Saving of fuel and working time in field operations through steering assistance and automatic guidance system in tractors

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Abstract:
Steering Assistance Systems (SAS) and Automatic Guidance Systems (AGS) in tractors are more used in large scale agriculture because of their benefits e.g. physical and mental release of permanent steering, the efficient usage of fuel and working time. In a field investigation on three same plots (a´ 3,186 ha) the effect of fuel and working time reduction in stubble field skimming with a short disc harrow (5 m) was measured with three steering variants: conventional steering without assistance (CS), SAS and AGS. The Tractor (261 kW) was equipped with AGS, which allows parallel tracking according SAS. The GPS-receiver was StarFire – SF1 which uses EGNOS-correction. The mean working time per turning event was for CS 17,4 sec., for SAS 10,6 sec. and for AGS 13,38 sec. Through the faster turning events via the turning circle at the headland the working time for the whole field operation could be reduced at 13.4 % for SAS and 8.5 % for AGS. Moreover the fuel consumption could be reduced by 9,8 % (SAS) and 9,0 % (AGS). The analysis of the system-accuracy shows that for conventional steering without assistance an average overlapping of 30 cm each track (= 6,07 % per pass) existed. With SAS respectively AGS the mean overlapping per track is 7,50 cm (= 1,05 %) and 6,60 cm (= 1,32 %).

Keywords: Steering Assistance System, Automatic Guidance System, Fuel Consumption

1. Introduction

Driving agricultural machinery requires concentration and skill on the part of the driver, especially for operations with large working span. Following benefits by using guidance systems are mentioned [1, 2, 5]:

- Physical and mental release from permanent steering. Investigations have shown, that more than 60 % of the concentration is used for vehicle steering (DIEKHANS 2000 [1]).
- Reduction of overlapping between paths or faulty distribution.
- Reduction of fuel, pesticide and fertilizer consumption.
- Increase the field performance through reduced overlapping and faster turning events.
- Expansion of the field working time to dawn and night.
- Increase of the intrinsic motivation for drivers.
- Establishment of new field operation systems (e.g. On-Land Ploughing, Controlled Traffic Farming).

The market offers a certain number of on-board guiding systems, which make it possible to ensure parallel paths (**Figure 1**).

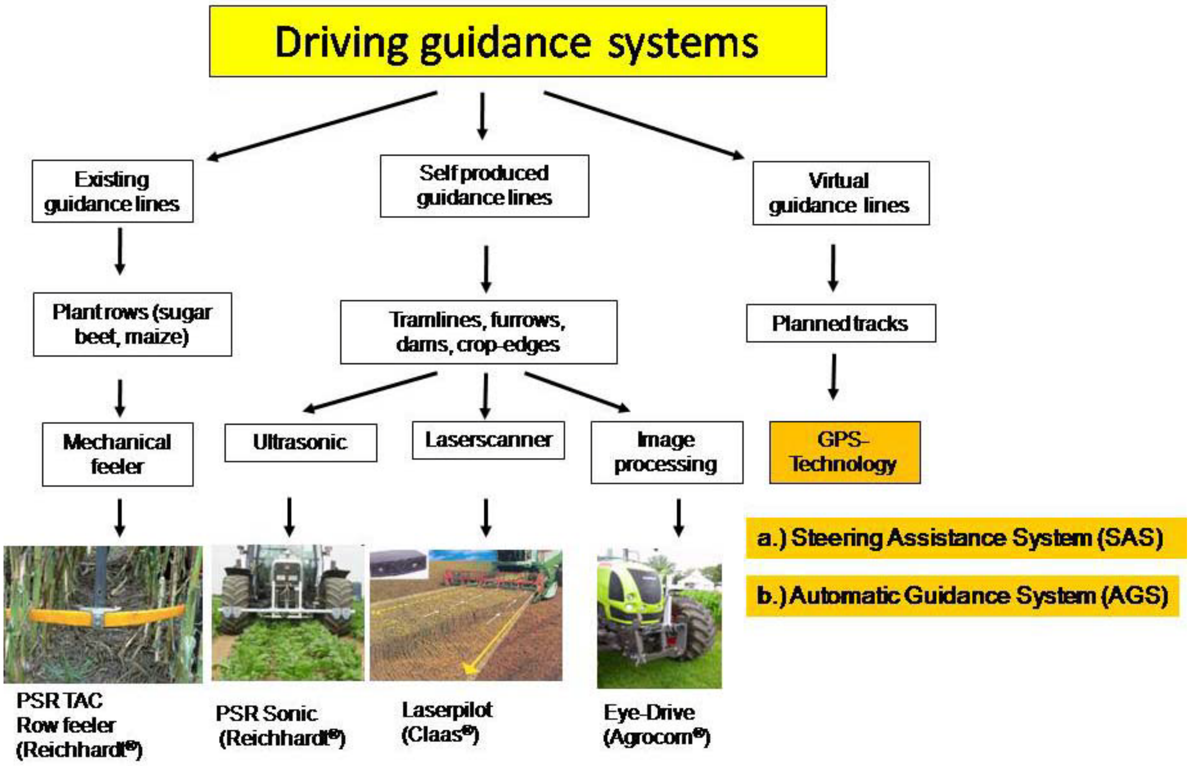


Figure 1: Classification of driving guidance systems

GPS-based guidance systems are now very common used in field operation. Basically there are two systems in application. The group of GPS-steering assistance systems consists of a GPS-receiver and data processor with a display. The driver is active in the steering process but get assistance with acoustic and/or visual signals to show him the ideal driving line. Automatic guidance systems engage into the steering hydraulic system via electro-hydraulic steering valve or via a friction wheel and engine, which is mounted to steering wheel. Apart from steering during turning at the headland, the driver is discharged form steering during field operation.

The reliability and the system accuracy are important factors for the application of GPS-Steering Systems. Following GPS errors are mentioned: atmospheric influences (ionospheric and tropospheric progagation delay); clock error in satellite and receiver; multipath effects in areas with large reflective surfaces (e.g. forest) and geometric satellite constellation.

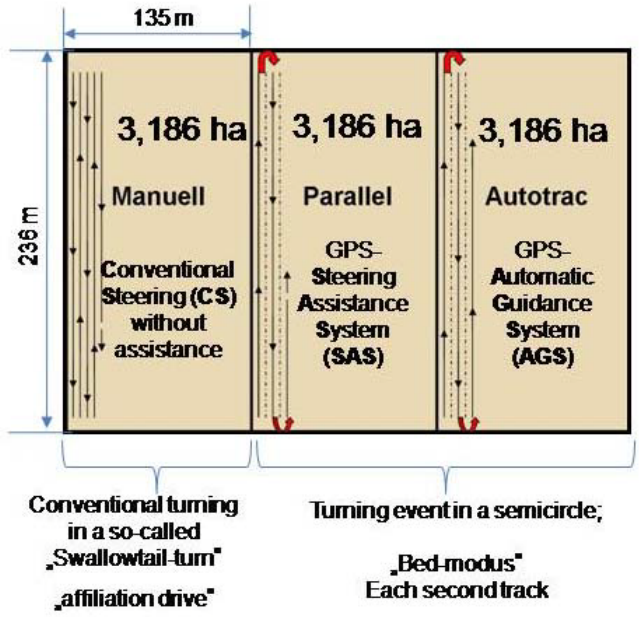
The track-to-track accuracy is determined by the field operation. A high track-to-track accuracy (< 5 cm) is needed for example in seeding operation. This could only be reached with the Real Time Kinematic (RTK) approach.

European **G**eostationary **N**avigation **O**verlay **S**ystem (**EGNOS**) is completely free of charge service of correction. There are two commercial DGPS-correction services with offers correction data for agricultural machinery guidance: OmniSTAR and StarFire. OmniSTAR-VBS (Virtual Base Station)- and StarFire SF1-Signal are a one-frequency-service and are free of charge with accuracy between 20 and 30 cm. The chargeable OmniSTAR-HP (High Performance)-signal and StarFire SF2-Signal need a two-frequency receiver. The system accuracy is between 5 and 20 cm.

The objective of the investigation was to analyse the effect of three different steering variants with the same tractor on fuel and working time consumption during stubble field skimming with a short disc harrow.

2. Material and method

The investigation (**Figure 2**) was carried out on a farm in Upper Austria in summer 2008. The field was flat and not surrounded with a forest. The used Tractor (261 kW) was equipped with an Automatic Guidance System (AGS), which allows also parallel tracking (SAS). The GPS-receiver was Starfire – SF1 which uses the EGNOS-correction. For the stubble field skimming a short disc harrow (5 m) was applied. The adjusted working width for the virtual guidance line was 4,9 m that means 10 cm are reserved for the inaccuracy of the guidance systems (SAS and AGS).



Constant trial conditions:
- driver
- working speed
- gear adjustment

Figure 2: Investigation design

For each trial following parameters are measured:
- Fuel consumption (via tractor terminal and via volumetric measurement)
- Working time for turning and field operation
- System accuracy

3. Results and discussion

3. 1 Fuel consumption

The investigation shows a reduction in fuel consumption for SAS of 9,8 % and for AGS of 9,0 % (**Figure 3**). This reduction has two reasons: accelerated turning event (**Figure 4**) and reduced overlapping. The reduced overlapping saves one passage in comparison to CS.

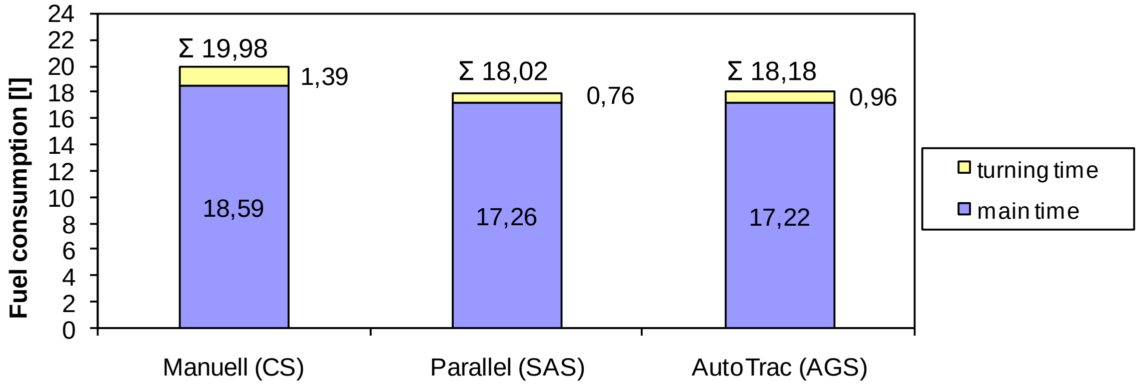


Figure 3: Fuel consumption for stubble skimming (field size: 3,186 ha)

3. 2 Field working time

The measured time elements for turning show (**Figure 4**) significant reduction for SAS and AGS. The mean time per turning event was for CS 17,39 sec., for SAS 10,61 sec. and for AGS 13,38 sec.

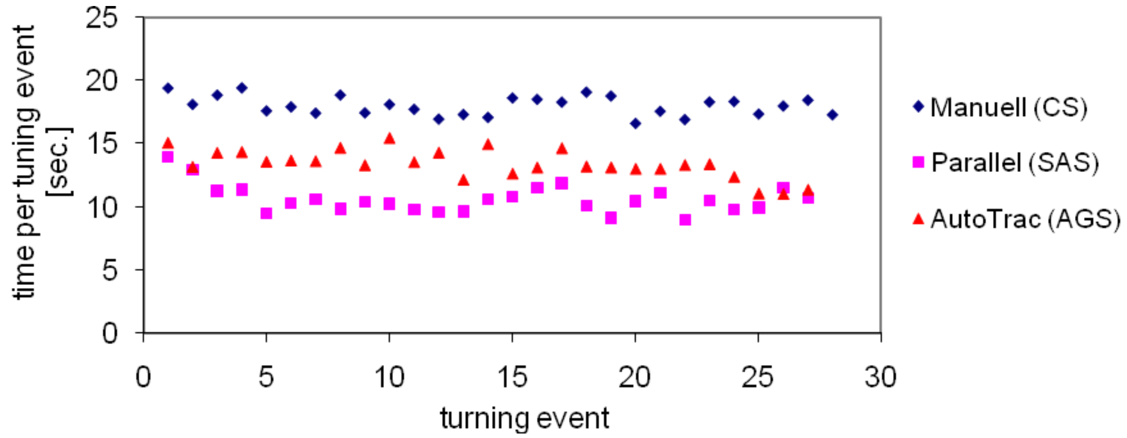


Figure 4: Measured time per turning event

This saving of time per turning event is a relevant factor (**Figure 4**, [3]) for reducing the turning time, which is shown in **Figure 5**. The reduction in the turning time was 43 % for SAS and 28 % for AGS. The difference between SAS and AGS was system-immanent. In the main time (= field working time – turning time) the difference between CS and SAS respectively AGS was approximately 1 min, which is explained in an additional passage for CS in order to treat the whole field of 3,186.

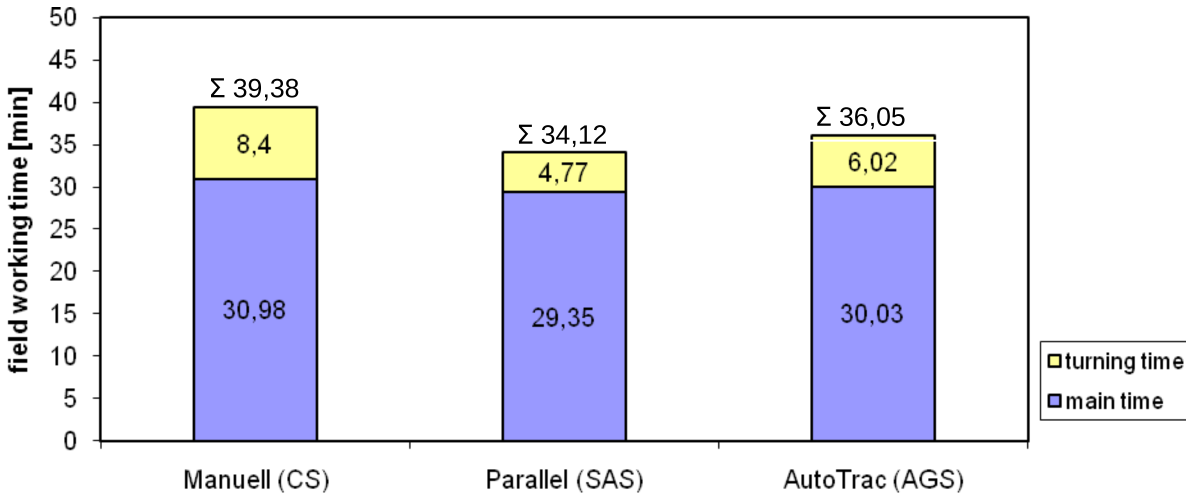


Figure 5: Field working time for stubble skimming (field size: 3,186 ha)

3. 3 System accuracy and overlapping degree

The visual survey of the treated field shows that there are no untreated stripes in the variant, where AGS was used. The adjusted working width of 4,9 m for AGS was right. Partial stripes are shown in SAS which resulted from the driver influence. A reduction to 4,8 m (that means a fixed overlapping of 20 cm) could avoid untreated areas.
The measurement and calculation for the mean overlapping in **table 1** shows that per pass with the short disc harrow (5 m technical working width) 30 cm are needed for overlapping.

Table 1: Overlapping degree for CS, SAS and AGS

	Set width* [m] a	Treated width measured [m] b	a-b [m]	Overlapping per pass [cm]	Overlapping per pass [%]
Manuell (CS)	130	122,10	7,90	30,30	6,07
Parallel (SAS)	130	128,05	1,95	7,50	1,50
AutoTrac (AGS)	130	128,29	1,71	6,60	1,32

* 26 passes x 5 m theoretical working width = 130 m

3. 4 Cost savings through guidance systems

In **table 2** the calculated saving costs for intercropping cultivation (field skimming and catch crop sowing) are shown. There is a benefit, if the capital costs (amortisation and rate of interest) of the guidance systems are lower than 4,9 €/ha respectively 4,4 €/ha.

Table 2: Calculated cost savings for combined field skimming and catch crop sowing for one hectare. Based on the parameters from the field investigation.

	Manuell (CS)	Parallel (SAS)	AutoTrac (AGS)
Necessary passes	9,2	8,6	8,6
Treated area [ha]	1,065	1,015	1,013
Seed amount [kg/ha]	26,6	25,4	25,3
Seed costs [€/ha]	**32,61**	**31,08**	**31,03**
Labour time [h/ha]	0,21	0,18	0,19
Labour costs [€/ha]	**2,06**	**1,80**	**1,89**
Tractor costs without fuel [€/ha]*	**8,24**	**7,20**	**7,56**
Fuel costs [€/ha]	**5,86**	**5,16**	**4,77**
Costs for short disc harrow with sowing machine [€/ha]*	**11,10**	**9,70**	**10,19**
Total costs [€/ha]	**59,87**	**54,95**	**55,44**
Difference [€/ha]		**- 4,92**	**- 4,43**

*Machinery costs calculated according the standard values of the Austrian Association for Agricultural Engineering and Landscape Development (ÖKL)

Based on the data in table 2 the break-even point for SAS (investment: 5.430 €, interest rate: 6 %, average life time: 8 years) in intercropping cultivation calculated via the annuity method is 178 ha. This can be much lowered if other field operations (e.g. application of fertilizer and pesticide; soil cultivation) are considered as it is used in the working reality. Calculations [4], done by the Association for Technology and Structures in Agriculture (KTBL) point out 80 ha/years and more for the break-even point using SAS. For Automatic Guidance Systems KTBL calculated minimum areas between 300 and 600 ha/years depending on farm type (arable farm or fixed farm).

4 Conclusions

The investigations show clear quantified benefits for using steering assistance and automatic guidance system in tractors. The physical and psychological release from permanent steering is an additional benefit especially in automatic guidance systems but this is more difficult to quantify them monetarily. The working reality shows that Steering Assistance Systems (SAS) with only visual signals needs a lot of attention sowing on the display. Steering according acoustic signals are much better in SAS. For the holistic evaluation of guidance systems, ergonomic analysis especially for the human- machinery-interface is necessary.

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