SINGLE VS MULTIPLE HORTICULTURAL OPERATIONS WITH GNSS ASSISTED STEERING

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Abstract. In the last years, the increasing implementation of Global Navigation Satellite Systems (GNSS) has greatly enhanced the ability of farmers to apply precision management approaches. Many research studies demonstrate how such technologies can bring great benefits to extensive agriculture and viticulture, while specific studies are still lacking in the case of horticultural crops. The aim of the present work is to make a comparison on the performances of single and multiple operations, carried out using manual and assisted steering. The experimental study was carried out in an 8 ha area, planted with watermelon and pumpkin. Specifically bed formers, mulching machines and seed drills were analyzed, considering three different approaches: single operations, semi-combined operations and fully combined operations. Data were collected on direct and indirect costs, operation times and working capacity.

Keywords: Assisted Steering, Global Navigation Satellite Systems, Precision Horticulture.

Introduction

Precision Agriculture is an approach to agricultural and livestock production based on quantification and management of the spatial or individual variability allowing optimization of resource efficiency, productivity, profitability and environmental sustainability [1-3]. Many advancements in machinery and technologies used for precision agriculture have been done in the last few years and implemented, mainly for extensive crops. The same technologies have had relevant applications also in the case of different farm as for instance in vineyards, orchards or in horticultural productions, however in this case only few research studies have been published on actual efficiency and profitability.

Many technologies can contribute to the success of precision agriculture approaches: soil and crop sensors [4], three-dimensional instruments [5, 6], robotics and automation [7, 8], decision support systems [9], etc. Above all, tractor guidance and steering control is certainly the most mature of agricultural precision technologies, having been in commercial use for about two decades. These systems enable tractors to be precisely positioned in the field with minimal driver interaction [1], potentially allowing improvements of machines and driver performances. With respect to the machinery, it is possible to minimize skips or overlaps during seeding, spraying, fertilizing and harvesting, and to better localize machine for controlled traffic, inter-row seeding or strip tillage. With reference to the driver, steering attention is reduced in such a way that implements operations can be better monitored, and fatigue reduced. Such improvements permit a reduction of inputs costs (agrochemicals, working hours, machine and maintenance costs,…) and an increase in the overall efficiency of agricultural operations and of environmental performances allowing improvements of agricultural products sustainability [10, 11].

Despite low diffusion, implementation of positioning and of automatic steering systems in horticultural farming has the potential to bring not only some of the advantages seen for herbaceous crops (as the reduction of driver stress or optimization of positioning), but also other specific benefits, such as the automatic localization of different varieties or the possibility of executing combined operations. The latter is particularly relevant in relation to mechanization. Indeed, due to the fact the some horticultural operations are often carried out in quick succession, the possibility of combining some operations is interesting not only for time and costs reduction but also for minimization of soil compaction. While in conventional systems the combination of operations is limited by the fact that the driver cannot simultaneously control the tractor and two or more implements, in the case of automatic steering systems such limitation is overcome.

The aim of this paper is to compare the efficiency and the economical convenience of single and multiple operations, carried out in two typical horticultural crops (watermelon and pumpkin) through manual and assisted steering.

Materials and methods

Experimental site

For the present research, a set of experiments was carried out in a private farm in north-eastern Italy in a typical Po Valley field (45.1346 N, 11.5866 E). An 8 ha fields was selected, cultivated with watermelon (4ha) and pumpkin (4 ha). Watermelon and pumpkin production system presented in this research employs raised beds covered with black plastic mulch (240 rows, 100 m long).

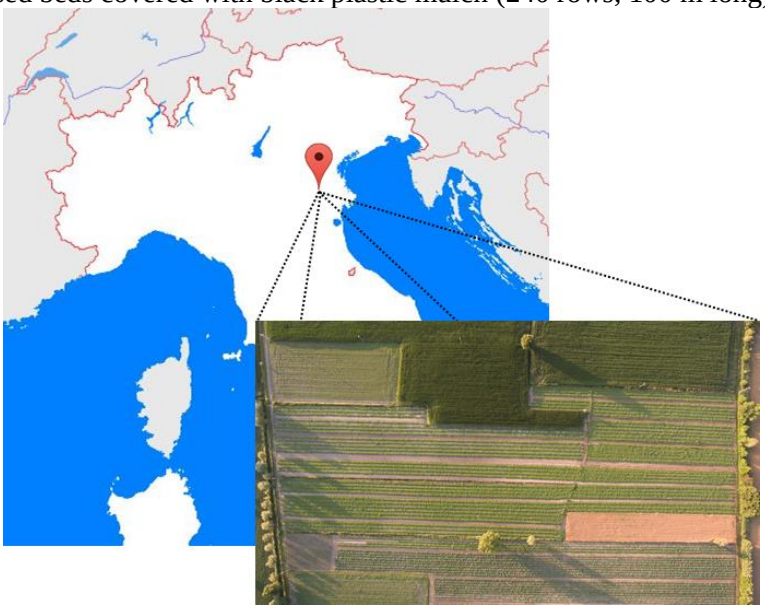

Fig. 1. **The horticultural field considered for the experimental tests**

Equipment

Operations considered for the present experiment included three main operations: bed shaping, mulching and transplanting. Implemented machinery is reported in Table 1, along with main characteristics.

Table 1

Equipment implemented for the experimental study

Equipment	Model	Weight [kg]	Width [m]	Length [m]	Other technical data
Tractor	New Holland t4.75	2850	1.95	3.88	Maximum power: 55 kw Turning radius: 3.8 m
Bed shaping	Hortech AB	260	1.60	1.25	Needed power: 22 kw Speed: 5 km/h
Mulching	Hortech P	320	1.50	1.70	Needed power: 30 kw Speed: 4.5 km/h
Transplanting	Hortech Over	250	1.80	2.00	Needed power: 37 kw Speed: 4 km/h
Monitor	Trimble FM750	-	-	-	Precision: 2.5 cm Accuracy: 20 cm
Steering system	Trimble EZ Pilot	-	-	-	

Scheduled operations

As mentioned above, the experimental study has been focused on the evaluation of efficiency and of economical convenience of single operations compared to multiple operations combined in one passage thanks to the implementation of automatic steering system. To this end, the following parameters where considered and measured or estimated:

- single and combined operations working speeds

- timing: implements set up (hook up and unhook, installation of mulch film, transfers, plant trays upload) and turning operations at the end of the row;
- single and combined operations fuel consumption.

Additionally, costs of used equipment and manpower were considered in the analysis.

For sake of simplicity, here on "BMT" is used in order to indicate combined bed shaping, mulching and transplanting operations, "BM+T" refers to combined bed shaping and mulching and separated transplanting, while "B+M+T" stands for separated single operations.

Results and discussion

Operation times analysed during field tests allowed estimation of working capacity for different management approaches. Main results are summarized in Table 2.

Table 2

Operation time for different management strategies on the 8 ha experimental field

Management strategy	Acronym	Operations	Operation times [h]	Manpower [h]
Single operations	B+M+T	1 bed shaping + 1 mulching + 1 transplanting	52.02	88.03
Two combined operations	BM+T	1 bed shaping & mulching + 1 transplanting	39.07	78.14
Three combined operations	BMT	1 bed shaping & mulching & transplanting	22.98	45.96

It should be noted that total manpower is different from total operation times since mulching and transplanting request one driver onboard the tractor and one person assisting implement operation (control and replacement of polymer films and plant trays upload. It is clearly evident how integration and combination of multiple operations in one passage allows reduction of working times with total saving as high as 57% for machinery and 49% for manpower.

Timing needed for the operations has to be combined with equipment costs in order to evaluate total operating costs for the three different proposed approaches. Economic analysis results are summarized in Table 3.

Table 3

Total costs for single, two combined and three combined operations

	Tractor	Bedshaper	Mulcher	Transpl.	Bedshaper + Mulcher	BMT	Steering system
Initial value (€)	31000	1000	3000	3000	5000	8800	7800
Depreciation (€/year)	2635	85	255	255	425	220	195
Average life (years)	10	10	10	10	10	10	6
Interests (€/year)	775	25	75	75	125	220	195
Other costs (€/year)	372	5	15	15	25	44	39
Main costs (€/year)	3782	115	345	345	575	1012	1534
Maintenance (€/h)	3.66	1.33	3.36	3.36	4.16	5.68	0.90
Manpower (€/h)	18	-	18	18	18	18	-
Total costs (€/h)	30.66	8.09	42.92	37.79	52.42	67.68	4.74

Combining the costs of tractor, of single or combined operations and steering system, linear models can be produced, indicating a fixed cost which is ranging between 1167 € (in the B+M+T case) and 1361 € (BMT case), and variable costs which are ranging 249.4 €/ha (B+M+T), 228.3 €/ha (BM+T) and 126.0 €/ha (BMT). The models are represented in Figure 2a, showing how the implementation of the combined BMT approach is profitable (compared to single operations) with a

farm size larger than 2 ha; similarly, bed shaping combined with mulching is profitable whenever the farm size is larger than 7 ha. Considering the return on the initial investment, on a planning horizon of 10 years, an average 11 ha farm is needed in the case of BMT combination approach while 45 ha are needed in the case of a BM+T like management approach. Due to manpower and machinery savings, the BMT is clearly recommendable, allowing maximization of profits even on the case of small farms. In the case of large farms, the combination of only two operations can be profitable, while the automatic steering system can bring additional benefits in the improvement of efficiency and reduction of overall working times.

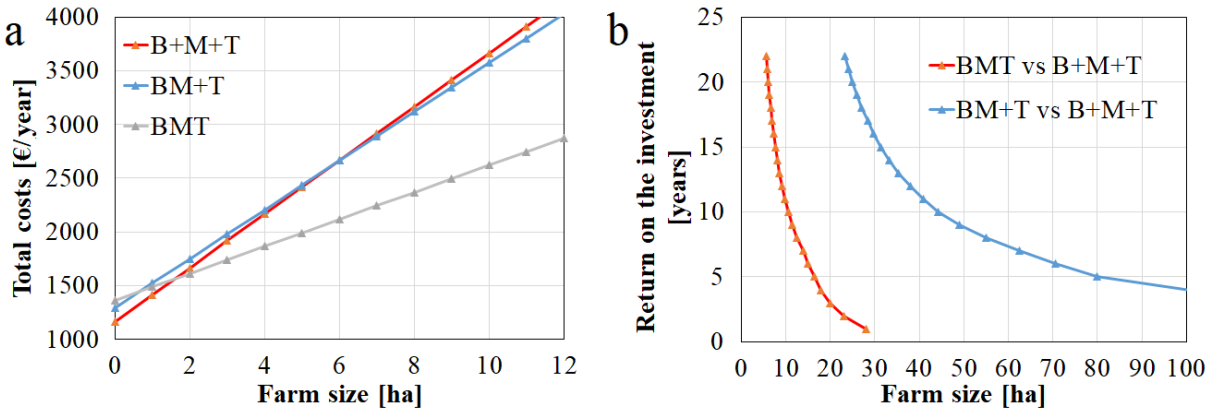

Fig. 2. **(a) Total costs for the three analysed management approaches as a function of farm size and (b) average time for the return on the investment as a function of the farm size.**

Conclusions

Assisted steering can have positive results in horticultural mechanization. While a manual control is subject to performance decay due to the increase of fatigue, decreased attention, decreased visibility, an assisted steering system guarantees more stable performance, regardless of the skill of the driver and his psycho-physical state, even in the case of large farms. Assisted steering can be successfully applied in order to allow combination of multiple operations. Compared to single managed operations, such approach can provide relevant benefits in terms of time and economic savings. Reported field tests highlighted how assisted steering and combination of operations can brings to:

- an increase of efficiency with working time reduction up to 51% (inclusive of machinery and manpower)
- a reduction of costs up to 123 €/ha

Such improvement can guarantee a return on the investment for advanced steering equipment, in particular in the case of medium or large farms, with a total cultivated area larger than 10 ha.

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