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Savings through RTK based guidance in field vegetable growing

The vegetable production makes high demands on the precision of the work performed. GPS-assisted guidance systems can relieve the driver and increase the quality of work. So far, data were missing for profitability, in small scale vegetable production. For this reason, a bachelor thesis at the University of Geisenheim dealt with the savings in field vegetable, through the use of a Real Time Kinematic (RTK) based automatic steering. It was shown that the investment is worthwhile even for small and medium farms.

Keywords

GPS, RTK, automatic steering systems

Abstract

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Arable crop production trials confirm that overlapping of bouts [1] can be reduced by up to 10 % by application of an automatic guidance system. Concurrently, working time can be reduced by up to 8.5 % [2]. Associated more efficient application of inputs can bring savings of around 27 €/ha [3]. However, there are a number of differences in growing methods between conventional arable crops and field vegetables. Because of these, it can be assumed that the results are not directly transferrable. For example, working widths are much smaller in vegetable growing. Often the work is carried out within the tractor track widths of < 2 m following track-by-track systems. Additionally, working speed is limited because the fine seeds need a very high quality seedbed. Speeds therefore often do not exceed 3 km/h. In vegetable growing, headland area is minimized and not sown-out because this would hinder subsequent crop care and harvesting work. The two types of crops also differ in the establishment of irrigation pipeline ways and harvesting access tracks to suit their respective requirements.

Field trials

To determine the saving potential in vegetable growing, plots should be cultivated on a commercial farm in Rheinland-Pfalz in each case with and without application of automatic steering guidance. Work data should then be recorded during the operation "seedbed rotavating", the primary operation in the creation of seedbeds. Power unit in the trial was a Fendt 412 Vario with 2 m track and mounted Forigo seedbed rotary cultivator. (**Figure 1**).

The tractor was fitted with an automatic guidance system and GPRS/WLAN modem and was able to receive signals from a static RTK station. To record savings in work time, turning time was measured in the GPS variant. Hereby the conventional track-by-track tillage method served as comparison value for the optimized variant "turn". This was calculated from the so-called "seedbed mode" through which only every second bout treated at first. As the rotavating and sowing of every second seedbed is not practical under unsuitable weather conditions the field should be rotavated from one side and at the same time the turning circle of the tractor optimally exploited. The solution here was to drive in a circuit. (**Figure 2**).

A section comprised five seedbeds with the first one in free field. A deviation of > 15 cm from the ideal track led to undesirable curves in the seedbed lines and this meant that the tractor had to be precisely positioned in each case with the help of the terminal. In that this precision could not be achieved in this trial, even after several attempts, the turning procedure took substantially longer compared with the track-by-track variant. On average the turning time increased by 12 seconds. A saving in work time could therefore not be demonstrated.

Fig. 1

Fendt 412 Vario with a track width of 2 m and Forigo cultivator (Foto: Hege)

Fig. 2

Scheme of the optimized GPS variant of "turn around" (Foto: Hege)

As a further step the degree of overlapping was measured whereby area widths were measured using GPS. The results were calculated with the number of seedbeds, their respective widths plus the number of pipeline tracks and their widths. The results showed that the seedbeds in the variant without automatic guidance were often not close enough and that 1.6 % of the available area was not used.

Implementing a model operation

Using a farm model allowed the effects of the achieved results to be economically evaluated. So that the model could cover as many enterprises as possible within vegetable growing, it was set-up for an operation with respectively 40 ha lettuce as seedling crop, 40 ha wash carrots as seed crop and 40 ha spinach as typical industrial crop. Model farm size was established as 60 ha which, with double cropping, gave 120 ha of crops per year. Database for calculating costs of work operations was based on [4]. 5 % overlapping was assumed for power harrowing and fertilizer spreading bouts, 1.6 % for all seedbed operations.

In that not all work was affected by application of automatic guidance, the relevant operations were first of all identified. The next step involved taking account of the extra costs for work time, farm inputs, machinery wear and for seed or seedlings incurred through additional treatments of the missed areas. These were, however, covered by an increase in yield from the areas. (**Table 1**).

With the wash carrots a saving of 161 €/ha could be determined, with the respective saving for lettuce 118 €/ha. With spinach the savings potential was 35 €/ha, which could be explained through the fact that growing industrial vegetable crops is very similar to arable crop methods. Mostly, no seedbed is established. Soil preparation is with power harrow or cultivator combination and sowing in some cases with cereal drill. This approach means the track-by-track method is not used and, similarly to arable cropping, overlapping occurs. With such crops gross margin is also in most cases lower. Further in the farm model calculations, the total savings (120 ha) are assessed against the annual costs of a guidance system. Hereby, a tractor should be fitted with a complete system comprising antenna, operating terminal, navigation computer, steering angle sensors and steering valves and a further tractor pre-fitted. For the calculation there are now two different variants. Because not every farm has reception for an existing signal, the costs for buying an RTK station are calculated as well as those where an existing signal can be accessed. (**Table 2**).

Altogether, it was calculated that the farm model variant with own base station could achieve an additional profit of nearly 3500 € per year. Using an existing signal could increase this to almost 5500 €. The variants paid for themselves on the farm in 5.5 and 3.4 years respectively.

Also interesting for users is knowing minimum crop areas required for economically efficient application of the systems. With the cropping pattern followed in the calculation the farm model must have available an area of 44 ha (with base station) or 34 ha (without base station), both double cropped. Sown crops such as wash carrots would require a minimum 57 and 44 ha, seedling crops such as lettuce 77 and 60 ha and 258 and 202 ha for industrial crops such as spinach.

Conclusions

In summary it has to be recognized that the automatic steering guidance systems are not able to save working time. The degree of inaccuracies in seedbed work without automatic guidance was 1.6 %. In practice this figure is often higher. At the agricultural economics level it could be shown that investment in a GPS-steering system can pay off, even for smaller and medium-sized vegetable growing farms. There are other factors that were not considered in this work. Thus, labor costs for fulltime staff were assumed. But this is a system capable of producing straight tracking in the field with less experienced drivers. Drivers become less tired because there is no longer the need for continuous steering corrections to ensure straight tracking. At the same time the work quality increases because the driver has more time for control and adjustments. Easier operation for the driver might also mean further savings through applying implement combinations with the operator able to concentrate on two simultaneous work passes.

Table 1

Savings of the crop washing carrot

Arbeitsgang *Operation*	**Diverse Kosten**[1] *various costs*	**Arbeitszeit**[2] *Working hours* [€/ha]		**Diesel**[3]	**Maschinenkosten** **Machine costs** [€/ha]		**Einsparung** *Savings*
	[€]	**Fest** *tenured*	**Saison** *seasonal*	[€/ha]	**Fix** *fixed*	**Variabel** *variable*	[€/ha]
3 m Kreiselegge; 83 kW Traktor *3 m power harrow; 83 kW tractor*		13.95		12.21	13.63	26.40	
GPS: -5 % Überlappung/*-5 % overlap*		13.25		11.60	13.63	25.08	2.02
Dünger streuen mit 1,5 m^3 Streuer und 67-kW-Traktor *Fertilizer application with 1.5 m^3 spreaders and 67 kW tractor*		8.40		3.52	9.93	13.24	
GPS: -5 % Überlappung/*-5 % overlap*		7.98		3.34		12.58	1.08
Kosten Dünger/*Fertilizer costs*	309.00 €						
GPS: -5 % Überlappung/*-5 % overlap*	293.00 €						15.00
Fräsen mit Dammfräse 2,0 m; 3-reihig; 67-kW-Traktor *Rotary Hiller 2.0 m; 3-row, 67 kW tractor*		58.35		25.19	76.62	85.94	
GPS: + 1,6 % Mehrverbrauch *+ 1.6 % increase in consumption*		59.28		25.59		87.32	2.31
Säen 3 Doppelreihen, 2,0 m; 45-kW-Traktor *Seeding 3 double rows, 2.0 m, 45 kW tractor*		42.75		8.14	59.69	68.89	
GPS: + 1,6 % Mehrverbrauch *+1.6 % increase in consumption*		43.43		8.27		69.99	1.79
Saatgut/*Seeds*	704.48 €						
GPS: + 1,6 % Mehrverbrauch *+ 1.6 % increase in consumption*	715.75 €						11.27
Pflanzenschutzmaßnahmen: 5 x *Crop protection measures: 5 x*		74.25		14.30	119.20	70.10	
GPS: + 1,6% Mehrverbrauch *+ 1.6 % increase in consumption*		75.44		14.53		71.22	2.31
Pflanzenschutzmittel gesamt *Total plant protection*	179.49 €						
GPS: + 1,6 % Mehrverbrauch *+ 1.6 % increase in consumption*	182.36 €						2.31
Durch GPS entfällt die Handjäte auf 1,6 % der Flächen *By using GPS -1.6 % manual weed control*			2.90	0.01	0.08	0.06	2.97
Möhrenvollernter; 2-reihig, 4-t-Bunker; 83-kW-Traktor *Carrot harvesting; 2-row, 4 t bunker, 83 kW tractor*		113.40		139.70	1.339.60	534.86	
GPS: + 1,6 % Mehrverbrauch *+ 1.6 % increase in consumption*		115.21		141.94		543.42	10.37
Transport zum Hof Anhänger, 18 t; 83-kW-Traktor *Transport for farm 18 t trailer, 83 kW tractor*		41.40		18.37	155.17	98.02	
GPS: + 1,6 % Mehrverbrauch *+ 1.6 % increase in consumption*		42.06		18.66		99.59	2.23
Aufbereiten und Verpacken *Processing and packaging*			338.80		2.704.00	24.00	
GPS: + 1,6 % Mehrverbrauch *+ 1.6 % increase in consumption*			344.22			24.38	5.80
Kundentransport/*Transport to customer*		129.30		24.86	98.89	78.43	
GPS: + 1,6 % Mehrverbrauch *+ 1.6 % increase in consumption*		131.37		25.26		79.68	3.32
Tiefgrubbern, 3,0 m; 83-kW-Traktor *Deep cultivation, 3.0 m, 83 kW tractor*		10.95		14.30	8.82	24.65	
GPS: -5 % Überlappung /*-5 % overlap*		10.40		13.59		23.42	1.78
Leistung/*Output*	11,340.00 €						
GPS: + 1,6 % Mehrleistung/*+ 1.6 % more output*	11,521.44 €						181.44
Gesamt Einsparungen/*Total savings*							**161.35**

[1]Kosten für Dünger, Saatgut, Pflanzenschutzmittel/*cost of fertilizer, seeds, pesticides.*
[2]Lohnkosten für Festangestellte 15 €/h; Saisonarbeitskräfte 6,05 €/h /*labor costs for permanent workers 15 €/h, seasonal workers € 6.05/h.*
[3]Dieselkosten 1,10 €/l /*diesel costs 1.10 €/l* .

Table 2

Investment Analysis for RTK automatic steering of Trimble, according to [3]

Kennzahl *Index*	**Einheit** *Unit*	**Autopilot/***Automatic steering system*		**Vorrüstung weiteres Fahrzeug** *Pre-fitting additional vehicle*
		Eigene Referenzstation *Own reference station*	**Zugriff auf Referenzstation** *Access to reference station*	
Erreichbare Genauigkeit *Achievable accuracy*	cm	2.5	2.5	2.5
Investitionsbedarf *Investment costs*	€	36,940[1)]	23,670	5,000
Abschreibung bei 10 Jahren Nutzungsdauer *Depreciation at 10 years of useful life*	€/Jahr *€/year*	3,694	2,367	500
Zinsansatz 5 %/Jahr *Interest approach 5 %/year*	€/Jahr *€/year*	924	592	125
Reparaturkosten[2)] *Repair Costs*[2)]	€/Jahr *€/year*	1,108	713	150
RTK Signal *RTK signal*	€/Jahr *€/year*	-	1.000[3)]	-
Jährliche Kosten *Annual costs*	€/Jahr *€/year*	8,386	6,379	775

[1)] Anschaffungskosten eigene Referenzstation/*cost own reference station 13.270 €.*
[2)] 3 % vom Investitionsbedarf/*of investement costs.*
[3)] Schätzwert nach Anwenderaussagen/*estimate by users statements.*

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