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Conservation Agriculture and Precision Agriculture as a Method to Reduce Energy Consumption in Agricultural Systems

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Abstract: Climate change (CC) is caused by the increasing concentration of six greenhouse gases. Many studies show how human actions affect CC. Particularly, Carbon dioxide (CO_2), which comes from burning fossil fuels, is the gas that has higher concentration in the atmosphere. Agriculture is the third human activity in the amount of CO_2 emissions, so actions that reduce the energy consumption in this sector are very interesting. Conservation agriculture (CA), based in the reduction and/or suppression of tillage, and precision agriculture (PA) that allows a more efficient field work, both reduce fuel and input consumption.This work belongs to a European project, Life+ Agricarbon, and it shows the results of one year survey campaign carried out in three farms in southern Spain. In total, 6 experimental fields in each farm. three under conservation agriculture (CA) together with precision agriculture (PA) and three under conventional tillage. Through the instrumentalisation of the machinery used, it is possible to remotely know the fuel consumption and working capacity of each system. In addition, it is feasible to obtain yield maps of crops and other indicators. Results show the significant decrease in the energy consumption with CA system combined with PA, although it is important to remark that the results may vary depending of the crop studied and the different field tasks done on each farm.
Key words: Energy saving, conservation agriculture, precision agriculture, climate change

INTRODUCTION

Kyoto protocol is an international agreement about climate change signed in 1997 by most of the world countries, although some key countries as the USA did not sign the agreement. The objective is to reduce the concentration of the gases causing gases: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), Hydrofluorocarbons (HFC), perfluorocarbons (PFC) and sulfur hexafluoride (SF_6). The world reduction percentage will be about 5% during the period 2008-2012, referred to the emissions of the 1990. However, this copromise is not common for all the countries. For example, Spain could increase its emmision by 15 %. Unfortunately for Spain, its emissions have risen over a 40% respect to the reference year, 1990 (MARM, 2009). Andalusia is the largest emitter, summing a 15% of the global emission of the whole country (MMA, 2007).

Agriculture is the third human action emitting global warming gasses, with a 13.5% of the total (8Gt) (Mckibben, 2007). Mainly they come from the burning of petroleum products, used for running different agricultural machines or to synthesize various agrochemicals.

Andalusia is located in the south of Spain and it is the main agricultural region of the country. Rainfed herbaceous crops represent 38% of its total agricultural area, 3.594.119 ha (MARM, 2010). Therefore, actions that could reduce the agricultural energy consumption, would be very interesting to implement due to the largerelated area.

No tillage (NT), a practise included in CA reduces significantly the fuel consumption because of the supresion of tillage (Álvaro-Fuentes et al., 2010; Triplet and Warren, 2008; Hernanz, 2005). If we combine CA with PA, the energy saving increases respect to conventional tillage (Jat et al., 2009; Bertocco et al., 2008; Auernhammer, 2001), because of the drastic reduction of overlaps and the possibility of applying variable distribution of inputs. That situation also reduces the costs for the farmers (Sánchez-Girón et al., 2007).

The objective of this paper is to verify and quantify the energy savings due to the sinergy between NT and PA can provide respect the CT in a typical crop rotation of the andalusian countryside.

MATERIALS and METHOD

The Mediterranean zone, where is the study area, corresponds to a xeric moisture regime, according to standards established by the Soil Taxonomy (USDA, 1998). The climate has two opposite periods: one cold and wet during the fall and winter, and another warm and dry during spring and summer. In the latter, the crops suffer an important water deficit. The temperature regime is termic. The precipitations are very variable during the year and between years, see Figure 1.

This work belongs to a European project, Life+ Agricarbon, and it shows the results of one year survey campaign carried out in three representative farms of the andalusian countryside: Cordoba (Field 1), 37º 55′ 50.4″ N 4º 43′ 07.7″ W; Carmona (Field 2), 37º 25′ 31.0 N 5º 38′ 01.2″ W and Las Cabezas de San Juan (Field 3) 36º 56′ 37.8″ N 5º 55′ 13.6″ W, both of them in the province of Seville. The physical and chemical characteristics of the fields appear represented in Table 1.

Table 1. Physical and chemical characteristics of the different fields. N: nitrogen; OM: organic matter; CO3-: 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: clayly

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

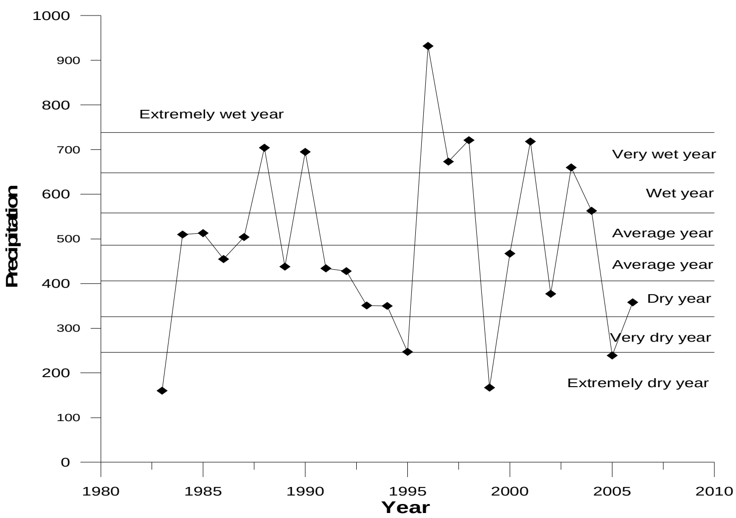

Figure 1. Evolution of precipitation in Carmona. Year 1983-2006

The project is based on the establishment of a network of three pilot farms, working 90 hectares of herbaceous crops under two soil management systems (conventional tillage vs. CA supported by PA). Trials, in each management system, have a typical crop rotation of the Andalusian countryside: winter wheat, sunflower and legume. The crops sowed in the experimental fields were: Durum wheat (Triticum durum) and Sunflower (Helianthus annuus) in the 3 farms and chickpea (Cicer arietinum) in farm 1 and 3, and bean (Vicia faba) in farm 2. Agronomically, farms are conducted according to the landowners' guidelines.

Remotely, as explained below, we study different parameters of the diverse operations make in every crop and management system. The indicators studied in every operation are: time duration (1); working surface (1); average speed (1); real work capacity (1); theoric work capacity (1), overlap (1); fuel consumption (2) and position of the tractor rear hitch (3). To this end, we have implemented 3 tractors (one for each farm), 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. Furthermore, in the treatments under PA the tractor have installed a helps guide bar model model AgGPS EZ-Guide 500 Trimble. As data acquisition system is used a data Taker (DT 85). It is a programable machine with capacity to interpret and store 48 different signals, as analogics, as digitals. The storage information about the operation is transmited via modem to a PC with necessary software. Moreover, complementary to all information adquired, the crop production was monitorized with a crop yield monitor, Ceres 8000i RDS. The yield maps were obtained using the program Farm Works version 2010.1.433.

As a complement, were noted or reported the incidents occurring during the work and other aspects such as dose of inputs (seeds and agrochemicals). From these data, using a specific software "Reporter Life" developed in Basic language for this project, we study each separate operation finally determining the energy associated with their own work and consumption of agricultural inputs in the two systems analyzed.

The methology used in the energy analysis is the proposed by the International Federation of Institutes for Advanced Studies (IFIAS) in 1973. It associates the amount of non renewable energy to each of the factor of a process (Hernanz, 2005). It defines two types of energy: **direct-use energy**; related to the use of fuel, and **indirect-use energy**; related to manufacture and maintenance of mechanical equipment, fertilizers, seeds and agrochemicals.

This analysis considers two main parameters: **Energy Eficiency (EE)**. It is defined as the ratio of the heat energy contained in the final product and the required to develop the product. **Energy Productivity (EP)**. It is defined as the amount of product produced (kg/ha) per unit of energy supplied (Mj/ha).

RESULTS and DISCUSSION

The precipitations registrated during the campaign 2009-10 wery extremely large, see Figure 2. The rainfalls measured in field 1 were 1.061 mm, 913mm for 2 and 773 mm for 3, well above average for the region, that is 470 mm.

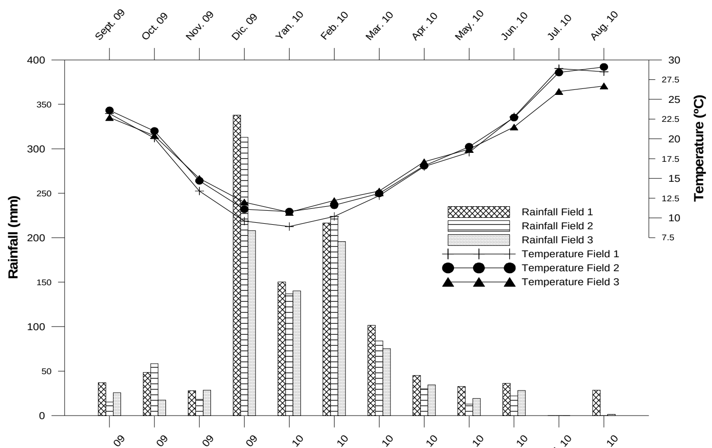

Figure 2. Evolution of precipitation and temperature in experimental fields. Campaign 2009-10

The crops sowed in the experimental fields were: Durum wheat (Triticum durum) and Sunflower (Helianthus annuus) in the 3 fields and chickpea (Cicer arietinum) in field 1 and 3, and bean (Vicia faba) in field 2. The large winter precipitation made spoiled the winter crops, wheat and bean. In most of the fields the harvest was under the average of the region (CAP, 2011), see Table 2. On the other hand, the production of the spring crops, sunflower and chickpea, were near the average, except in field 1 where the legume suffered many deseases and it could not be harvested.

Table 2. Crop Production (kg/ha) in experimental fields. Campaign 2009-10

	Field 1		Field 2		Field 3	
	NT	CT	NT	CT	NT	CT
Wheat	727	680	2.620	2.972	1.037	1.024
Sunflower	1.345	1.512	1.312	1.140	1.332	1.292
Legume	-	-	492	1.282	2.058	1.446

The operations varied in function of the crop, and the experimental field. For example, Table 3 represents the different tillage, fertilizers and phyto-sanitary used in the field 3.

Table 3. Different machinery used, fertilisers and herbicide

		Wheat		Sunflower		Legume	
		NT	CT	NT	CT	NT	CT
Machinery (number of times)	Chisel	1	-	-	1	-	1
	Disk harrrow	2	-	-	2	-	2
	Cultivator	1	-	-	-	-	2
	Seeder	1	1	1	1	1	1
	Sprayer	2	3	2	1	3	2
	Spreader	2	2	-	-	-	-
	Harvester	1	1	1	1	1	1
Fertiliser (kg/ha used)	Nitrogene	148	148	-	-	-	-
	Phosphate	60	60	-	-	-	-
	Potasium	-	-	-	-	-	-
Phyto-sanitary (l/ha used)	Glyphosate	1,5	-	1,5	-	5,5	4
	CP+CM	0,5	0,5	-	-	-	-
	A+ID	0,3	0,3	-	-	-	-
	Tribenuron Metil	1	1	0,04	0,04	-	-
	Clortalonil	-	-	-	-	2	2

The direct-use energy is calculated multiplying the fuel consumption by 38.6 MJ/l; this value is calculated with the lower heating value of fuel (46.000 kJ/kg) and its density (δ = 0.84 kg/L). The results in average fuel consumption and overlaps are represented in table 4.

Table 4. Average fuel consumption and overlap in the different operations studied

Operation	Fuel consumption (l/ha)	Overlap
Moldboard	22.5±4.1	16.2±3.7
Chissel	14.4±0.4	12.0±8.1
Semichissel	6.7±3.1	4.7±1.3
Disk harrrow	7.6±1.4	26.2±14.3
Cultivator	5.6±0.8	11.7±1.5
Seeder NT	7.1±1.3	4.7
Seeder CT	5.9±1.2	13.2
Sprayer	1.2±0.4	14.6±1.5
Spreader	1.7±0.3	12.1±1.4
Harvester	10.5±0.7	-

The fuel consumption results are similar to obtained by Green (1987). The higher consumptions are found in the deep tillage (Moldboard and Chissel). The fuel consumption in the NT seeder was higher than the CT, due to that the weight of the machinery in most of the occasions was more than the double.

Regarding the total fuel consumption in different crops and experimental farms; Figure 3 shows that NT always brings a large decrease in all cases. The higher reduction was found in the legume crop of the exrimental field 3 (63.2%) and the lower in the wheat of the field 2 (26.2%). The average reduction in wheat was 46.6% and in sunflower and legume 52.9%. It represents a decrease in fuel consumption of 25.3 l/ha, 26.8 l/ha and 26.2 l/ha respectively, corresponding a save of 78.3 l/ha in the whole rotation. These results are slightly lower than those obtained by Perea and Gil (2006) in similar conditions of the Andalusian countryside with wheat-sunflower rotation, due to a greater intensity in the primary tillage.

Table 5 represents the energy produced by the harvest of the crops and the energy used during their life cycle. Not only the wheat is the crop with higher energy production, but also has the higher energy consumption, due to a high need of nitrogen fertilizers (Safa et al., 2011). These kind of products need a lot of energy for their manufacturing. It

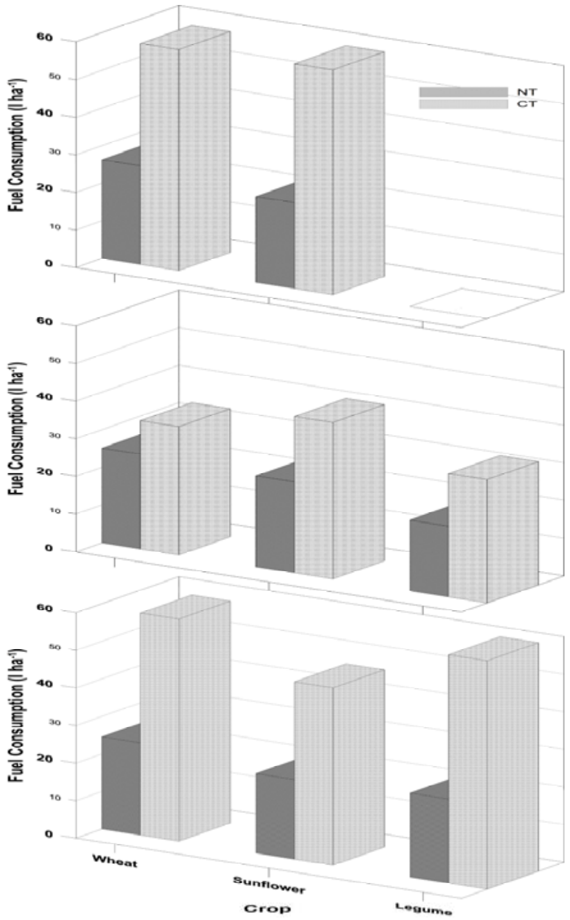

Figure 3. Crop production in the different experimental fields. 1 up, 2 medium and 3 bellow

means between 60 to 80% of the total energy consumed by the crop. These data are slighty higher than those measured by Hernanz et al. (1995) in similar conditions. In the sunflower and legume the use of fertilizers is not so common, so the energy is lower. The great reduction of the energy use in the crops appear for the sunflower in the field 3, 43,5%. Anyway, the average reduction for the crops is not so big, but it is also important anyhow. The average reduction in wheat was 13,7%, 24,9% for sunflower and 15,6% for legume. In all ocasions, except for the legume in field 3, EE and EP resulted in highest levels for the NT.

Figure 4 shows that exist important differences in the crops production between the different places of the field.

Table 5. Energy production and consumption (MJ ha^{-1}) and the energy efficiency (EE) and energy productivity (EP)

				Energy consume							
				Direct energy	Undirect Energy						
Field	Crop	Tillage system	Energy produce		Machinery	Seeds	Fertilicers	Agrochemicals	Total	EE	EP
1	Wheat	NT	14950	1257	316	2940	8918	997	14428	1,04	0,08
		CT	11200	2805	704	2940	9642	406	16497	0,68	0,05
	Sunflower	NT	18904	1094	275	84	1688	1179	4320	4,38	0,31
		CT	20989	2853	716	84	1892	9	5554	3,78	0,27
	Legume	NT	-	-	-	-	-	-	-	-	-
		CT	-	-	-	-	-	-	-	-	-
2	Wheat	NT	21313	1199	301	3454	16317	302	21573	0,99	0,08
		CT	18750	1625	408	3454	18291	346	24124	0,78	0,06
	Sunflower	NT	13358	1152	289	84	2451	1299	5275	2,53	0,18
		CT	12913	1983	498	84	2748	493	5806	2,22	0,16
	Legume	NT	18696	898	226	2357	348	339	4168	4,49	0,39
		CT	15960	1562	392	2726	431	388	5499	2,90	0,25
3	Wheat	NT	45750	1175	295	3234	11240	701	16645	2,75	0,22
		CT	43875	2824	709	3234	12880	681	20328	2,16	0,17
	Sunflower	NT	10230	1013	254	84	0	298	1649	6,20	0,45
		CT	9619	2255	566	84	0	16	2921	3,29	0,24
	Legume	NT	5016	1070	269	1704	0	3705	6748	0,74	0,07
		CT	11799	2905	730	1704	0	1960	7299	1,62	0,14

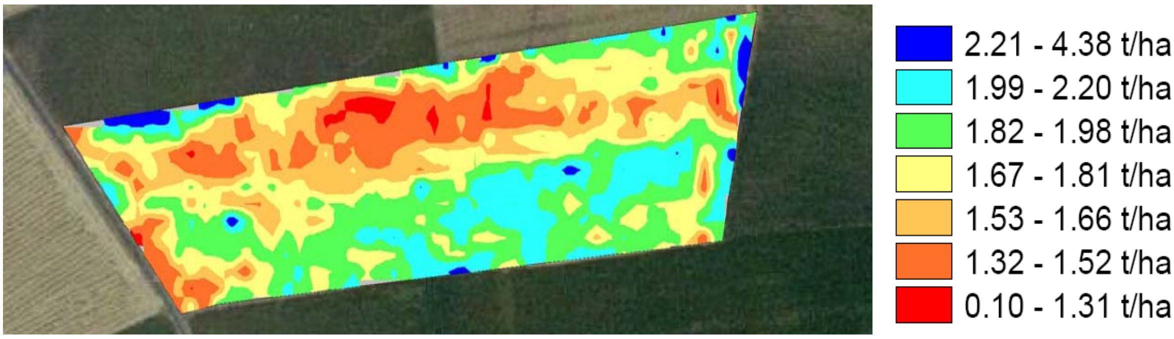

Figure 4. Harvest map of the wheat crop in field 2

CONCLUSIONS

Results show how the combination between CA and PA is a good way to obtain at least average zone yields, reduce fuel consumption in more than 45 % in all crops studied, and energy use between a 13% to a 25%. Another conclusion is that PA is a good way to reduce energy consumption by programming site-especific fertilization. Indeed, that is the next objective of the project.

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