THE EFFECTIVENESS OF AUTOSTEER SYSTEMS IN CEREAL SOWING

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Abstract

The accuracy and consistency of sowing using tractors with autosteer or manual steering was compared by measuring the distance between tramlines in winter sown cereals in the East of Scotland. Autosteer systems were significantly more accurate and consistent than manual systems. Overlaps produced by manual systems resulted in extra variable costs (£7.44-19.92 per ha) and machinery costs (£1.70-£4.55 per ha). Depending on the level of savings and total area sown, the capital costs could be recouped in 2-6 years while reducing operator fatigue.

Keywords: autosteer precision farming cereal sowing tramlines

Sub Theme: Farm Management

Introduction

The advent of the Global Positioning System (GPS) makes it possible to accurately determine and record the position of an appropriate receiver continuously (Neményi, *et al.*, 2003). The accuracy of GPS receivers can be improved by differential correction systems (DGPS), which deliver sub-metre accuracy (Gan-Mor, *et al.*, 2007) using a series of fixed position ground stations to calculate the error in the signal. Greater accuracy can be achieved using a system known as real-time kinematic GPS (RTK GPS) which can deliver almost instantaneous point coordinates with centimetre level accuracy (±2cm) (Chang and Rizos, 2004). This allows a high level of accuracy to be maintained on the move but requires a fixed base station to be in relatively close proximity to the rover unit (within a few kilometres) so that the signals can be transmitted instantaneously via radio data link which require dual frequency GPS receivers. There are many applications that can take advantage of RTK technology, including vehicle guidance and automation (Riley, *et al.*, 2000).

Using RTK technology the steering of tractors can be fully automated being adjusted either by a hydraulic valve or by an electric motor on the steering wheel allowing the driver's full attention to be focussed on the machine to optimise performance.

The accuracy of an autosteer system can be used in a variety of applications including the sowing of cereal crops.

When sowing with a manually steered system, the driver sets up markers on the seeder that make a scratch on the soil surface parallel to the current pass with which the tractor is then aligned on the next pass. How well the driver sets up and follows the markers determines the accuracy of the sowing. Commonly drivers set up machines cautiously to avoid unsightly missed areas resulting in overlaps with the seeder and in subsequent operations. At sowing tramlines are set out by shutting off selected spouts on the seeder every set number of passes across the field, leaving uncropped areas in which tractor wheels run, to achieve the correct distance between passes for future operations. An autosteer system uses RTK GPS to position and steer the tractor down the field at the correct distance between passes so the edge of the seeder is positioned precisely to the edge of the already sown ground. It is claimed this can lead to a reduced overlap in the sowing compared with a manually steered system, potentially saving crop production costs.

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Materials and Methods - Experimental Design and Procedure

A comparison was made of sowing carried out using autosteer systems and manually steered systems by measuring the distance between tramlines in newly germinated winter sown cereal crops and comparing it to the intended distance. The study was undertaken in autumn 2008 in the East of Scotland. Measurements were made on three farms using autosteer, two with 4m trailed seeders and one with a 3m mounted seeder. The latter farm had previously used manual steering so measurements were also made on the preceding year's stubble allowing a comparison of the two systems using the same farm, operator and equipment except for the autosteer. Other manual systems were a further two 3m mounted, one 4m trailed and two 4m mounted seeders.

The exact distance between neighbouring tramlines was measured a minimum of twenty-five times at each farm in a transect line across the middle of the fields, excluding the outer tramlines to avoid inaccuracies caused by angled endrigs.

To ensure accuracy it was essential that the tape measure was perpendicular to the tramlines. This was done using Pythagoras theorem. Using string, two canes were tied together four metres apart and another length of string, eight metres long, with a knot splitting the length into five and three metre sections, was also tied to the two canes. The cane that had the three metre section of the eight metre length was marked as the starting cane this was pushed into the ground exactly on the first row of seedlings at the edge of the tramline. The four metre length was then stretched out along the tramline until the string was tight and the second cane was pushed into the ground also exactly on the first row of seedlings. A third cane was then used to stretch out the eight metre length so that the cane was at the knot and both the five and three metre lengths of string were taught. The third cane was pushed into the ground forming a right-angled triangle. The end of the tape measure was held at the starting cane and pulled out to the same point on the next tramline. Using the canes ensured that the tape measure was running square to the wheelings and the distance between the two tramlines was recorded. Figure 1 shows a diagrammatic representation of the method used.

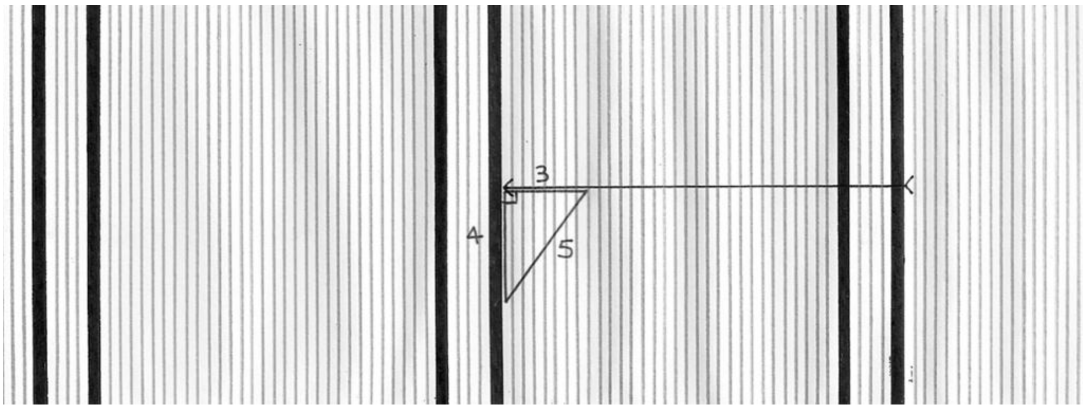

Figure 1: Diagram showing how the measurements were taken.

In total 330 measurements were taken across the farms giving a good range of data from the different systems (manually steered and autosteer) and different seeder types (trailed and mounted). A series of unpaired t-tests were conducted in Minitab 15 in order to try to establish any significant differences between the results obtained from each sowing system and seeder type.

Both accuracy and consistency were considered. Accuracy was taken to mean how close to the intended distance between tramlines the system achieved i.e. an accurate measurement in a system with intended twenty-four metre tramlines would have an average measurement which was as close as possible to twenty-four metres. Consistency refers to the level of variability in the measurements

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i.e. a group of consistent measurements would show a relatively small range. For example the mean overlap for a set of measurements was found to be 0.02% but the range was −2.3% to +2.5%. The mean figure would indicate that the sowing was accurate but it would not be as consistent as a set of measurements where the mean overlap was 1.2% and the range was 0.9% - 1.4%. The consistency of the sowing in the second example is much better and even though the accuracy is not as good this may be a more desirable level of performance to achieve.

Results

Table 1 shows the system, mean and standard error of the tramline width for each farm. The mean tramline width for autosteer systems is very close to that intended whereas manually steered systems appear to vary considerably from the intended tramline width. The exception is Claremont Farm where the mean for this manually steered system is very close to the intended tramline width.

The percentage overlap for each measurement was calculated to allow comparison across the different tramline widths. A skip (a measurement that was wider than intended, indicating missed ground) is represented as a negative percentage overlap. Minitab 15 was used to summarise this information in box plots to give a good visual representation of the data. The average data for the two systems (Figure 2) shows that sowing with autosteer is more consistent and accurate than that done with manual steering. An unpaired t-test between the means returned a p-value = 0.000 indicating that the average percentage overlap in sowing is significantly greater done with a manually steered system than using an autosteer system.

There is a variation in accuracy and consistency of sowing between individual farms (Figure 3), particularly those with manual steering. Unpaired t tests were used to compare the individual manual steered systems with the autosteer system of the same width. 3m systems were all mounted but for 4m ones the autosteer were trailed while the manual included both types. The average percentage overlap was significantly greater with the manually steered systems than with the autosteer systems (Table 2) except for Claremont.

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Farm	System	Seeder Type	Seeder Width (m)	Tramline Width (m)	Mean Measurement (m)	Number of Measurements (n)	Standard Error of Mean (σ/√n)
Hilton of Fern	Autosteer	Trailed	4.00	24.00	24.05	53	0.02
Marcus Estate	Autosteer	Trailed	4.00	24.00	24.00	26	0.03
Backboath	Autosteer	Mounted	3.00	24.00	24.06	54	0.01
Backboath	Manual	Mounted	3.00	24.00	23.69	52	0.04
Claremont	Manual	Trailed	4.00	20.00	20.01	45	0.04
Kirktonbarns	Manual	Mounted	4.00	24.00	23.57	25	0.03
Inverdovat	Manual	Mounted	4.00	28.00	27.51	25	0.03
Scotscraig	Manual	Mounted	3.00	15.00	14.49	25	0.04
West Hillhead	Manual	Mounted	3.00	18.00	17.47	25	0.06

Table 1: Table presenting information on each farm visited and the measurements taken.

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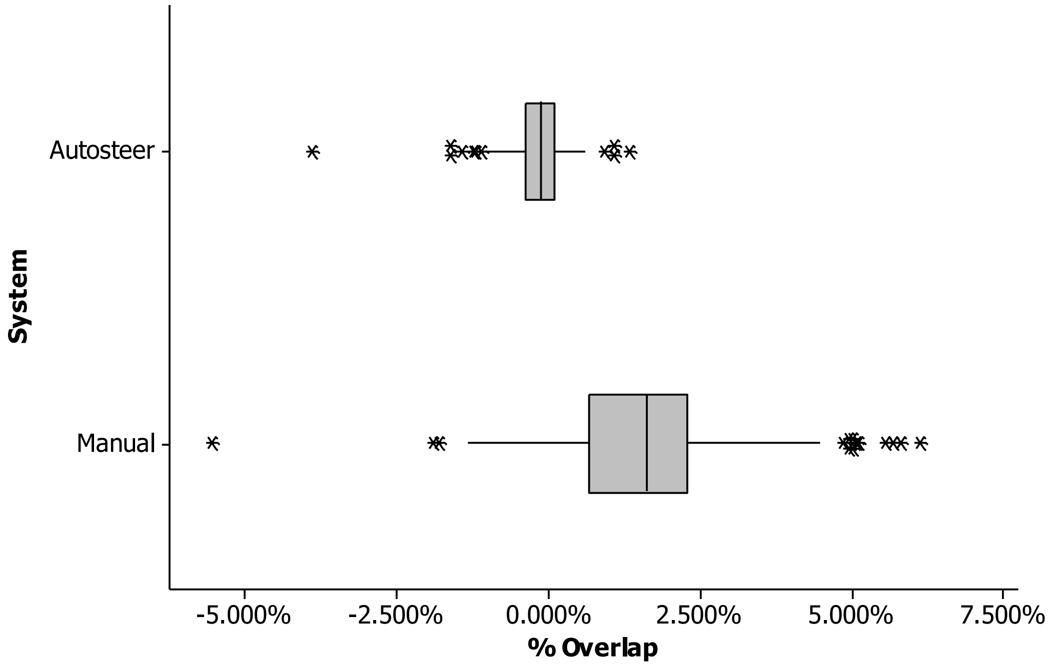

Figure 2: Box plot displaying the percentage overlap data for each system. The asterisks mark any outlying data points.

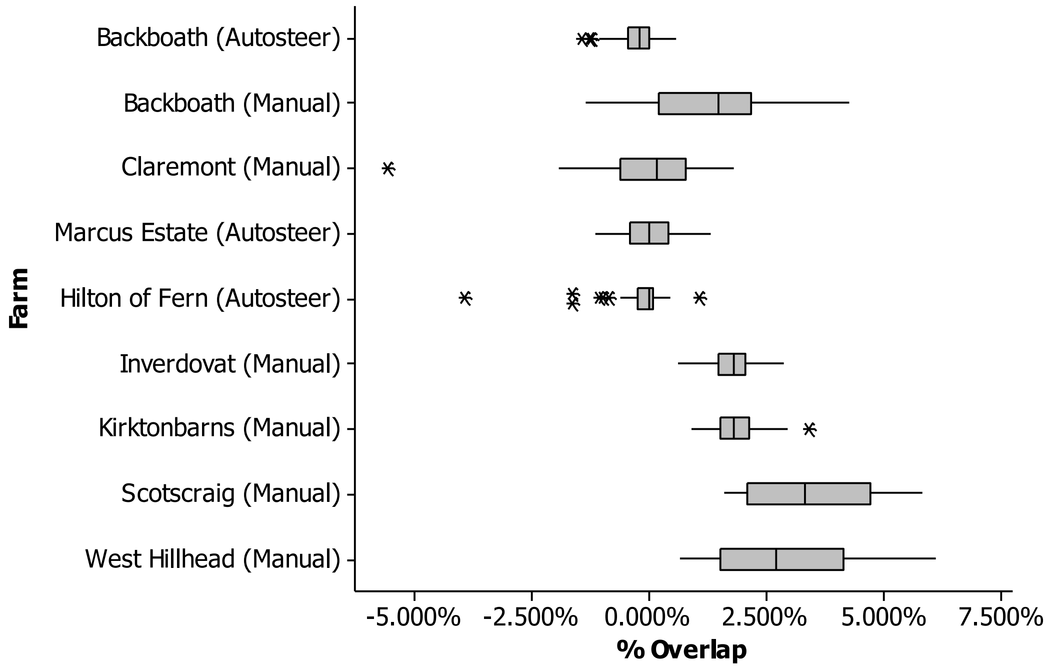

Figure 3: Box plot displaying the percentage overlap data for each individual farm. The asterisks mark any outlying data points.

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Farm				Claremont	Kirktonbarns	Inverdovat	Backboath	Scotscraig	West Hillhead
	System			Manual	Manual	Manual	Manual	Manual	Manual
		Seeder Type		Trailed	Mounted	Mounted	Mounted	Mounted	Mounted
			Seeder Width	4.00	4.00	4.00	3.00	3.00	3.00
Hilton of Fern & Marcus Estate	Autosteer	Trailed	4.00	p = 0.635	p = 0.000	p = 0.000			
Backboath	Autosteer	Mounted	3.00				p = 0.000	p = 0.000	p = 0.000

Table 2: Table showing the comparisons made and the p-values returned from the t-tests.

Discussion

The farms with autosteer systems were not only more accurate but tended to be more consistent. An exception was found at Marcus Estate where consistency was poorest of the autosteer systems and worse than the manual systems at Inverdovat and Kirktonbarns. There were a lot of trees surrounding the fields sampled at Marcus Estate which may have disrupted the GPS signals resulting in greater variation than in the other autosteer systems.

Manually steered systems were generally both less accurate and less consistent and showed variation between farms which could be due to differences in driver skill or concentration during long days. There was less variation between autosteer systems where driver skill has less impact.

Claremont, however, used a manually steered system and appeared to be quite accurate yet was less consistent than the farms using autosteer systems. Both Inverdovat and Kirktonbarns used manually steered systems but appeared to be fairly consistent in their level of accuracy although this level of accuracy was not as good as that shown by farms using autosteer systems.

Financial Implications of Results

Using the mean overlap figure for each farm, the additional costs incurred can be calculated. As the seed rate will have been set at the optimum level given plant’s ability to tiller (Spink *et al* 2000) any overlap will waste seed, incurring extra cost for no increase in yield. As the tramlines are used for subsequent applications of sprays and fertilisers these will also be over–applied, increasing costs. The additional areas sown and treated for the mean level of overlap for each farm are shown in Table 5.

Using typical variable costs for Winter Wheat in 2009 (Table 3) the variable costs that would be incurred on this additional overlap area were calculated (Table 5). From this the additional cost per hectare of cereals grown were calculated. In these calculations it is assumed the whole area is sown to Winter Wheat whose variable costs are greater than for other cereal crops so may overestimate the total farm costs. The extra machinery costs that result from covering the extra ground can also be calculated from the Machinery Costs in Table 4 and are shown in Table 6. The farms which were calculated to have on average a negative overlap i.e. skipped ground were excluded from Tables 5 and 6 and analysed separately in Table 7. For each of these farms the average area of ground missed on each seeder pass was calculated and found to be extremely small so it is highly unlikely that any loss of output due to unused ground would be realised.

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COSTS		Rate per Ha	Unit price	Price per Ha		
Seed		0.20	360	£72.00	**£72**	
Fertiliser	0:20:30	0.30	550	£165.00		
	34.5 N	0.58	380	£220.40	**£385.40**	
Herbicides						
Autumn	Treflan	1.00	2.15	£2.15		
	IPU	2.00	2.35	£4.70		
	Hurricane	0.10	41.95	£4.20		
T1	Duplusan	0.50	4.2	£2.10		
	Starane 2	0.50	13.2	£6.60	**£19.75**	
Fungicides						
T0	Opus	0.35	25.5	£8.93		
	Flexity	0.25	34.5	£8.63		
T1	Tracker	1.00	21	£21.00		
	Bravo	1.00	4.4	£4.40		
T2	Opus	0.75	25.5	£19.13		
	Bravo	1.00	4.4	£4.40		
T3	Proline	0.30	36	£10.80		
	Folicur	0.30	13	£3.90		
	Bravo	1.00	4.4	£4.40	**£85.58**	
Insecticides						
Autumn	Hallmark Zeon	0.025	75	£1.88		
T3	Hallmark Zeon	0.03	75	£2.25	**£4.13**	
Trace elements						
Autumn	Mn DF	1.00	1	£1.00		
T0	Mn DF	1.00	1	£1.00	**£2.00**	
Growth Regulators						
T1	Chlormequat	1.50	1.225	£1.84		
	Moddus	0.10	32.5	£3.25	**£5.09**	
Desiccant						
	Roundup 360	2.00	4.12	£8.24	**£8.24**	
Total per Ha					**£582.17**	

Table 3 Variable Costs for 2009 winter wheat (Quaker).

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Machinery costs						
Plough & Press					54.00	
One pass grain only					54	
Roll					9	
Top dress @ £8.50	4				34	
Spraying @ £9/Ha	5				45	
Combine & cart					108	
Load out £1.50/t					**13.50**	
Drying @ £8.50/t for 5%					81.00	
					£398.50	
Net Margin					**£9.33**	

Table 4: Machinery Costs for 2009 winter wheat (Quaker).

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Farm	System	Area Sown Annually (ha)	Mean % Overlap	Area Sown with Overlap (ha)	Extra Area Sown (ha)	Variable Costs for Winter Wheat (£/ha)	Extra Variable Costs Incurred per Year (£)	Extra Variable Costs per Hectare per Year (£/ha)
Marcus Estate	Autosteer	160	0.014%	160.02	0.02	582.17	13.43	0.08
Kirktonbarns	Manual	800	1.812%	814.49	14.49	582.17	8437.58	10.55
Inverdovat	Manual	570	1.763%	580.05	10.05	582.17	5849.81	10.26
Backboath	Manual	320	1.277%	324.09	4.09	582.17	2379.43	7.44
Scotscraig	Manual	140	3.421%	144.79	4.79	582.17	2788.52	19.92
West Hillhead	Manual	160	2.940%	164.70	4.70	582.17	2738.53	17.12

Table 5: Table to calculate additional variable costs caused by overlap.

Farm	System	Area Sown Annually (ha)	Mean % Overlap	Area Sown with Overlap (ha)	Extra Area Sown (ha)	Machinery Costs (£/ha)*	Extra Machinery Costs per Year (£)	Extra Variable Costs per ha per Year (£/ha)
Marcus Estate	Autosteer	160	0.014%	160.02	0.02	133.00	3.07	0.02
Kirktonbarns	Manual	800	1.812%	814.49	14.49	133.00	1927.61	2.41
Inverdovat	Manual	570	1.763%	580.05	10.05	133.00	1336.42	2.34
Backboath	Manual	320	1.277%	324.09	4.09	133.00	543.59	1.70
Scotscraig	Manual	140	3.421%	144.79	4.79	133.00	637.05	4.55
West Hillhead	Manual	160	2.940%	164.70	4.70	133.00	625.63	3.91

Table 6: Table to calculate extra machinery costs incurred due to overlap.

* One Pass @ £54/ha + Top Dress * 4 @ £8.50/ha + Spray * 5 @ £9/ha

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Farm	System	Area Sown Annually (ha)	Mean % Overlap	Mean % Skip	Seeder Width (m)	Tramline Width (m)	Mean Tramline Width with Overlap (m)	Number of Seeder Passes Between Tramlines	Average Skipped Ground Each Seeder Pass (mm)
Hilton of Fern	Autosteer	150	-0.19%	0.19%	4	24	24.046	6	7.61
Backboath	Autosteer	320	-0.25%	0.25%	3	24	24.059	8	7.38
Claremont	Manual	325	-0.03%	0.03%	4	20	20.006	5	1.20

Table 7: Table to calculate the average ground skipped per seeder pass.

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Investing in an Autosteer System

Investing in an autosteer system involves a considerable sum of money. This depends upon the system and the tractor to which it is to be fitted. The figures given here are from Soil Essentials (Wilson 2008) who provided the autosteer systems on the farms studied.
The first consideration is whether or not the tractor with which the system is to be used is autosteer-ready i.e. an autosteer console can be plugged into the tractor and it will be able to control the steering via the already fitted hydraulic valve without any additional requirements. This adds £3000-4000 to the price of a new tractor (Wilson, 2008). Soil Essentials MojoRTK system can be purchased for £9980 (Leica Geosystems). All that is then required is for the base station to be set up, the autosteer console to be plugged into the tractor and the system is operational as soon as a connection between the two has been made. There is also an annual fee of £200 for product support and software updates (Wilson, 2008).

However, if an autosteer tractor is not readily available there are two possible options. The first is to fit an electric motor to operate the steering wheel. Soil Essentials version of this costs £2000. The second option is to fit a hydraulic valve to operate the steering which costs in the region of £3000-4000, similar to the cost of adding it to a new tractor on purchase. Whichever is selected, the purchase of the MojoRTK system (£9980) and the annual fee for product support and software upgrades (£200) will be required (Wilson, 2008).

As the savings generated vary with the accuracy and the total area so will the payback period but for the farms studied would be between 2 and 6 years.

Other advantages

The number of passes between tramlines will be greater for the smaller seeders which may increase error. For example, a six metre wide machine would make half the numbers of passes that a three metre machine would to cover the same area of ground. If the three metre machine was overlapping by 4cm on every pass, after ten passes there would have been 40cm of ground overlapped. The 6m machine would only make five passes and if it was also overlapping by 4cm there would only be a total of 20cm of ground overlapped. This could equate to a significant difference in the level of overlap over a larger area. It is possible that this could explain some of the extra per hectare costs in Tables 5 and 6. West Hillhead and Scotscraig with 3m seeders show the largest level of extra variable and machinery costs on a per hectare basis. However, Backboath where a 3m manually steered machine is shown to be incurring less extra costs per hectare than both Inverdovat and Kirktonbarns which use 4m machines. This may indicate individual driver skill is also important. The variations in accuracy and consistency noted in the manual systems, with Claremont very accurate and Inverdovat and Kirktonbarns very consistent, may be down to driver skill. If checks were made regularly on the accuracy then the manual markers could be adjusted and drivers such as those at Inverdovat and Kikrtonbarns who are very consistent might achieve accuracy and consistency of the autosteer system. However checks would be best made after the crop has emerged so could not be immediately applied unlike an autosteer system. Even with skilled drivers tiredness and fatigue may reduce performance which would not affect an autosteer system. This may be especially so in poor visibility or reducing light levels when work might have to stop. Gan-Mor, *et al* (2007) claimed that the advantages of an autosteer system over a manually steered

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system became particularly evident during low visibility conditions. Auto steer might allow less skilled drivers to be used to continue sowing during long days and permit operator rest breaks.

Conclusions

The study showed a significant difference in the level of performance achieved between sowing using a manually steered tractor and using a tractor fitted with autosteer. The calculated financial loss being incurred by some of the farms using a manually steered tractor when sowing was considerable and one that most farmers would not be aware of. The total savings would depend on the accuracy of the manual system and the total area worked but could pay for the investment in 2-6 years while reducing operator fatigue and allowing working in poor visibility.

References

Chang, H-C., Ge, L. and Rizos, C. (2004). Assessment of digital elevation models using RTK GPS. University of New South Wales, Sydney, Australia.

Gan-Mor, S., Clark, R.L. and Upchurch, B.L. (2007). Implement lateral position accuracy under RTK GPS tractor guidance. Computers and Electronics in Agriculture. Vol. 59(1-2). Pp 31-38.

Neményi, M., Mesterházi, P.Á., Peize, Zs. and Stépán, Zs. (2003). The role of GIS and GPS in precision farming. Computers and Electronics in Agriculture. Vol. 59(1-2). Pp 31-38.

Riley, S., Talbot, N. and Kirk, G. (2000). A new system for RTK performance evaluation. IEEE Position Location and Navigation Symposium.

Spink, J.H., Semere, T., Sparkes, D.L., Whaley, J.M., Foulkes, M.J., Clare, R.W. and Scott, R.K. (2000). Effect Of Sowing Date On The Optimum Plant Density Of Winter Wheat. Annals of Applied Biology. Vol. 137 (2). Pp 179-188.

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