replaced by pellets; thus, the footprint could be reduced by 61.88% in relation to fossil fuels.

Integrated farming practices are the key to reduce the carbon footprint of field crops. The key practices include optimizing fertilization to meet the nutrient requirement for plant growth, using pulse crops to fix atmospheric N_2 to partially replace inorganic N fertilizer, and increasing soil carbon input through crop residue management. Farmers play a key role in ensuring the provision of low-emission materials to the food chain. There are huge gaps between the development of new cropping technologies and the implementation of the technologies in farming operations. With relevant agro-environmental policies in place, along with the adoption of improved agronomical tactics, increasing food production with no cost to the environment can be achieved effectively, efficiently, and economically[24].

4 Conclusions

Using the RTK control method 15.7% less time and 8.66% less fuel were spent with a 3 m width working connection. With 6 m working connection the 10.6% less time between RTK and manual driving were estimated. To tillage the entire surface (1 hm^2), 5.4 L of fuel in 10 rounds at RTK mode and 5.9 L of fuel in 11 rounds at manual driving were spent. 8.28% of the fuels were saved from RTK mode. During manual guiding the lines were not completely parallel as in the case with the RTK mode. In the case of a working connection of 3 meter, 22 rounds were needed to process the plot. That is additional 2 rounds as were needed in the case of RTK. At 6 m working connection, it took 11 turns. That is one turn more than at RTK mode. From the number of necessary roundabouts, the precision of manual driving were studied. At both working connections (3 m and 6 m), 10% more bends were needed at manual driving on the experimental plot. When comparing the turning time at the manual guiding and the RTK system at 3 m working connection, 50.12% of the time were saved in RTK system, while at a working connection of 6 meter it was 18.1% saved in RTK system. The largest footprint was estimated in manual guiding with 3 m wide chisel (12745.1 m^2/kg). RTK tillage with the same chisel has a 15.9% lower footprint (10718.7 m^2/kg) than manual guiding. 12.9% lower ecological footprint was estimated at RTK tillage with 6 m wide chisel. The maximum amount of CO_2 is released while hand guiding at tillage with a 3 m working connection. At the RTK soil tillage 11.9% less CO_2 was released. In the case of pre-cultivated soil tillage with the cultivator, only half of the CO_2 is released as in the basic tillage. The same is with the global warming potential (GWP).

It can be confirmed that in the soil tillage and production in agriculture, a lot of carbon was released into the atmosphere. It can be concluded that RTK technology is very important in terms of nature protection issues. Less emission of greenhouse gases and energy can be achieved during RTK tillage. The continuous work can be focused on comparison of different types of soil tillage that most appropriate in terms of nature protection, and evaluation on the differences in CO_2 emissions.

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