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Reduction of the operational times and crop costs by applying No Till and Guide Assistance in rainfed arable crops in Southern Spain

Jesus A. Gil-Ribes; Francisco Márquez-García; Gregorio Blanco-Roldán and Juan Agüera-Vega, Department of Rural Engineering, University of Cordoba. Medina Azahara Avenue 5. 14071 Córdoba, Spain

Emilio J. González-Sánchez, Asociación Española Agricultura de Conservación. Suelos Vivos. 14004. Córdoba, Spain

Abstract

Andalusia, located in the South of Spain, is one of its main agrarian regions. The rainfed arable crops occupy a 39 % of its total agricultural area, more than 3.5 Mha. The continuously increasing of the agricultural inputs costs (labor, fuel, herbicides, fertilizers, etc.), and the maintenance or decreasing of the yields prices, have produced a serious reduction of incomes for the Andalusian farmers. No Till (NT) in arable crops, based in the suppression of the plow, and Guide Assistance (GA) that allows a more efficient and homogeneous work, reduce fuel and inputs consumption, and consequently the agricultural costs. Also, as they reduce and optimize the number of operations, NT & GA decrease the operational time needed to cultivate the crops.

However, the change of soil management system, not only could produce variation in the yield, but also increased some inputs costs, as herbicides. So the aim of this work is: 1) Study the yield variation of arable crops managed with NT and conventional tillage (CT) in rainfed conditions. 2) Study the reduction in the operational times and crop variable costs that NT & GA could bring respect CT.

This work belongs to a European project, Life + Agricarbon, and it shows the results of four seasons carried out in three rainfed farms in Southern Spain. On each experimental field, 30 hectares of arable crops, with two soil management systems (CT and NT & GA) were studied. Trials in each system followed a typical crop rotation of the Andalusian countryside: winter wheat, sunflower and legume. Different parameters on mechanized operations made in each crop and management system were logged using a remotely data acquisition system. The indicators studied in each operation were: time duration; working surface; average speed; work capacity; overlap and fuel consumption. To this end, one tractor in each farm was instrumented with different technology: GPS; fuel flow sensor, implement lift sensor and a guide assistant bar. As data acquisition system a data logger was used. The stored information about the operation was transmitted via GPRS modem to a PC. Moreover, the crop production was monitored with a crop yield monitor.

The variable costs of the crops were studied for each season. They were divided in the price that farmers paid for the farming operations, seeds, agrochemicals and fertilizers used each year in the farms.

Results show how there was no significant differences in the average yield of crops managed with the different soil management systems. Furthermore, NT & GA, approximately reduced

the variable costs of the wheat production in 58 € ha^{-1}, 73 € ha^{-1} for sunflower, and 62 € ha^{-1} for legume. This decrease was related to the reduction in the fuel consumption contributed by the NT (53 %) and the overlap of the seeding, spraying and fertilization contributed by GA. In addition to this, the operational times were average decreased in a 61 %.

Keywords: costs, remote monitoring, guide assistance, no till, arable crops

1. Introduction

Andalusia, located in the South of Spain, is one of the main agricultural producers of this country. This region accounts around a 21 % of the total agricultural area of Spain, 16,981,259 ha (Spanish Government, 2013). The rainfed arable crops represent a 39 % of the Andalusian countryside. However the continuously increasing of the costs of the agricultural inputs (labor, fuel, herbicides, fertilizers, etc.), and the maintenance or decreasing of the yield prices have produced a serious reduction of incomes for the farmers. The EUROSTAT (2011) estimates that in the year 2010 Spanish farmers have suffered a decreased of a 9.5 % of its agricultural incomes respect to the average of the period 2000-2004.

In order to maintain the agrarian production in these regions, it is necessary to implement techniques that allow improving the profits of the crops. To this end, two situations could be used: increase the yields or reduce the agricultural costs. The first one could be possible by using more agrochemicals and making a more intensive agriculture. However, this fact could produce problems of economic and environmental sustainability of the agricultural productions (Sartori, Basso, Bertocco, Oliviero, 2005).

The use of conservation agriculture techniques for arable crops, No till (NT), have widely demonstrate to decrease farming variable costs in many parts of the world. The suppression of the soil tillage produces an important reduction of the fuel consumption and the number of farming operations (Holland, 2004; Sánchez-Girón, Serrano, Hernánz, Navarrete, 2004; Triplet & Dick, 2008; Singh, Prakash, Srinivas, Srivastva, 2008).

Guide assistance (GA) systems that allow a more efficient and homogeneous work and optimize the farming operations (Perez-Ruiz, Slaughter, Gliever, Upadhyaya, 2012; Vellidis et al., 2013) produce a reduction of the overlaps and consequently a decrease of the use of agricultural inputs (Aernhammer, 2001; Borch, 2007).

However, the change of soil management system, not only could produce variation in the yield, but also increased some inputs costs, as herbicides (Sánchez-Girón et al., 2007). So the aim of this work is: 1) Study the yield variation of arable crops managed with NT and conventional tillage (CT) in rainfed conditions. 2) Study the reduction in the operational time and crop variable costs that NT & GA could bring respect CT.

2. Materials and methods

The Mediterranean region, where the study area is located, corresponds to a xeric moisture regime, according to the standards established by the Soil Taxonomy (USDA, 1998). The temperature regime is termic, and the climate has two opposite periods: one cold and wet during the fall and winter, and another warm and dry during spring and summer. During the last one the crops suffer an important water deficit. Furthermore, the precipitations are quite variable throughout the year and between them.

This work belongs to a European project, Life + Agricarbon, and it shows the results of four seasons carried out in three representative rainfed farms of the Andalusian countryside: Cordoba (Field 1), 37º 55’ 50’’ N 4º 43’ 07’’ W; Carmona (Field 2), 37º 25’ 31” N 5º 38’ 01’’ W and Las Cabezas de San Juan (Field 3) 36º 56’ 37’’ N 5º 55’ 13’’ W, both of them in the province of Seville, figure 1.

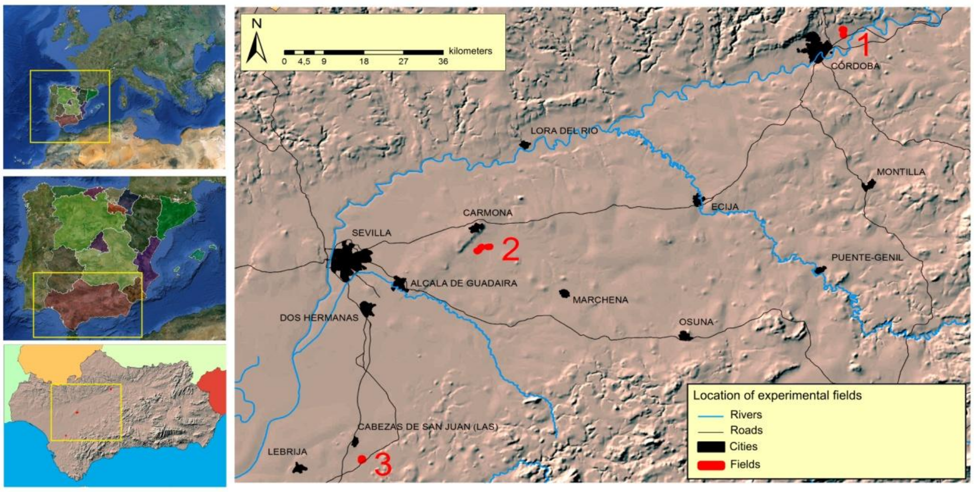

Figure 1: Location of the experimental fields.

The physical and chemical characteristics of the experimental fields appear summarized in Table 1.

Table 1: Physical and chemical characteristics of the different experimental fields. N: nitrogen; OM: organic matter; CO_3^-: carbonates; pH in calcium chloride; CEC: cation exchange capacity; K: potassium; P: phosphorus; S: sand; L: lime; C: clay; Text: texture; F-A; clay-loamy; A: clayey

Field	Depht (cm)	N (%)	OM (%)	CO_3 (%)	pH Cl_2Ca	CEC	K (ppm)	P(ppm)	S (%)	L (%)	C (%)	Text.
1	0-20	0.10±0.03	2.9±0.6	11±9	7.2±0.5	24±10	263±96	13±17	31±13	32,±5	37±12	F-A
	20-40	0.07±0.03	2.3±0.7	13±10	7.2±0.6	27±12	189±72	11±11	31±14	31±5	38±12	F-A
	40-60	0.05±0.02	1.8±0.6	16±15	7.3±0.6	27±12	162±62	8±8	28±14	31±7	41±11	A
2	0-20	0.12±0.02	1.6±0.4	4±2	7.7±0.1	34±8	407±119	30±12	20±5	29±3	51±5	A
	20-40	0.11±0.02	1.4±0.3	5±2	7.7±0.1	35±9	321±93	23±11	19±5	28±2	53±4	A
	40-60	0,10±0.02	1.2±0.3	6±2	7,7±0.1	34±10	261±98	17±10	19±5	28±3	53±5	A
3	0-20	0.12±0.05	1.9±0.4	11±8	7.8±0.1	34±11	590±146	17±7	16±4	26±4	58±6	A
	20-40	0.11±0.02	1.8±0.3	11±8	7.8±0.1	34±12	512±124	14±6	16±4	25±4	59±6	A
	40-60	0.10±0.02	1.6±0.3	12±8	7.8±0.1	35±12	485±139	15±7	17±5	26±6	57±7	A

The project was based on the establishment of a network of three pilot farms. In ach experimental field 30 hectares of rainfed arable crops were cultivated under two soil management systems (CT and NT supported by GA). Trials, in each management system, had a typical crop rotation of the Andalusian countryside: winter wheat, sunflower and legume. Agronomically, farms were conducted according to the landowners' guidelines.

Different parameters on the mechanized operations made in each crop and management system were logged using a remotely data acquisition system. The indicators studied in each operation were: time duration (1); working surface (1); average speed (1); work capacity (1); overlap (1); fuel consumption (2) and position of the tractor rear hitch (3). To this end, one tractor in each farm was instrumented with different technology: 1) gps model GM-48 UB Sanav; 2) flow gauging model AIC-4008 Veritas y 3) potenciometer model JX-PA-30-N14-21S Unimeasure, figure 2. Furthermore, in the fiar operations with precision agriculture the tractor was equipped with a guide assistance bar model AgGPS EZ-Guide 500 Trimble for the operations of fertilization and spraying, and an Autopilot Trimble for the seeding. As data acquisition system a data logger was used (Datataker (DT 85)). The stored information about the operation was transmitted via GPRS modem to a PC. Moreover, the crop production was monitored with a crop yield monitor Ceres 8000i RDS.

As a complement, the incidents occurred during the work and other aspects such as dose of inputs (seeds and agrochemicals) were noted or reported. From these data, using specific software "Reporter Life" developed in Basic language for this project, we studied each individual farm operation, determining the different indicators in the two systems analyzed.

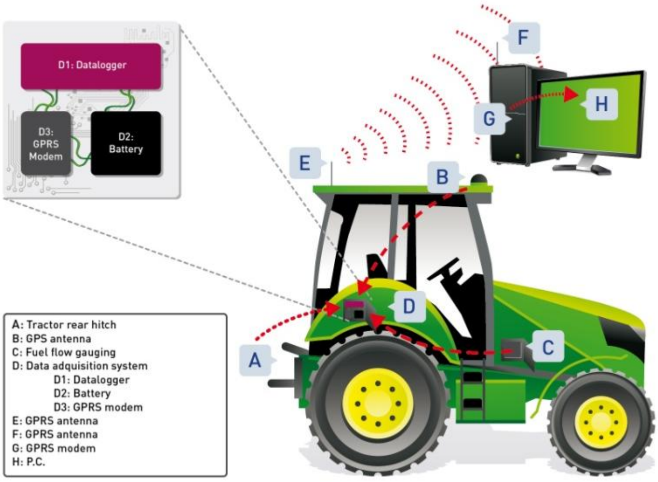

Figure 2: Scheme of the instrumentation installed in the tractor.

The variable costs of the crops were studied for each season. They were divided in the price that farmers paid for the farming operations, seeds, agrochemicals and fertilizers used each year in the farms.

The statistical analysis of the data was developed with the software Statistix 8.0, Tallahassee, USA. The Tukey test was used to make the comparisons of means using a significance value (p) ≤ 0.05.

3. Results and Discussions

During the four years of study, the crops implanted in the different experimental fields varied in function of the decision of the farmers and climate conditions. Table 2 summarized the diverse winter cereals and legumes seeded in them. In all the experimental fields and seasons, the sunflower was included in the rotation.

Table 2: Cereals and legumes implanted. Seasons 2009 to 2013.

	Field 1		**Field 2**		**Field 3**	
	Cereal	**Legume**	**Cereal**	**Legume**	**Cereal**	**Legume**
Season 2009/10	2	4	1	3	2	4
Season 2010/11	1	3	-	3	2	4
Season 2011/12	1	3	2	3	2	5
Season 2012/13	2	3	-	-	2	5

1: Flour wheat (*Triticum aestivum*); **2**: Durum wheat (*Triticum durum*); **3**: Bean (*Vicia faba*); **4:** Chikpea (*Cicer arietinum*); **5**: Pea (*Pisum sativum*)

The weather conditions were variable during the study period. The first, second and fourth years were extremely wet, with an annual precipitation around to 1000 mm, nearly the double of the average of the region (Andalusian Government, 2014). The second one was very dry with an accumulated rainfall around 300 mm. This situation produced a high variation in the crops production not only between years, but also between experimental fields and soil management systems. However, for each crop the average annual yield was quite similar for to the two systems studied, CT and NT & GA, figure 3. No significant differences were found in any crop.

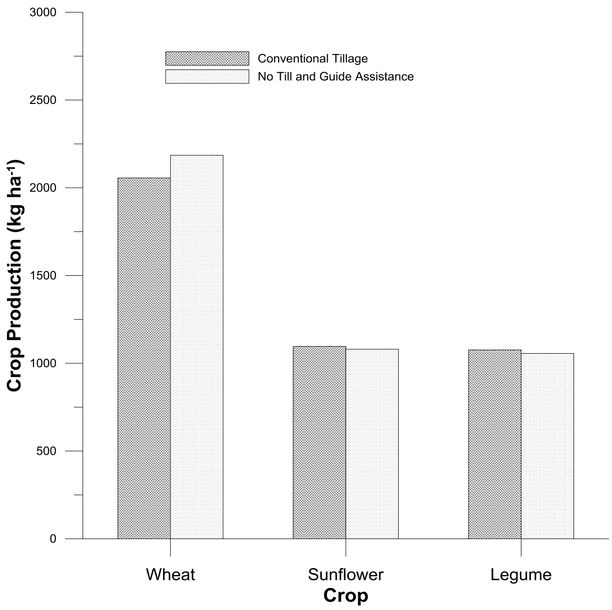

Figure 3: Average annual production of the different crops studied. Seasons 2009 to 2013.

The farming operations varied in function of crops, experimental fields and years. They were made depending on the crop necessities, the weather conditions and the usual practices of the area. The higher consumptions were found in the deep tillage (Moldboard, 22.5 l ha^{-1} and Chissel, 14.1 l ha^{-1}), table 3. The fuel consumption in the NT seeder was higher than in the CT. The reason was that the weight of the machinery used in NT was more than the double respect to the CT. It seems to be a high correlation between the fuel consumption and the operational time. The sprayer and spreader operations showed a higher overlap under CT, due to they did not use guide bar. The bigger overlap appeared for the disk harrow, 35.1 %. The most common operation was sprayer in NT. Because of the conservative systems used a slightly higher amount of herbicide to kill weeds, instead of tillage (Kassam et al., 2012).

Table 3: Fuel consumption, overlap, operational time and number of times that the different farming operations studied had been used. Seasons 2009 to 2013.

Operation	Fuel (l ha^{-1})	Overlap (%)	Operational time (h ha^{-1})	Costs (€ ha^{-1})	n
Moldboard	22.5 ± 4.1	16.2 ± 3.7	2.5 ± 0.6	53	5
Chissel	14.1 ± 0.8	16.2 ± 11.6	0.7 ± 0.3	28	11
Disk harrrow	7.7 ± 1.1	35.1 ± 7.8	0.4 ± 0.1	23	31
Semichissel	6.7 ± 3.1	4.7 ± 1.3	0.4 ± 0.1	25	9
Scarifier	6.4 ± 1.5	6.4 ± 2.0	0.7 ± 0.1	25	12
Cultivator	6.1 ± 1.2	12.5 ± 11.3	0.4 ± 0.1	20	32
Seeder NT	7.7 ± 1.0	5.5 ± 5.9	0.5 ± 0.1	50 y 20*1	32
Seeder CT	6.0 ± 1.6	8.4 ± 7.0	0.5 ± 0.1	30 y 20*2	32
Sprayer NT	1.1 ± 0.3	7.4 ± 7.2	0.1 ± 0.0	9	89
Sprayer CT	1.1 ± 0.4	12.7 ± 9.7	0.1 ± 0.0	9	60
Spreader NT	0.9 ± 0.4	5.5 ± 3.6	0.1 ± 0.0	8	38
Spreader CT	0.9 ± 0.5	14.7 ± 9.7	0.1 ± 0.0	8	33
Harvester NT	11.4 ± 0.9	0	0.5 ± 0.1	50	32
Harvester LC	10.0 ± 0.7	0	0.5 ± 0.1	50	32
Baler	5.2 ± 0.2	0	0.5 ± 0.0	0	16
Compactor roler	1.7 ± 0.2	0	0.2 ± 0.0	13	25

NT: No tillage; **CT:** Conventional tillage; **n:** number of times used. ***1**: 50 € for cereal and legume and 20 for sunflower. ***2**: 30 € for cereal and legume and 20 for sunflower.

Regarding to the total fuel consumption in the different crops, figure 4 shows that NT always brought a large decrease in all cases. The average reduction in wheat was 51.6 %, 52.9 % for sunflower and 55.7 % in legume. It represents a decrease in fuel consumption of 25.7 l ha^{-1}, 24.9 l ha^{-1} and 28.5 l ha^{-1} respectively, which corresponded to a save of 79.1 l ha^{-1} in the whole rotation. These results are comparable with other studies carried out in similar conditions in Spain (Hernanz, Girón, Cerisola, 1995; Moreno, Lacasta, Meco, Moreno, 2011).

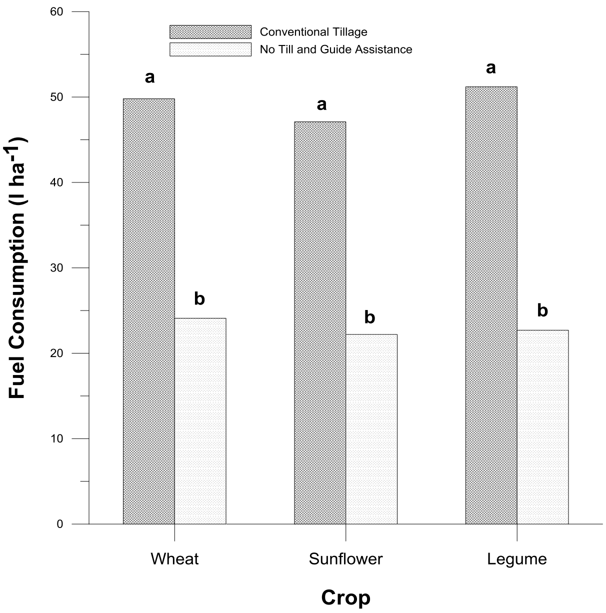

Figure 4: Average annual fuel consumption of the different crops studied. Seasons 2009 to 2013. Different letters show significant differences for the Tukey test, p ≤ 0.05.

Table 4, which summarized the average annual variable costs of the crops, shows how NT & GA always brought an important reduction of the total variable costs respect to CT: 9.2 % for wheat, 18.7 % for sun-flower and 15.4 % for legumes. Sunflower and legume showed significant differences. Although these reductions were lower than obtained by Hernánz, Girón & Cerisola (1995) in similar conditions. In all the crops, the farming operations suffered an important reduction of its variable costs for NT & GA, due to the suppression of the soil tillage. However, NT increased the costs of herbicides in 11.7 € ha^{-1} for wheat, 15.0 € ha^{-1} for sunflower and 3.6 € ha^{-1} for legumes. These data are slightly higher than those obtained by Sánchez-Girón, Serrano, Suárez, Hernanz & Navarrete (2007) in Spain for semiarid conditions in rainfed arable crops. The costs of seeds and fertilizers were lower for the sustainable combination, owing to the reduction of the overlaps of the farming operations that GA systems brought.

Table 4: Average annual farming variable costs of the different crops studied. Seasons 2009 to 2013.

		Costs (€ ha^{-1})				
Crop	**Tillage system**	**Farming operations**	**Seeds**	**Agrochemicals**	**Fertilizers**	**Total**
Wheat	**NT & GA**	144,3 b	98,3 a	108,4 a	215,8 a	**566,8 a**
	CT	184,0 a	101,8 a	96,7 a	243,8 a	**626,4 a**
Sunflower	**NT & GA**	93,4 b	86,3 a	66,2 a	17,0 a	**263,0 b**
	CT	177,9 a	88,7 a	51,2 a	17,8 a	**335,6 a**
Legume	**NT & GA**	115,4 b	126,3 a	61,2 a	37,1 a	**340,0 b**
	CT	178,1 a	127,4 a	57,6 a	38,8 a	**402,0 a**

NT: No tillage; **GA**: Guide assistance; **CT**: Conventional tillage. Different letters show significant differences in rows for each crop.

For wheat, GA was responsible of the 53.0 % of the total costs reduction and NT of the 47.0 %, due to a higher use of fertilizers in these crops. However, for the sunflower and legumes the results were opposite. The suppression of the tillage was the main parameter in the economic saving. For sunflower NT was responsible of the 95.6 % of the total reduction and for legume of the 95.5 %.

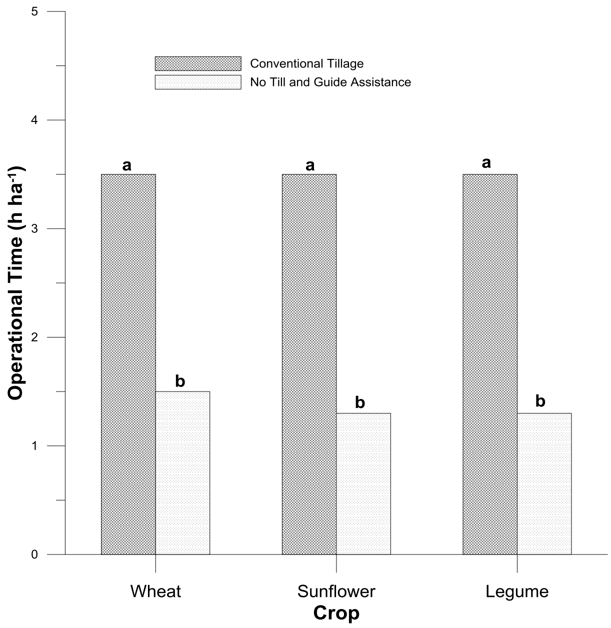

Figure 5: Average annual operational times of the different crops studied. Seasons 2009 to 2013. Different letters show significant differences for the Tukey test, $p \leq 0.05$.

Not only NT & GA brought an important economic saving respect to CT, but also produced a significant reduction of the operational times for cultivating the crops. Figure 5 shows how the farmers spent 3.5 h ha^{-1} in the whole year to cultivate wheat under CT. However, with NT & GA they spent 1.5 h ha^{-1}, a reduction of 57.8 %. For sunflower and legumes the decrease was higher, obtaining an operational times saving of 62.8 % for both crops. All the crops showed significant differences.

4. Conclusions

Results show how there was no significant differences in the average yield of crops cultivated under the different soil management systems. Furthermore, NT & GA, approximately reduced the variable costs of the wheat production in 58 € ha^{-1} (9.2 %), 73 € ha^{-1} for sunflower (21.6 %), and 62 € ha^{-1} for legume (15.4 %). This decrease was related to the reduction in the fuel consumption contributed by the NT (53 %) and the overlap of the seeding (5.5 % respect 8.4 %), spraying (7.4 % respect 11.7 %) and fertilization (5.5 % respect 14.7 %) contributed by GA. For wheat GA contributed to the 53 % of the total economic saving. However in sunflower and legumes the results were opposite and NT produced the 95.6 % and 95.5 % of the total saving respectively. Furthermore, the average operational times were decreased in a 57.8 % for wheat and 62.8 % for sunflower and legumes. According to the results, the farmers not only saved money by applying NT & GA, but also reduced the operational times. So, they could spend less hour in the tractor or they could cultivated more surface, improving their economy.

5. Acknowledgements

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