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Efficient tractor operation through satellite navigator

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A nine tyne tractor operated cultivator and spinner type fertilizer spreader were used to evaluate the efficiency of tractor. Tractor was operated without navigator and with navigator guidence to the operator to observe the missed area, overlapped area and actual productivity of the machines. Missing percentage was only 8.5% of total area cultivated in case of navigator assisted cultivator as comaperd to the 23.5% missed area without navigator guidence. For smaller field having area were 4.2 and 14% espectively of the total area under trials. But for larger area of 1.62 ha, on an average percentage missed area observed without and with navigator trials were 19.8 and 5.5% of the total area under trial. Overlapped area during cultivation without navigator was observed to be 0.042 or 18% as comaperd to the overlapped area of 0.006 ha or 3% by using navigator. Areas of overlap during fertilizer spreading for without and with navigator trials were observed to be 0.066 or 13.75% and 0.002 ha or 0.4% respectively for smaller fields. But for larger field, without navigator trial overlap of 0.027 ha which is 1.7% was obsereved and with navigator trial overlap was observed for area 0.048, which is 2.9% of total area of 1.62 ha. The actual productivity of the operation without navigator was 0.53 ha/h with 23.5% missing area as comapred to the actual productivity of cultivator with navigator i.e. 0.75 ha/h with 8.5% missing. It was concluded that actual productivity by using satellite navigator guided cultivator was 1.42 times more as compared to the actual productivity without navigator. During fertilizer spreading, the actual productivity of the spreader using navigator was 1.64 times more than the machine without naviagator. For larger field, satellite navigator guided fertilizer spreader was about having 1.37 times more productivity than spreader without navigator.

Key words: Satellite navigator, global positioning system (GPS), overlapped area, missed area, machine productivity, precision farming.

INTRODUCTION

Farm mechanization at every stage of crop production is playing a vital role in agriculture. Due to which, there is increase in yield and labour productivity over traditional agriculture. Skilled drivers are needed to operate tractor or combines efficiently. The requirement placed on farm equipment operators have changed drastically with increase in equipment size, power, multiple equipment functions, and speeds well as monitors reporting on

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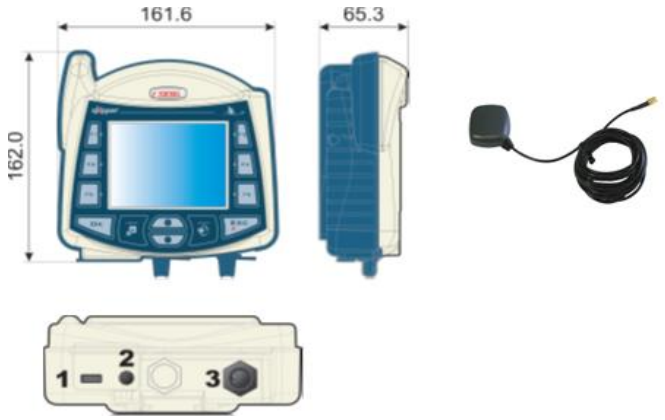


Figure 1. Satellite Navigator and GPS antenna (all the dimentions are in cm); Legends: 1-USB host port (pen drive etc.) ; 2-GPS antenna; 3-Power supply.

specific system performance. These increasing demands on the operator can result in increased errors in function, costs, environmental problems, and operator fatigue (Robert et al., 2009). Missed area after completion of work or repeat operation over the work already done that is, overlap decides work quality. Which is difficult to predict visually. To maintain the work quality one has to repeat the operation over the whole field. These causes an additional expenditure for the same quality of work over unit area. If these overlapping oprations are carried over the missing oprations rather than repeating the whole operation, so many inputs of the agriculture like fuel, labour, time etc. would be saved. Which mainly includes time-for which we are paying more than any other agricultural input. Also in farming work using agricultural vehicles such as tractors, it is important to minimize the area of unworked and double-worked land by driving the vehicle straight and at a constant interval in the field in order to achieve high efficiency and the optimum use of inputs such as fertilizers and chemicals (Yasuyuki et al., 2009).

In India, operator drives the tractor or combine harvester simply by their judgment. Due to which there may have missing or overlapped areas in the fields, resulting lesser productivity. Jatin et al. (2012) studied the Global Positioning System (GPS) for precise area measurement in the field. The author found GPS is very useful for the geo-referencing and to calculate the area harvested by combine harvester. In agriculture, better positioning combined with other spatial information permit significant reductions in use of fertilizer, pesticides and other environmentally sensitive chemicals. The error in area measured by GPS and actual ranged from 5.0 to 7.0%.

Tractors are sometimes fitted with navigator to increase the productivity of the machine. These navigator fitted tractor can be used for any operation performed by the tractor. Fulton et al. (1999) analysed a variable-rate spinner spreader, equipped with Differential Global Positioning System (DGPS) and a variable rate control system to assess its distribution accuracy. The authors found that the quality of the fertiliser application depends upon the accuracy of the guidance system used. Ehsani et al. (2002) studied important issues related to testing and comparing the guidance systems which they defined and explained, and a method of evaluating GPS guidance systems while following a straight line was introduced. According to their results, comparing the performance of the guidance systems with a real-time kinematic (RTK) GPS is the easiest method and probably the most accurate way of field-evaluating guidance systems. The advantage of this method is that it reflects the overall performance of a guidance system on the farm and the results can be used directly by the end user. According to Griffin (2009), the use of the guidance systems to guide the farm machines during their work on the field brings several benefits including the reduction in overlap, increased working speed during the field operations, workday expansion, and appropriate placement of spatially sensitive inputs. During recent years, many researchers studied different effects of using the guidance systems in view of accuracy, economical efficiency, etc. The use of the field guidance systems has some specific economical consequences, and therefore Griffin et al. (2008) and Griffin (2009) used a linear programming model to compare 5 types of the guidance system:

(1) A baseline scenario with foam, disk, or other visual marker reference,
(2) Lightbar navigation with basic GPS availability (+/–0.3 m accuracy),
(3) Lightbar with satellite subscription correction GPS (+/–0.1 m),
(4) Automated guidance with satellite subscription (+/–0.1 m),
(5) Automated guidance with a base station RTK GPS (+/–0.01 m).

The results obtained indicated that RTK automated guidance becomes the most profitable alternative when farm size is increased while maintaining the same equipment set. Owing to these facts, to save the operational time by avoiding repeat operation over the single pass, GPS Navigator was used to guide the tractor and analyzed the effect on seedbed preparation with nine tyne tractor drawn cultivator and fertilizer application using spinner type applicator.

METHODOLOGY

Satellite navigator

SKIPPER LT satellite navigator of ARAG, Italy (Figure 1) was used for navigation applications when connected to the external GPS antenna. As per the manufacturer, satellite navigator was designed and built in compliance with EN ISO 14982 standard

Figure 2. Satellite navigator fitted the tractor for without navigator and with navigator trial.

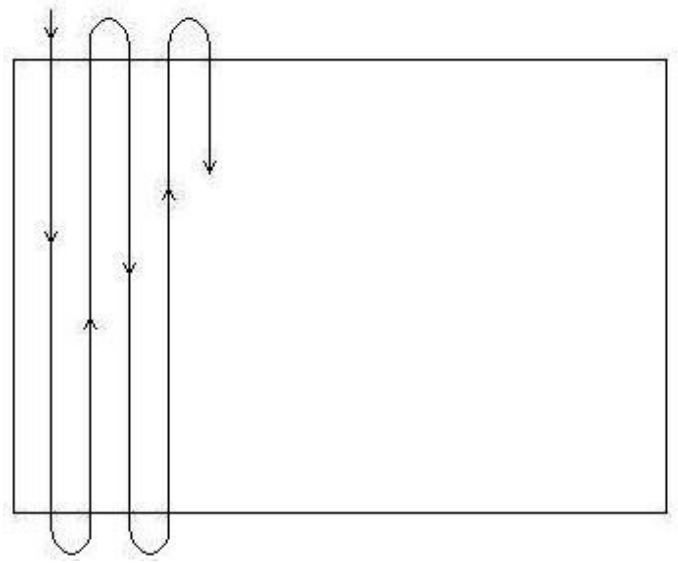


Figure 3. Straight parallel guidence pattern for Satellite navigator operation.

(Electromagnetic compatibility - Forestry and farming machines), harmonized with 2004/108/EC Directive. Satellite navigator mainly consists of navigator screen, of mounting bracket kit, power supply cable and GPS Antenna. Skipper LT navigator has the provision to save the various machine a configurations. After completion of job/desired operation, navigator saves the job automatically, the alternate name may be given manually if necessary. Machine setup mainly includes overall width of machine in operation and position of GPS antenna (antenna distance from the work point). To manage the saved data files in the navigator, satellite navigator manager software was provided by the firm.

Satellite navigator installation and connections

Installation of the satellite navigator was very simple. The navigator was supposed to fit on the body of tractors having low vibrations and shocks or away from moving parts of the tractors. The remote control unit should be in a visible position, without obstructing the operator's view, and within easy reach of the operator. Hence considering all these points satellite navigator was placed as shown in Figure 2. GPS antenna, as per the information manual of the firm, was to be installed on the highest point of the tractor. The roll over protective structure's frame served the base for the antenna. Having magnetic base, GPS antenna was easily get stuck to the place to receive the signals from satellite without much interruptions.

Connectons mainly include connection of the GPS antenna to navigator and battery connection of navigator with tractor battery for power supply. The electric power supply for satellite navigator was given from the tractor battery (12 Vdc). Positive and negative connections of the navigator were made as per the sign conventions given in information brochure of the GPS navigator. There are two available modes of guidence pattern in the satellite navigator i.e. one is in straight parallel (A-B pattern) and another in curved parallel. Because the plots were rectangular in shape, hence straight parallel (A-B pattern) guidence pattern was chosen for the operation (Figure 3). Observational data for without navigator and with navigator trials were simplified by using SKIPPER NAVIGATOR MANAGER software.

Field planning

Tillage

The seed bed preparation was done by using a conventional cultivator of width 9 x 30 cm in single pass operation by mlounting it with Massey Ferguson 5245 DI make tractor. To conduct experimental trails, the plots having dimention 55 x 36.4 m (Area 0.20 ha) were selected at the experimental farm of Punjab Agricultural University, Ludhiana, Punjab. Trails were conducted without navigator and with navigator guidance. Without navigator position, satellite navigator's display was kept out of eyesight of tractor opreator and operator was cultivating by traditional practice using cultivator. But with navigator, the machine operator was guided by the sattelite navigator. The satellite navigator was placed and fitted in front of trator operator, from where satellite navigator's functional keys were easily accessed by the operator. The operator had been oriented and trained the use of the navigator to drive the tractor along and over the reference lines displayed on the navigator's display. Operator was told to activate and deactivate working of cultivator by pressing the user option key of the satellite navigator while coming inside and going outside field boundries.

Fertilizer application

Multi-utility high clearance tractor (Singh et al., 2013) used for

Figure 4. High clearence tractor (HCT) with fertilizer spreader used for urea spreading.

Table 1. Observational data during seedbed preparation without navigator and with navigator.

Parameter	Without navigator	With navigator
Location of research plot	30.908464°N 75.817375°E	30.908489°N 75.817566°E
Area to be cultivated (ha)	0.20	0.20
Operating width of machine (m)	2.7	2.7
Position of GPS antenna from cultivator (m)	1.7	1.7
Visibility of navigator to operator	Not visible	Visible
Actual operation time, HH:MM:SS	00:22:43	00:16:01
Perimeter of the field (m)	175	175
Missed area of the field, ha (%)	0.047 (23.5%)	0.017 (8.5%)
Overlapped area, ha (%)	0.042 (21%)	0.006 (3%)
Actual productivity (ha/h)	0.53	0.75

% area's in the bracket were calculated with respect to the area to be worked that is, 0.20 ha.

mounting the fertilizer spreader to apply the fertilizer urea to paddy crop. Test trials were conducted for two fields of 0.48 and 1.62 ha areas having dimensions 60 x 80 m and 108 x 150 m respectively. Trails were conducted without guidence of satellite navigator and with navigator. Spinner type fertilizer spreader of Make Swan Agro Iindustry, Ludhiana was used for the trials. The fertilizer spreader having heavy duty gear box with combination of gears to absorb possible changes in power. There is a slitter lever, which allow to scatter only at left or right as per requirement. It distribute fertilizer evenly on each vane. Necessary setting of the control lever of spreader was done before the trials. Machine parameter includes mainly width of spread that is,12 m of fertilizer spreader (Figure 4) with fixed position of lever and constant rpm of tractor engine.

Selection of parametres

Three main parametres were selected to determine the efficiency of the navigator. These parameters were missed area, overlapped area and actual productivity of the tractor with machine. Missed area is the area, which was left without actual work done by the machine. Overlapped area was the area where more than once the desired operation was done by the machine. Actual productivity of the machine was effective work done per unit time, which was affected by the overlapped area and missed area. With more overlap area, productivity will be losses but with more missed area, productivity will also be more.

RESULTS AND DISCUSSION

Field observations without navigator and with navigator trial, for the nine tyne cultivator and fertilizer applicator are tabulated in Tables 1, 2 and 3. Actual field conditions showing missed area, overlapped area and headland area during cultivation and fertilizer application with and

Table 2. Observational data during ferilizer spreading without and with navigator for field 1.

Experimental parameter	Without navigator	With navigator
Location of research plot	30.900816°N 75.815544°E	30.908442°N 75.817215°E
Area to be fertilized (ha)	0.48	0.48
Spread width of machine (m)	12	12
Position of GPS from delivery of spreader (m)	2.5	2.5
Visibility of navigator to operator	Not visible	Visible
Fertilizer spreader delivery setting to maintain recommended Urea rate of 112 kg/ha	2	2
Spreading time, HH:MM:SS	00:07:11	00:04:23
Missed area of the field (ha)	0.020 (4.2%)	0.067 (14%)
Overlapped area (ha)	0.066 (13.75%)	0.002 (0.42%)
Actual productivity (ha/h)	4.01	6.57

Table 3. Observational data during ferilizer application without and with navigator field 2.

Experimental parameter	Without navigator		With navigator	
	R1	R2	R1	R2
Location of research plot: Latitude; Longitude	30.900078°N 75.816559°E	30.900690°N 75.815010°E	30.900690°N 75.815010°E	30.900743°N 75.815025°E
Area to be fertilized (ha)	1.62	1.62	1.62	1.62
Spread width of machine (m)	12	12	12	12
Position of GPS from delivery of spreader (m)	2.5	2.5	2.5	2.5
Visibility of navigator to operator	Not visible	Not visible	Visible	Visible
Fertilizer spreader delivery setting to maintain recommended urea rate of 112 kg/ha	2	2	2	2
Spreading time, HH:MM:SS	00:21:27	00:13:29	00:10:48	00:13:53
Missed area of the field, ha (%)	0.275 (16.97%)	0.366 (22.59%)	0.084 (5.18%)	0.094 (5.8%)
Overlapped area, ha (%)	0.027 (1.7%)	00	0.046 (2.8%)	0.050(3.1%)
Actual productivity (ha/h)	4.5	7.2	9	7

without navigator are shown in Figures 5 to 12. Next is a detail discussion of these areas.

Missed area

Tillage

Missed area is the sum of all the missed areas observed during the cultivator operation. Figure 6 shows missed area in both the cases and data values are tabulated in Table 1. Out of the targeted area that is, 0.20 ha to be cultivated 0.047 and 0.017 ha area were missed or not cultivated without navigator and with navigator trials. It is clear that missing percentage is only 8.5% of total area cultivated in case of navigator assisted machinery as compared to the 23.5% missed area without navigator guidence. Tractor operator/driver also got physical relief assisted by the use of navigator to some extent which would be helpful to do more work per unit time.

Fertilizer application

Tables 2 and 3 shows the missing areas without and with navigator trials. Out of the targeted area that is, 0.48 ha for field no.1, about 0.020 and 0.067 ha areas were missed or no urea was spreaded without navigator and with navigator trials, which was 4.2 and 14% espectively of the total area under trials (Figure 7). More missing in crop with navigator may be due to the ignorance of operator to navigator signal. For field no. 2 having total area of 1.62 ha, 0.320 ha area was missed without navigator as compared to only 0.089 ha missed area with the use of navigator. On an average percentage missed area observed without navigator and with navigator trials were 19.8 and 5.5% of the total area under trials. About 20% area, where there is no fertilizer spreaded is

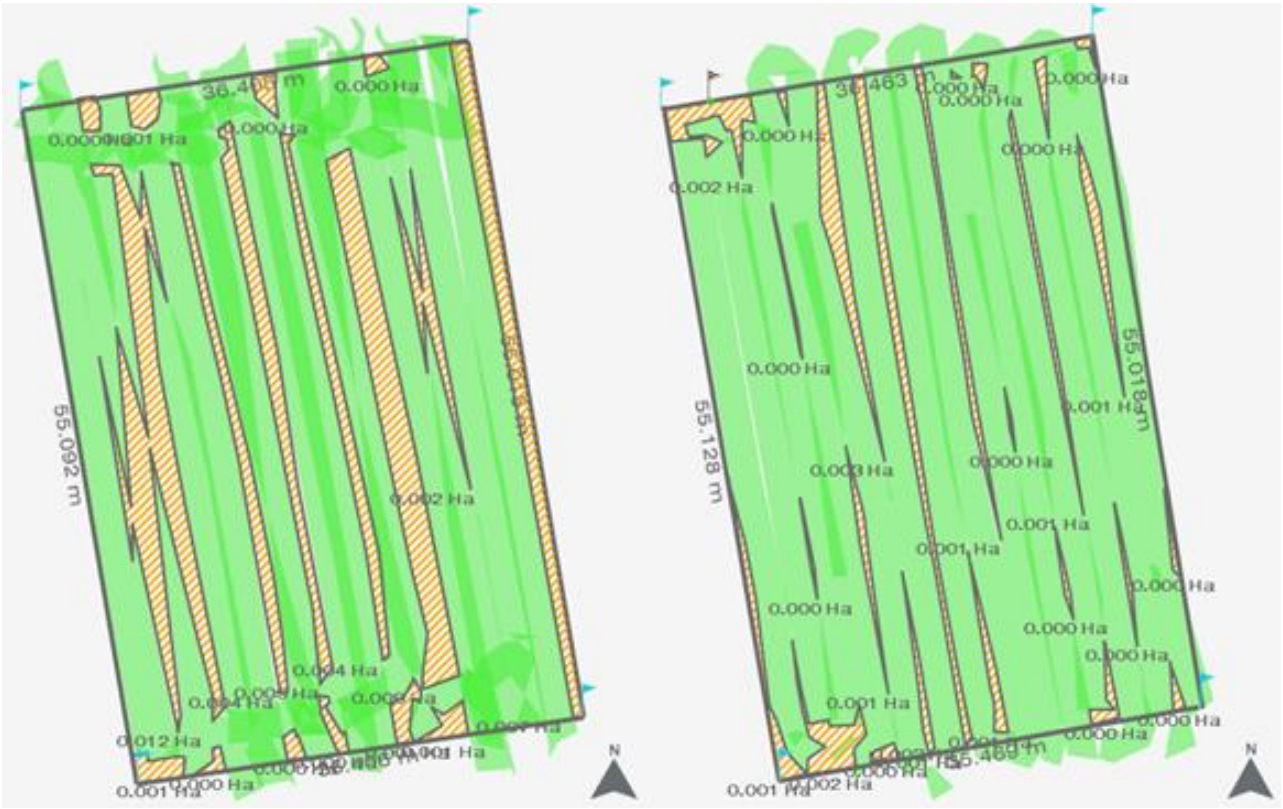


Figure 5. Missed area in cultivator working: (a) Without navigator (b) With navigator.

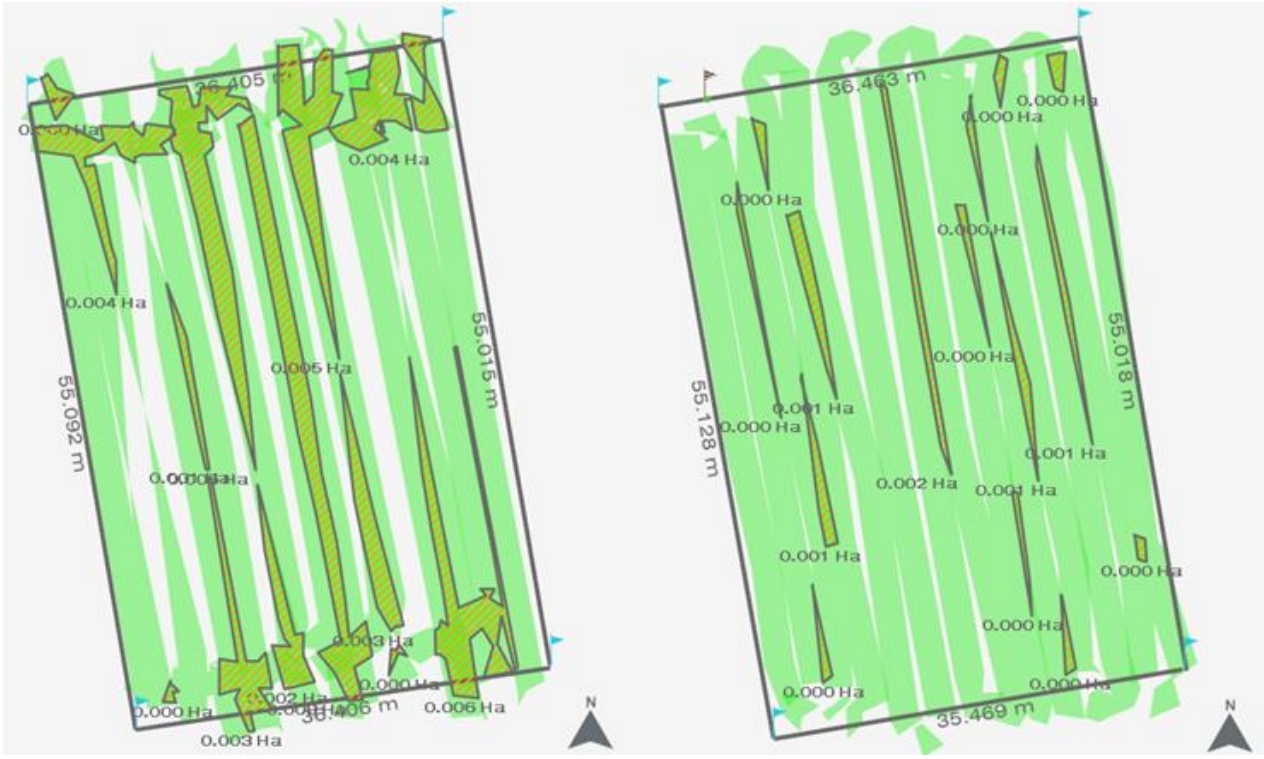
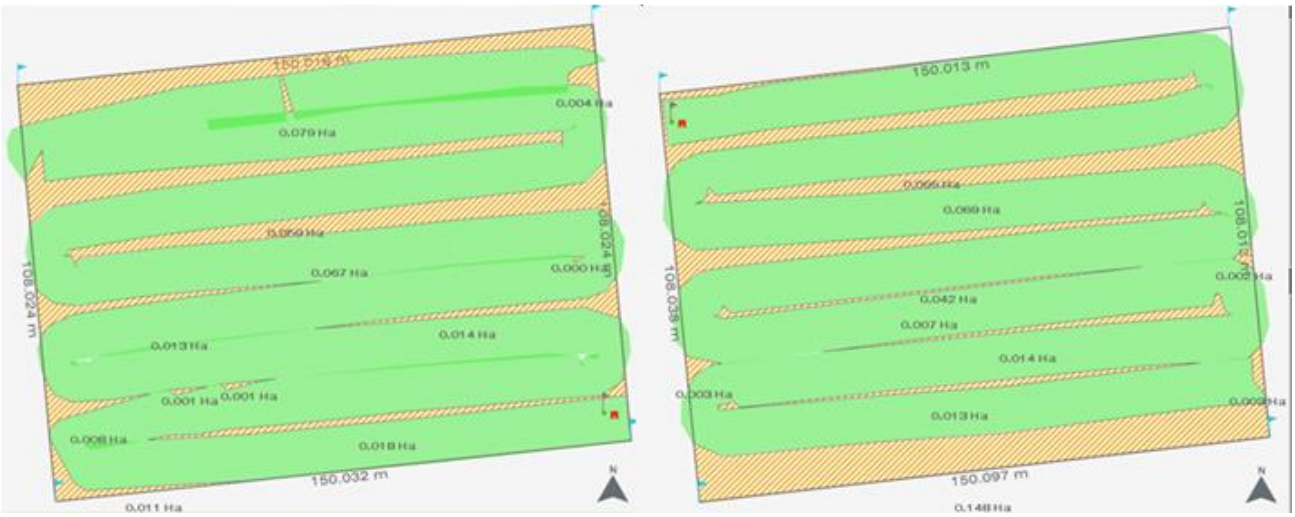


Figure 6. Overlapped area in cultivator working: (a) Without navigator (b)With navigator.

Figure 7. Missed area in fertilizer spreader for Field No. 1 (a) Without navigator (b) With navigaor.



R1 **R2**

Figure 8. Missed area without navigator fertilizer spreader for field no. 2.

considerable area that may affect the yield of crop significantly.

Overlappped area

Tillage

Same operation performed more than once over the same area is termed as overlap. Figure 6 shows the field view showing overlapped area for both the cases of seedbed preparation. Gross values of overlap area without navigator and with navigator trial were observed to be 0.042 and 0.006 ha respectively. It means the overlapped area was only 3% by using navigator as compared to the 18% area overlapped without using navigator.

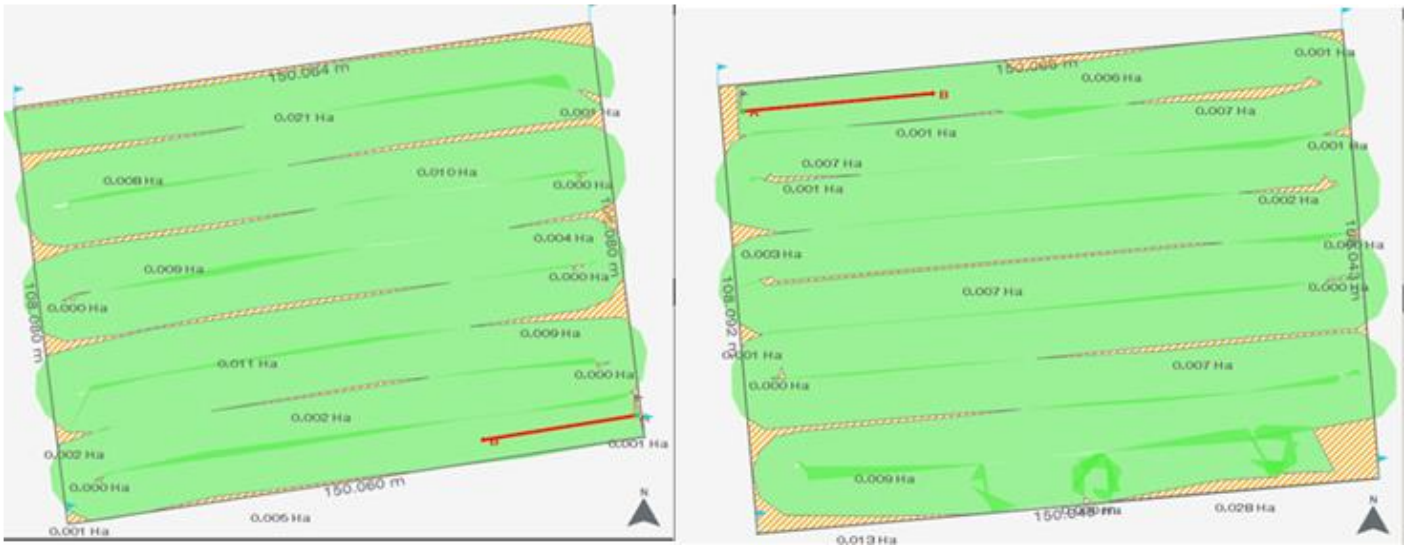


Figure 9. Missed area with navigator fertilizer spreader in field no. 2.

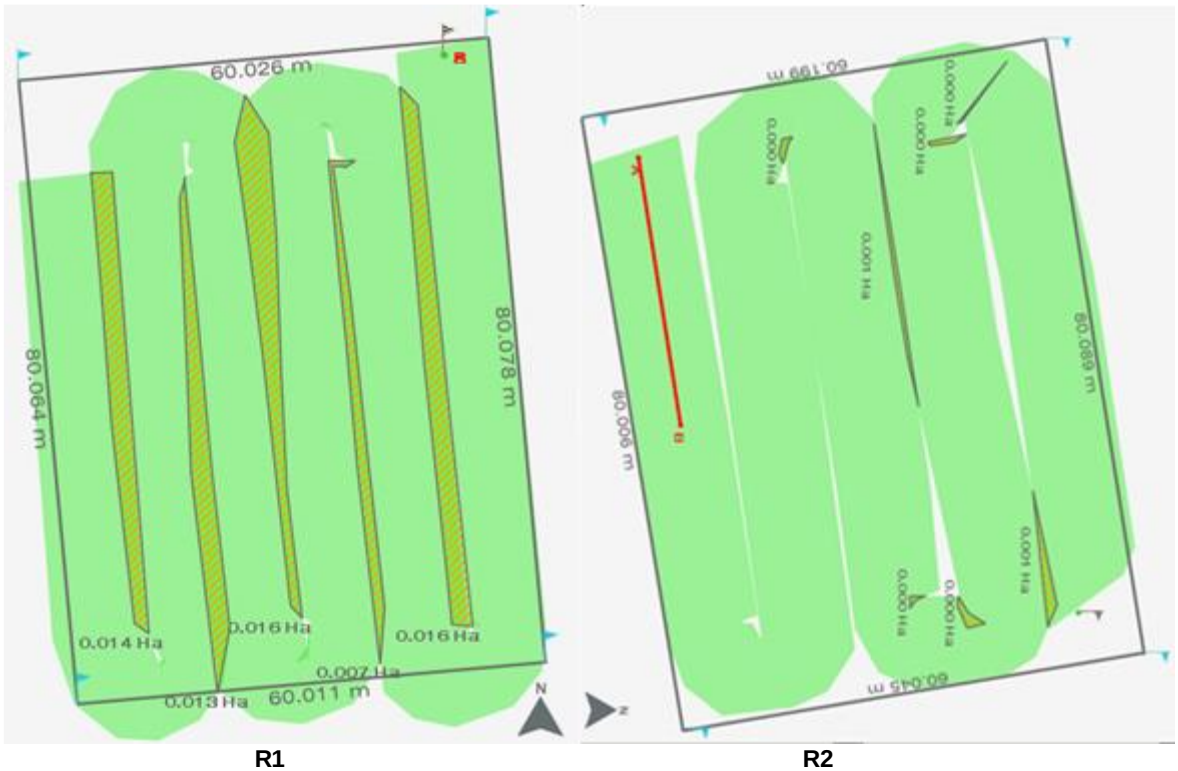


Figure 10. Overlapped areaby fertilizer spreader in field no. 1 (a) Without navigator (b) Without naviagator.

Fertilizer application

To cover the width of 60 m, machine without navigator made 6 strips instead of 5 strips. Hence, areas of overlap without navigator and with navigator trials were observed to be 0.066 or 13.75% and 0.002 ha or 0.4% respectively. It means, about 14% of the fertilizer may be saved by using navigator. The overdose of fertilizer may lead unacceptable long-term retention of chemical components results in environment degradation. Overlap

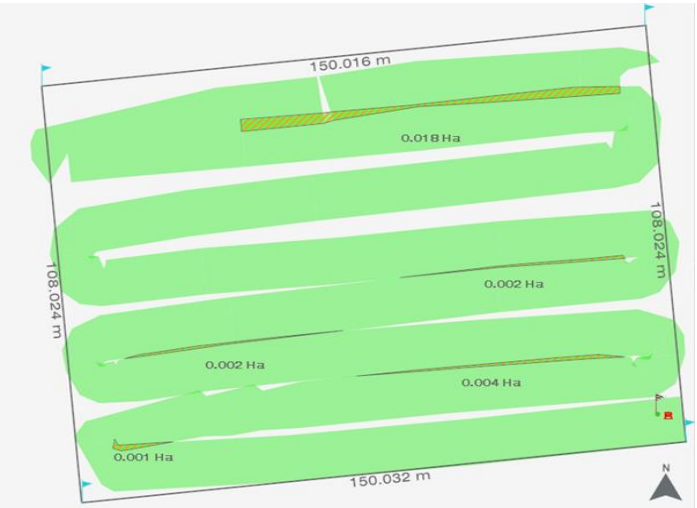
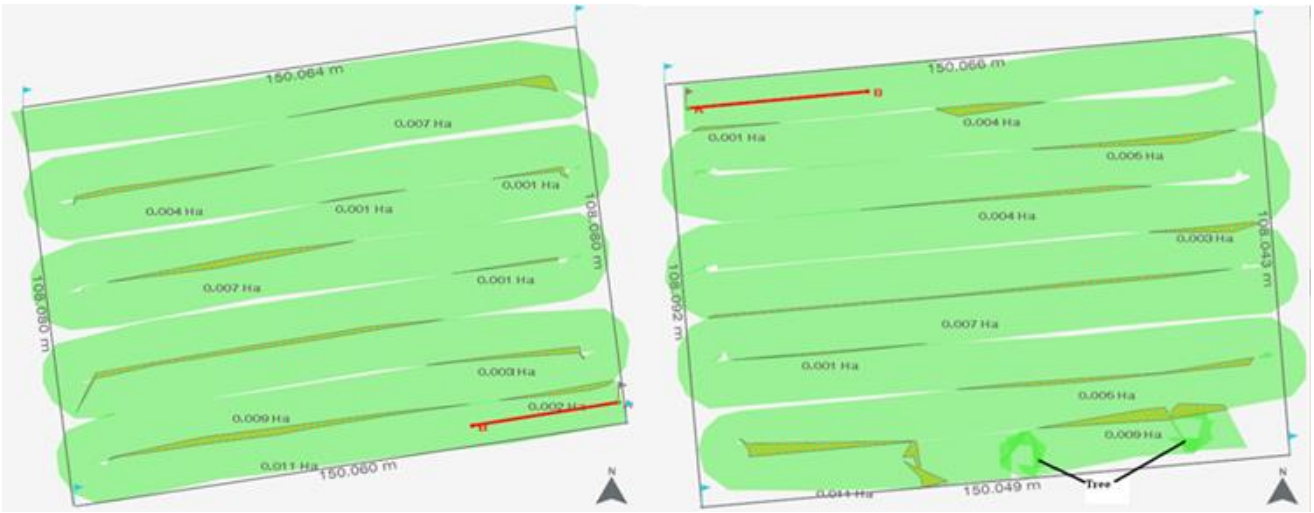


Figure 11. Overlapped area without navigator fertilizer spreader in field no. 1.



R1 **R2**

Figure 12. Overlapped area with navigator fertilizer spreader in field no. 2.

of 0.027 ha was obsereved without navigator trial for field no. 2 having area of 1.62 ha. In case of with navigator trial overlaps were observed for area 0.048 ha, which is 2.9% of targeted area of 1.62 ha. All the areas of overlaps were almost along the strips and also distributed over entire field uniformly.

Actual productivity

Tillage

Actual productivity is the effective worked area per unit time. Effective worked area is the cultivated area within the predefined boundry of the field. To calculate effective worked area, missed area was deducted from the targeted area that is, 0.2 ha. Without navigator and with navigator trials, effective worked areas were 0.158 and 0.183 ha respectively. Time taken to complete these trials were 22:43 and 16:01 min without navigator and with navigator, in which considerable time that is, 06:42 min (33.75 min per ha) were saved with navigator as comapred to without navigator trial. These effective worked areas per unit time are actual field capacities of the machine in both the cases which includes 23.5 and 8.5% missed area. Hence, various time based agricultural inputs like fuel, labor etc required to cultivate

the field can be calculated which were saved by using navigator. The actual productivity of the machine without navigator was 0.53 ha/h, whereas actual productivity of the machine with navigator was 0.75 ha/h. Hence, it can be concluded that actual productivity by using satellite navigator guided cultivator was 1.42 times more as compared to the actual productivity without navigator.

Fertilizer application

For field no. 1, 07:11 and 04:23 min were required to apply the urea over 0.48 ha without and with navigator. The actual productivity was 4.01 and 6.58 ha/h without navigator and with navigator respectively. The actual productivity of the spreader using navigator was 1.64 times more than the machine without naviagator. For field no. 2, average time required without navigator and with navigator trials were 17:28 and 12:20 min to spread urea over an average effective areas of 1.3 and 1.53 ha respectively. On an average actual productivities without navigator and with navigator were calculated to be 5.85 and 8 ha/h respectivitly. Satellite navigator guided fertilizer spreader was having 1.37 times more productivity than spreader without navigator.

Conclusions

(1) Missing percentage was only 8.5% of total area cultivated in case of navigator assisted machinery as comaperd to the 23.5% missed area without navigator guidence.
(2) For smaller field having area of 0.48 ha, the missed area or where no urea was spreaded without navigator and with navigator trials were 4.2 and 14% espectively of the total area under trials. But for larger arae of 1.62 ha, on an average percentage missed area observed without navigator and with navigator trials were 19.8 and 5.5 per cent of the total area under trial.
(3) Overlapped area during cultivation without navigator was observed to be 0.042 or 18% as comaperd to the area of 0.006 ha or 3% by using navigator.
(4) Areas of overlap during fertilizer application without navigator and with navigator trials were observed to be 0.066 or 13.75% and 0.002 ha or 0.4% respectively for smaller fields. But for larger field, without navigator trial overlap of 0.027 ha was obsereved and with navigator trial overlaps were observed for area 0.048, which is 2.9% of total area of 1.62 ha.
(5) The actual productivity of the cultivator without navigator was 0.53 ha/h whereas actual productivity of the machine with navigator was 0.75 ha/h. Hence, it can be concluded that actual productivity by using satellite navigator guided cultivator was 1.42 times more and 15% lesser missing as compared to the actual productivity without navigator.
(6) For smaller field, actual productivity was 4.01 and 6.58 ha/h without navigator and with navigator respectively. The actual productivity of the spreader using navigator was 1.64 times more but also with more missing than the machine without naviagator.
(7) For larger field, on an average actual productivities without navigator and with navigator were calculated to be 5.85 and 8 ha/h. Satellite navigator guided fertilizer spreader was having 1.37 times more productivity than spreader without navigator.

Conflict of Interest

The authors have not declared any conflict of interest.

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