Land Use Policy 68 (2017) 326–333

Contents lists available at ScienceDirect

Land Use Policy

journal homepage: www.elsevier.com/locate/landusepol

A comparative multidimensional evaluation of conservation agriculture systems: A case study from a Mediterranean area of Southern Italy

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ARTICLE INFO

Keywords:
Conservation agriculture systems
Sustainable development
Viable Mediterranean agriculture
Economic assessment

ABSTRACT

To avoid the current paradoxes of the global agro-food system it is necessary to define and implement a viable agricultural sustainable model, combining satisfaction of food needs and land preservation. A possible solution can be found in a holistic production system consistent with a sustainable development model, designed to satisfy diverse "local" economies. The conservation agriculture (CA) could be a part of this model, as it includes a set of best practices available to preserve agrarian soil and its biodiversity. Briefly, we cover the CA background in Europe followed by the evaluation of its impact in terms of private/public interest, using the sustainability's metric.

To test the viability of a model based on CA in "local conditions", we compare economic performance of different conservation practices (i.e. minimum and no tillage) to that of conventional agriculture in a typical Mediterranean environment – Collina Materana – in Southern Italy (Basilicata region). Our findings suggest that: i) CA can actually be a viable alternative to conventional systems; ii) in Mediterranean agricultural areas CA has yield advantages especially during dry years, when conservation techniques increase water supply to crops; iii) public support is needed to direct farming choices in fact without financial incentives these practices would be not widely accepted and diffused; iv) European policy makers have to recognized the positive benefits of CA and pay them as ecosystem services in the framework of Good Agricultural Environmental Conditions and the present CAP subsidies.

1. Introduction

Global agro-food outlook has been recently reshaped by two landmark agreements, i.e. the Sustainable Development Goals (in 2012) and the Paris Climate Change Agreement (in November 2015). The challenge is hunger eradication and fair exploitation of terrestrial ecosystems keeping global warming below 2 °C by 2030.

Human activity has been the dominant cause of observed warming since the mid-20th century. The last Intergovernmental Panel on Climate Change assessment report confirmed that each of the last three decades has been successively warmer at the earth's surface than any preceding decade since 1850 (IPCC, 2014).

In the near future, this trend can be slowed only if a more sustainable growth path is undertaken.

The adoption of soil conservation practices is one of the tools that the European farmers could exploit to implement mitigation climate change policies, while achieving environmental, social and economic benefits.

During the last decade, the Food and Agriculture Organization (FAO) and the European Conservation Agriculture Federation (ECAF) have been developing and promoting techniques that allow to conserve agrarian soil and its biodiversity, in the context of sustainable agriculture; the set of best practices developed in this field is known as "*conservation agriculture*" (CA).

The roots of this production approach have to be found in the USA – in the 1930s – to combat soil desertification caused by wind and water erosion (Holland, 2004).

Conservation agriculture is defined by ECAF "as a sustainable agriculture production system comprising a set of farming practices adapted to the requirements of crops and local conditions of each

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http://dx.doi.org/10.1016/j.landusepol.2017.07.034
Received 5 October 2016; Received in revised form 13 July 2017; Accepted 18 July 2017

region, whose farming and soil management techniques protect the soil from erosion and degradation, improve its quality and biodiversity, and contribute to the preservation of the natural resources, water and air, while optimizing yields".

Conservation agriculture was introduced by the FAO (2008) as a concept for resource-efficient agricultural crop production based on integrated management of soil, water, and biological resources combined with external inputs (Reicosky, 2015).

Later, a set of soil-crop-nutrient-water-landscape system management practices that are the core of CA was included in the paradigm of "sustainable production intensification", proposed by FAO in 2011.

In recent years, awareness has grown that CA can play a significant role in achieving the main objectives of common agricultural policy revision (CAP 2020). The reform requires a production process that respects the environment and uses available knowledge and technology to optimize current production, while preserving natural resources to the benefit of the future generations. This approach mainly relies on the application of a realistic sustainable agriculture model combined with CA practices based on minimal soil disturbance, permanent soil cover and crop diversity (ECAF, 2013).

Past studies about the adoption of conservation agriculture in Europe have been mainly focused on: *i)* the results achieved from the agronomic and soil point of view and *ii)* the related economic advantage − i.e. the reduction in production costs (e.g. less labour hours, less chemicals, less fuels) compared with any yield reduction.

From our point of view, to improve the evaluation of CA as a sustainable production system the analysis should include: a) the whole of the economic and environmental aspects and their effects on social welfare; b) the impact level on the private vs. the public interest.

It is therefore necessary to evaluate not only the effects of the adoption CA in terms of the balance between costs and benefits but also their impact with respect to the private and the public interest.

Given this scenario analysis our study proposes: an update on information about the CA in Europe and the impact of its adoption – in terms of costs and benefits – with respect to sustainability dimensions, impact levels on private and public interest and area of incidence (Section 2); a comparative economic assessment of wheat production with different conservation tillage practices, in Collina Materana, in Basilicata region (Southern Italy) – where is produced high quality durum wheat (Section 3); in the final part of the study are given political intervention considerations for CAP future perspectives as well as are proposed suggestions for future researches (Section 4).

2. Conservation agriculture and its contribution to sustainable development in Europe

2.1. Conservation agriculture in Europe: background

Conservation agriculture production systems are used throughout the world. At present, the total area under CA is estimated around 157 Mha – mainly in North and South America (around 76.6% of the worldwide CA area) – corresponding to about 11% of field cropland (FAO, 2016).

There are currently over 7 Mha of arable cropland under CA system in Europe, – corresponding to about 4.4% of the worldwide CA area – mainly located in Russian Federation (around 64% of the total European CA area), followed by Spain (11.3%), Ukraine (10%) and Italy (5.4%) (FAO, 2016).

Various studies have reported (Bash et al., 2015; Kertész and Madarász, 2014; Friedrich et al., 2012) that the worldwide adoption of CA systems has increased at an average rate exceeding 7 Mha/yr, compared to the past millennium, and at the rate of some 10 Mha/yr since 2008/2009 (Kassam et al., 2015). Comparing the previous decades, Europe is one of the areas in which CA has a faster adoption rate also as a result of the reinforced technical role of the ECAF, which brings together fourteen national associations promoting – among Europe's farmers – CA soil management "best practice" aspects and the preservation of biodiversity of agrarian soil in the context of sustainable agriculture.

In Europe, the first attempt towards CA in the form of no-tillage was done in the UK in 1955, followed in the '60 s by the Netherlands, Germany, Belgium, Switzerland and Italy. France experienced CA in 1970, while Spain and Portugal in the early '80s. In most countries, the use of conservation tillage practices was driven by research institutions, while in Denmark and Finland the adoption process was farmer-driven (Basch et al., 2015). Finland is the EU country with the highest rate of CA of arable land (almost 9%). Here successful farmer-driven adoption has been sustained by the combined effort of an intensive research programme and a knowledge transfer process (Soane et al., 2012).

2.2. Impact of conservation agriculture on sustainable development in Europe

Until the end of last century, the adoption of CA in Europe was generally very low and mainly based on reduced tillage (minimum and/or zero tillage) practices. One of the reasons was the perceived economic loss due to the decrease in production in the short run.

The substantial change of CA from a collection of conservation tillage methods to an integrated production approach is marked by a report released by FAO in 2001, emphasizing the need of a novel approach to agriculture production, geared to a better use of agricultural resources, compared to conventional agriculture; this approach is based on the integrated management of available soil, water and biological resources such that external inputs could be minimised (Knowler and Bradshaw, 2007). The technical core of this approach was found in CA practices based on the maintenance of a permanent/semi-permanent cover which protects soils from natural events and creates a biotic community that provides biological tillage playing the same functions as conventional tillage (FAO, 2001).

Basically, the results of different soil management practices had been previously analysed as an individual farmer's choice evaluating the private profitability of a pure soil tillage system rather than the potential public benefits from the improvement of the whole system. Moreover, this integrated approach allows assessing the results of the CA not only with respect to yield results but also with respect to the reduction of costs and the long run impact on the environment.

Table 1 shows the benefits and costs of the adoption of CA, as emerging from an extended review and synthesis of recent researches (FAO 2001; ECAF 2013). For each benefit/cost, the sustainability dimension (i.e. economic, environmental and social, as in the Brundtland Commission Report, 1987) has been indicated, as well as the scope and sign of its impact, both at geographical level and on public and private interest.

The impact on private interests is definitely positive in terms of reduction of costs (e.g. see rows: 1, 2 and 3) and yield increase (row 4). Public benefits are related to the reduction of the environmental impact (e.g. see rows: 2, 7 and 13). The adoption of innovative practices has a negative effect on costs (e.g. see rows: 14, 17). The negative environmental impact on the public interest is basically related to the use of chemicals.

The distinction of the level of incidence of CA action on the local, national/regional and global scale is relevant for the application of supporting programmes and policy interventions.

It is interesting to further subdivide benefits and costs of CA in relation to different dimensions of sustainability. Most costs relate the economic dimension of sustainability, whereas the benefits mostly affect the environmental and hence social dimensions.

This scheme highlights two main findings: *i*) the trade-off between the costs of conservation agriculture adoption paid by farmers and the social benefits (Knowler and Bradshaw, 2007); *ii*) the global environmental and social effects of conservation agriculture.

In general, the trade off in favour of private/public interest can be

Table 1
Benefits and costs associated to CA: dimensions of sustainability, impact levels on private/public interest and area of incidence.
Source: our elaboration.

				Area of incidence		
	Benefits/Costs	Dimensions of sustainability	Impact level	Global	National/Regional	Local
1	Labour savings in perennial crops	Ec/So	1			x
2	Fuel savings in perennial crops	Ec/Env	3			x
3	Cost-savings in annual crops	Ec	3			x
4	Increase of yields	Ec/So	3	x	x	x
5	Reduction of off-site problems	Ec/Env	2		x	x
6	Improvement of soil properties	Env	3		x	x
7	Increase of biodiversity	Env	2	x	x	
8	Less erosion	Ec/Env	3		x	
9	Less CO2 emissions	Env/So		x	x	x
10	Increase of the CO2 sink effect of the soil	Env/So	2	x	x	x
11	Less contamination of downstream water	Env	2		x	
12	Less floods and landslides	Ec/Env	3		x	
13	Less landscape diversity loss	Ec/Env/So	3	x	x	
14	Purchase of specialized planting equipment	Ec	−1			x
15	Short-term pest problems due to the change in crop management	Ec	−1			x
16	Farmer needs new management skills – requiring farmer's time commitment to learning and experimentation	Ec	−1			x
17	Application of additional herbicides	Ec/Env	−3		x	x
18	Formation and operation of farmers' groups	Soc	−2		x	x
19	High perceived risk to farmers because of technological uncertainty	Ec	−1		x	x
20	Development of appropriate technical packages and training programmes	Ec/So	0		x	x

Note: Ec = economic; Env = environmental; So = social. 1 = positive impact on private interest; 2 = positive impact on public interest; 3 = positive impact for both; 0 = no impact; −1 = negative impact on private interest; −2 = negative impact on public interest; −3 = negative impact for both

reached if a mix of viable business choices and public policies is implemented.

Given that crop performances are evaluated from measured crop yields, long-term reviews and field results lead to the conclusion that in Europe: a) in general no-till gives crop yields within 5% higher of those obtained under conventional tillage, given the influence introduced by soil, crop and weather; b) increasing yield levels under drier conditions have been reported (Fernández-Ugalde et al., 2009); c) lower yields during the first two years from the adoption are often the consequences of the previous soil compaction, the relatively short time for the improvement of soil biodiversity, insufficient available N to meet crops' need (Soane et al., 2012); d) the possible initial decrease in yield is compensated, on average, after 3 years, through the improvement of soil properties (e.g. aggregate stability, pore structure, organic matter and biological activity), increased N and water availability in the soil; e) a proper economic assessment must also take into account the quality of production, because strict quality standards are extremely relevant for grain crops grown for industrial uses and animal feed as well as in case of perennials crops and main crop rotation systems (e.g. wheat-sunflower as proofed in southern Spain).

Recently ECAF (2013) has reported that the effect of erosion is to increase agricultural production costs by about 25% each year and that erosion risks could increase due to changes in climate with a greater number of rainstorms. CA practices fights the effects of erosion and for this reason mitigate its impact on farmers' costs. Additional benefits are coming from the reduced water needs when no-tillage and/or minimum tillage practices are adopted. In drier years this implies better yields than those obtained with conventional practices.

Last but not least, it must be taken into account the impact of CA in terms of lower landscape diversity loss. Each territory is represented by a typical agricultural landscape, often referred to as a cultural landscape, and it is a strategic asset in improving the well-being of society given its high aesthetic, ecological and economic value (Sayadi et al., 2009; Van Berkel and Verburg, 2014). However, due to agricultural intensification processes, the cultural landscape is turning into ways that negatively affect the provision of eco-systemic cultural services (Zimmermann, 2006). Therefore, it must be preserved and improved through sustainable farming practices.

3. The comparative economic assessment of conservation tillage in a Mediterranean environment

3.1. The case study of Collina Materana

The investigated area is that of *Collina Materana* – in Southern Italy – in the province of Matera (Basilicata region), where high quality durum wheats used for pasta's production are produced.

In this area, cereal yields are quite low (between 2 and 3 t/ha) compared to other more suitable areas of the region. The low unit productivity has negative impacts on farm accounts, causing a progressive abandonment of agricultural holdings and rural depopulation, with adverse consequences on the natural environment and landscape.

The natural landscape of the area under study is that of the Eastern part of Lucanian Apennines, made up of Lower Tertiary sandstones and clay soil, merging with Pliocene clay hills. This environment is characterised by areas with sub-flat to undulated morphologies and sandy-conglomerate lithology. Soils are mostly calcareous and highly permeable, although the presence of clays in some areas may provoke landslides.

The climate classification in the area under study was based on rainfall data measured in nearby rain gauge stations (Aliano, Gorgoglione, San Mauro Forte, Baraccone) and on temperature values recorded in Stigliano weather station from 2004 to 2015 (see Table 2). The total annual average rainfall is ranged between 642 and

Table 2
Rainfall data in Collina Materana (2004–2015).
Source: our elaboration based on data derived from ARPAB and Civil Protection Agency (www.arpab.it).

Weather station	Annual average rainfall (mm)	Maximum annual rainfall (mm)	Minimum annual rainfall (mm)	Rain days
Stigliano	789	1403	365	77
Aliano	723	1072	393	74
Gorgoglione	885	1647	453	86
Baraccone	642	920	351	71
S. Mauro Forte	699	1090	391	77

885 mm. Precipitation follows a Mediterranean pattern, characterised by summer minima and winter maxima, and a very high variability with a difference exceeding in some years 800 mm of rainfall.

The data measured in the unique temperature and rainfall weather station (Stigliano) show a mean average temperature of 12.4 °C; January is the coldest month, with an average temperature of 3.5 °C, while July and August are the hottest months, with mean values around 22.4 °C. The difference between day and night temperatures is 18.9 °C, so the climate may be classified as transitional from continental to intermediate.

3.2. Methodology

The study focuses on a comparative economic assessment concerning three different crop production systems, related to different soil management systems: a) *conventional tillage*, b) *minimum tillage* and c) *no tillage*. The economic analysis included crop production costs (operating farm machinery, seeds, etc.) and the total output (revenues). Comparing the two categories, costs and revenues, it is possible to determine the operating income, i.e. the economic result achieved through management over a period (conventionally equal to one year).

Yet, as climate variability previously described has a negative impact on productivity, the analysis was carried out on a three-year time frame. Durum wheat (*Triticum durum*) was the reference crop.

3.3. Evaluation of costs

A survey was conducted to quantify the costs of farming practices, via a questionnaire given to a sample of farm contractors working in the area under study. The interviews have been conducted, during March 2015, with fifteen medium-size (from 15 ha to 50 ha) cereal farms. Farming practices for the three crop production systems are indicated in Table 3.

The comparison of the costs of the main farming practices with the values reported in Basilicata price list of public works – years 2012, 2013 and 2014–allowed the validation of survey data.

The other cost items included in the analysis concerned seeds, fertilization and weed treatments. The estimated seeding rate for durum wheat was 200 kg/ha for all three cropping systems. Fertilization included a pre-seeding application of 150 kg/ha of diammonium phosphate (18% nitrogen and 46% phosphorus pentoxide) and a top dressing treatment with urea (46% nitrogen) at the rate of 170 kg/ha (80 units/ha). Weed control involved a pre-seeding treatment with 2.5 l/ha glyphosate in the *no tillage* system, and a top dressing in the two other systems, using a broadleaf and narrow-leaf herbicide. For quantifying costs, as it was done for farming practices, a survey was conducted among the main companies marketing agricultural products across the region's territory. Also for these cost items, results show significant differences related to different formulations available on the market, different active ingredients and concentration.

For each crop production system, the costs referred to the three-year period were evaluated based on the costs incurred on farming practices and the expenditure for durum wheat production (see Table 4). Results show an average cost for the three marketing years equal to 798.96 €/ha for *conventional tillage* against 635.63 €/ha for *minimum tillage* and 485.13 €/ha for *no tillage*.

Table 3
Farming practices.
Source: our elaboration.

Farming practice	Conventional Tillage	Minimum Tillage	No tillage
Plowing operation	40 cm of deep tillage	–	–
Tooth harrow	x	x	–
Disk harrow	x	x	–
Pre-Weed control	–	–	x
Pre-Fertilization	x	x	x
Traditional seed	x	x	–
Sod seeding	–	–	x
Post-fertilization	x	x	x
Post-Weed control	x	x	–
Threshing	x	x	x

3.4. Assessment of total production

The total production (TP) is basically the total output obtained in the farm. In the specific case under analysis, the TP is represented by durum wheat output sold at local prices. Straw, as a secondary output, is not considered due to the low economic value assumed in recent years (often left on the soil). Different tests, carried out in Mediterranean environments and semiarid areas to test the effects of different production systems (conventional tillage, minimum tillage, no tillage, etc.) on wheat yield and quality, provided results that are often contradictory (Ahmad et al., 2013; Ruisi et al., 2014; Imran et al., 2013; Wozniak, 2013; Bilalis et al., 2011; Al Ouda, 2011; De Vita et al., 2007; Pisante and Basso, 2000), showing that in most cases crop response is extremely variable from year to year and largely dependent on soil and climate conditions and on the cropping practices applied (crop rotations, fertilisations, etc.). However, the rain fallen in a given territory is the variable that mostly affects crop yields and the subsequent economic viability of a cropping system compared to another one.

The link between rainfall and crop yields was pointed out by De Vita et al. (2007) in trials run on durum wheat in the Foggia province, showing that below 300 mm annual precipitation, *no tillage* system is more cost effective than conventional tillage. *No tillage* actually reduces water evaporation from the soil to the benefit of the crop, with positive effects on crop yields and quality.

Given the experimental data lack about the yields obtained with the different crop systems in the study area, the potential estimate of resulting durum wheat yields was obtained using De Vita's equations (De Vita et al., 2007: p.74) for no tillage and conventional tillage, considering the rainfall recorded in the three-year period (2013–2015) in the area of *Collina Materana*. However, given the differences in the pedoclimatic conditions of the study area compared to the area where De Vita conducted the tests, the results were subsequently corrected based on the yield levels obtained by Pisante and Basso (2000) in the neighbouring municipality of Guardia Perticara, where soil and climate conditions are similar to those in the area under study.

The potential yield levels of the three-year period (2012–2013, 2013–2014 and 2014–2015) for the two cropping systems, i.e. *conventional tillage* and *no tillage*, in the area of *Collina Materana* are shown in Table 5.

The potential yields concerning *minimum tillage* related to the area under investigation have instead been calculated from the per cent differences observed between CT and NT, as resulting from the trials conducted by Pisante and Basso (2000) and equal to 26.09%.

Results point out that *conventional tillage* shows the highest yield levels as compared to *no tillage*, with values ranging respectively between 1.19 t/ha and 3.47 t/ha in the first case and between 0.91 t/ha and 1.71 t/ha in the second case. However, it should be noted that as rainfall decreases, the differences observed between cropping systems tend to disappear, while they increase with precipitation, in favour of the conventional system and in line with the outcome of many studies.

After the crop yields for the three cropping systems were estimated, revenues were assessed on the basis of the prices of durum wheat for the three-year period 2013–2015. To this end, reference durum wheat prices were taken from the price list applied in Foggia (www.mercatigrano.it/quotazioni) that recorded an average price of 272.72 (in 2013), 319.00 (in 2014) and 358.59 €/t for the first months of 2015.

On the basis of the average prices recorded in the three-year period 2013–2015, revenues were quantified (Table 6).

Table 4
Total costs of conventional tillage, minimum tillage and no tillage (period 2012–2015).
Source: our elaboration.

Marketing year	Cultivation system	Plowing operation (40 cm)	Tooth harrow	Disk harrow	Pre-Weed control		Pre-Fertilisation		Traditional seed		Sod seeding		Post-fertilization		Post-Weed control		Threshing	**Total**
		€/ha	€/ha	€/ha	Herbicide (€/ha)	Spraying machine (€/ha)	Fertiliser (€/ha)	Manure spreader (€/ha)	Seed price (€/ha)	Seed planters (€/ha)	Seed price (€/ha)	Seed planter (€/ha)	Fertiliser (€/ha)	Manure spreader (€/ha)	Herbicide (€/ha)	Spraying machine (€/ha)	€/ha	**€/ha**
2012-13	CT	183.33	60.00	53.33			79.20	23.33	86.40	60.00			69.36	23.33	55.50	23.33	76.67	**793.78**
	MT		60.00	73.33			79.20	23.33	86.40	60.00			69.36	23.33	55.50	23.33	76.67	**630.45**
	NT				25.00	23.33	79.20	23.33			86.40	73.33	69.36	23.33			76.67	**479.95**
2013-14	CT	183.33	60.00	53.33			86.40	23.33	79.68	60.00			66.91	23.33	55.50	23.33	76.67	**791.81**
	MT		60.00	73.33			86.40	23.33	79.68	60.00			66.91	23.33	55.50	23.33	76.67	**628.48**
	NT				25.00	23.33	86.40	23.33			79.68	73.33	66.91	23.33			76.67	**477.98**
2014-15	CT	183.33	60.00	53.33			77.76	23.33	109.4	60.00			65.28	23.33	55.50	23.33	76.67	**811.30**
	MT		60.00	73.33			77.76	23.33	109.4	60.00			65.28	23.33	55.50	23.33	76.67	**647.97**
	NT				25.00	23.33	77.76	23.33			109.4	73.33	65.28	23.33			76.67	**497.47**

3.5. Results

The cost effectiveness of the three cropping systems was evaluated from the annual cash flows generated in the three-year period considered for the three cropping systems:

$$FC_k = R_k - C_k$$

FC_k: annual cash flows;
R_k: annual revenues;
C_k: annual costs.

The cash flows concerning the three years are shown in Table 7 assuming that annual flows are deferred to the end of the considered period:

$$Net\ value_n = FC_k * (1 + r)^n$$

The applied discount rate reflects the interest rates charged by most banks in the area, and is estimated at 1.2%.

Results show a higher cost effectiveness of *no tillage* and *minimum tillage* in particularly dry years, whereas the traditional system is more profitable in rainy years (see Table 7). The good economic performance of the three cropping systems under analysis is clearly shown in the marketing year 2013–2014, in which higher rainfall has positive effects. In particular, the annual flow is € 315.47 for the conventional system, € 188.42 for MT and € 67.68 for NT. The negative result observed in the other marketing years is mainly due to the exclusion of the single CAP premium from the financial analysis. Actually, the significant CAP payments play a major role in sustaining agricultural activity especially in marginal rural areas, including *Collina Materana*, where low crop yields and poor revenues from sales of farm products have negative impacts on the farm's total economic balance sheet. For this reason, an additional evaluation has been carried out including the CAP premium in the balance sheet. Given the differences in payment between the old CAP programming period (2007–2013) and the new one (2014–2020), an average value of € 320.00 per year was considered (Table 7). Including this revenue item reverses the results, which turn out to be positive, despite the persistent differences between the three cropping systems, while still confirming the cost effectiveness of *no tillage* and *minimum tillage* in the years with moderate levels of precipitation.

Table 6
Revenues for the three cropping systems.
Source: our elaboration.

Year	Adjusted Conventional tillage (t/ha)	Revenue (€/ha)	Adjusted No tillage (t/ha)	Revenue (€/ha)	Adjusted Minimum Tillage (t/ha)	Revenue (€/ha)
2013	1.19	324.54	0.91	248.18	0.87	237.27
2014	3.47	1,107.28	1.71	545.66	2.56	816.90
2015	1.83	656.89	1.14	409.21	1.35	484.59

This result is confirmed in Figs. 1 and 2, in which the annual cash flows (with CAP payment) referable to the different cultivation systems are compared with the trend of rains and grain prices, respectively. The annual cash flows essentially follow the rainfall trend, which directly affects the production and therefore the revenues. However, graphs show clearly the higher sensibility of CT and MT to rainfalls with respect to *no tillage* practice that shows a trend more or less stable over time. Last but not least evidence is the positive cash flow achieved only by *no tillage* practice in 2012/2013 – period during which the lowest rainfall and prices levels have been recorded – mainly due to lower production costs.

In the last years, farmers face different challenges mainly related to the climate change, global market instability and political decisions that frequently make them vulnerable (Eakin, 2005; Harvey et al., 2014; Tschakert, 2007). In this context, the adoption of *no tillage* could therefore be a viable option to the management of risks related to climate change and price instability.

Table 5
Crop yields in Collina Materana.
Source: our elaboration.

Year	November-May rainfall (mm)	Conventional tillage (t/ha)	Adjusted Conventional tillage (t/ha)	No tillage (t/ha)	Adjusted No tillage (t/ha)	Minimum Tillage (t/ha)	Adjusted Minimum Tillage (t/ha)
2013	292.2	2.4	1.19	2.5	0.91	1.75	0.87
2014	653.0	7.0	3.47	4.6	1.71	5.14	2.56
2015	394.6	3.7	1.83	3.1	1.14	2.71	1.35

Table 7
Cash flows with/without CAP single payment.
Source: our elaboration.

	2012-2013				2013-2014				2014-2015				Net value at the end of the period
	Revenues	Costs	CAP Payments	Cash flow	Revenues	Costs	CAP Payments	Cash flow	Revenues	Costs	CAP Payments	Cash flow	
	€	€	€	€	€	€	€	€	€	€	€	€	€
Conventional tillage	324.54	793.78		-469.24	1,107.28	791.81		315.47	656.89	811.3		-154.41	-319.51
Minimum tillage	237.27	630.45		-393.18	816.9	628.48		188.42	484.59	647.97		-163.38	-379.88
No tillage	248.18	479.95		-231.77	545.66	477.98		67.68	409.21	497.47		-88.26	-260.22
Conventional tillage	324.54	793.78	320.00	-149.24	1,107.28	791.81	320.00	635.47	656.89	811.3	320.00	165.59	663.71
Minimum tillage	237.27	630.45	320.00	-73.18	816.9	628.48	320.00	508.42	484.59	647.97	320.00	156.62	603.35
No tillage	248.18	479.95	320.00	88.23	545.66	477.98	320.00	387.68	409.21	497.47	320.00	231.74	723.01

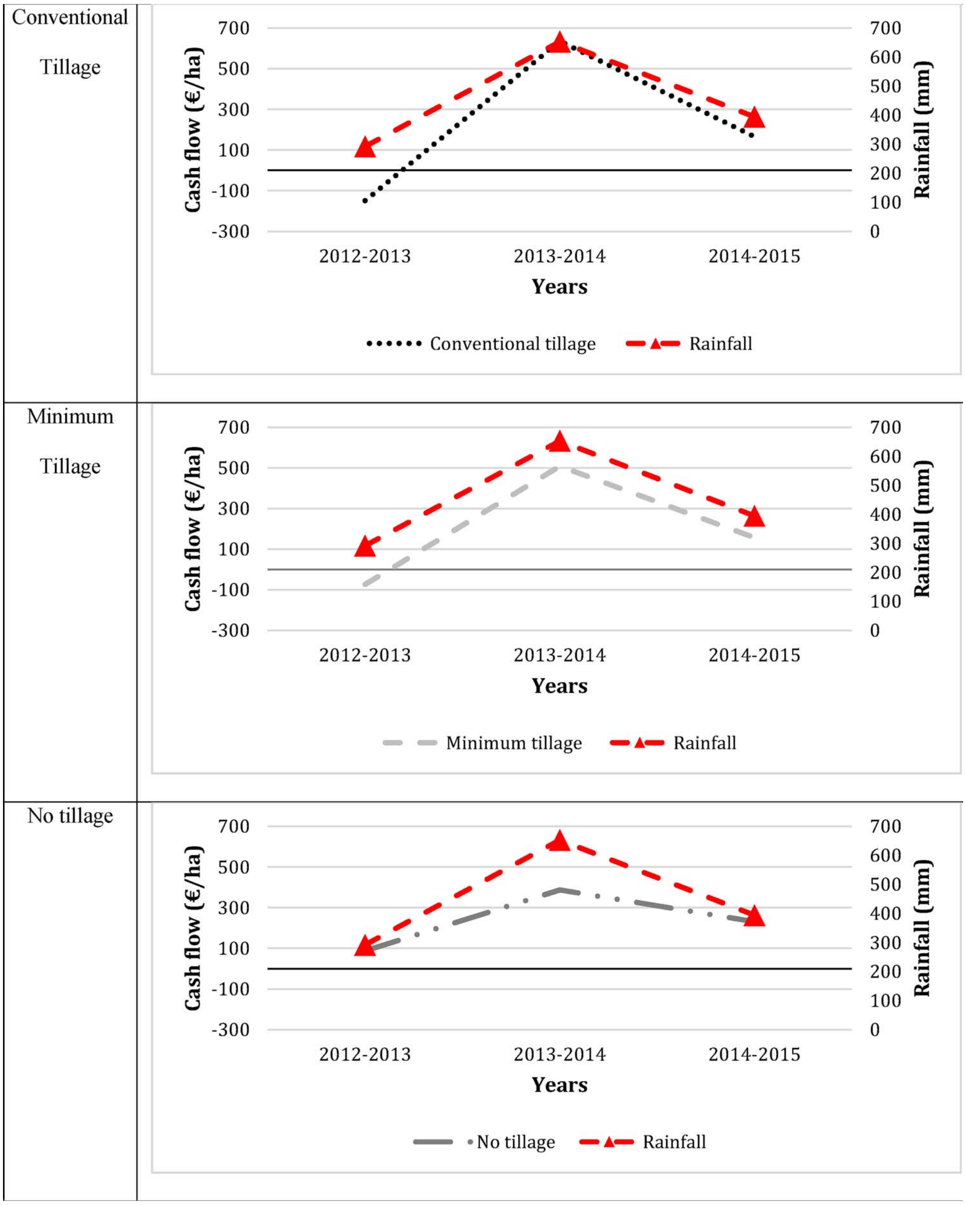

Fig. 1. Comparison of annual cash flow trends with the rainfall trend for the three crop systems (conventional tillage, minimum tillage, no tillage).

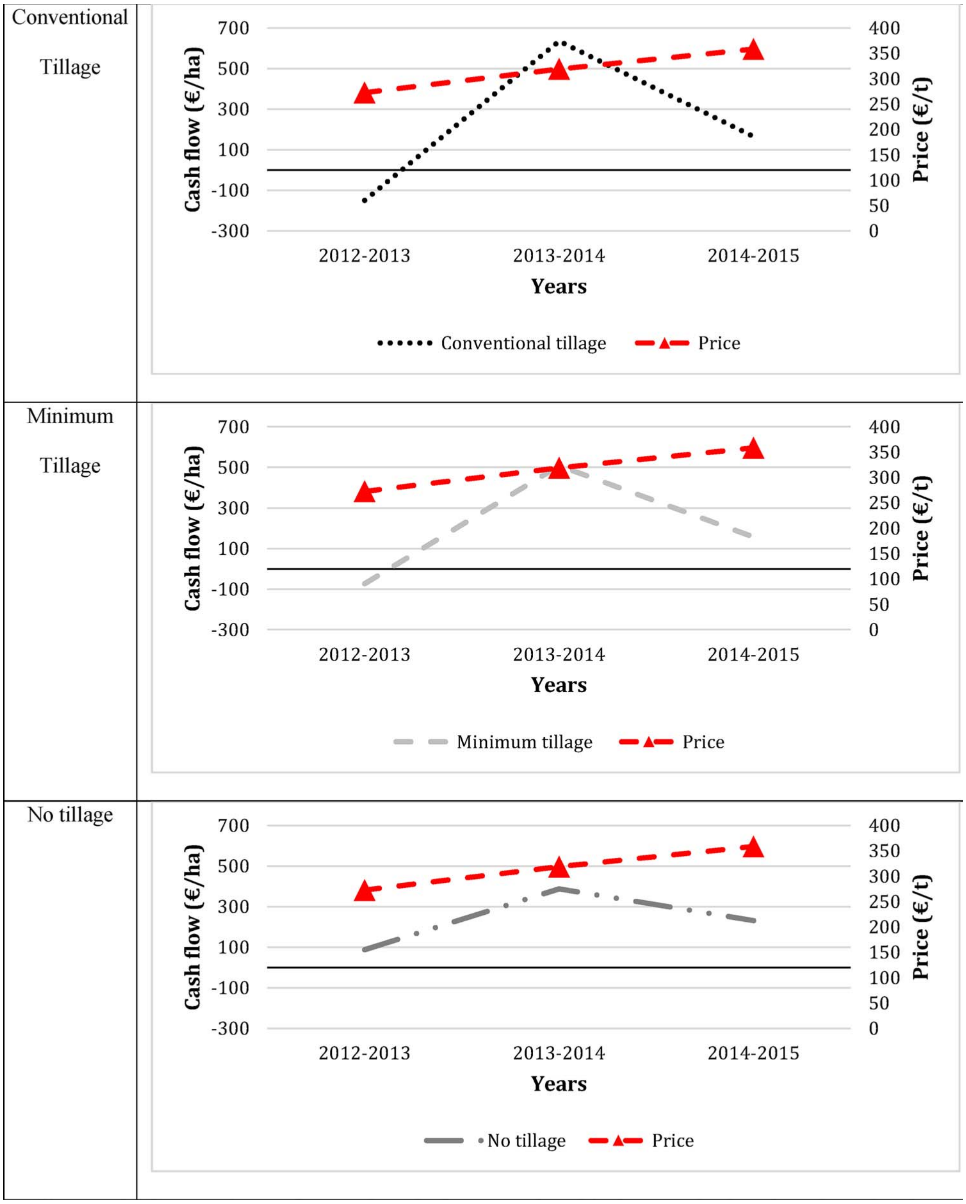

Fig. 2. Comparison of annual cash flow trends with the trend of grain prices for the three crop systems (conventional tillage, minimum tillage, no tillage).

In conclusion, economic benefits derive from the reduction in cropping costs mostly due to the lower intensity of farming practices. Costs may further fall as related to the size of the cropped area that enables reducing off-farm costs derived from the purchase of specific machines.

The economic disadvantage is related to: *i)* slightly lower yields, as compared to the conventional system; *ii)* decreased output that however depends and varies according to the soil and weather conditions; *iii)* the crop type and *iv)* the soil type. In the case study area, conservative farming practices result much less sensitive to variations in productions, and this aspect should not to be underestimated because it reduces farmer's risks while ensuring a positive profit over time.

The limited diffusion of CA in this territory is mainly dependent by farmers' insufficient knowledge and by their strong linkage with conventional farming practices. For these reasons, policies suitable to promote CA diffusion must be made available.

4. Final remarks

The adoption of conservation agriculture practices can be a viable alternative to conventional production systems. However, CA knowledge and diffusion in the agricultural sector are still insufficient while policy makers are still scarcely aware of the positive role this farming system can have in a sustainable agro-food system framework.

The results of the comparative economic assessment suggest that CA has significant potentialities yet to be exploited. Our analysis shows yield advantages especially during dry years, when conservation techniques increase water supply to crops; this feature has a dramatic significance in the light of the expect drier seasons in the Mediterranean area. Moreover, conservative farming practices produce more stable yields over time, that means lowering "technical" risk in producing durum wheat. This is a relevant feature, as risk management is typically one of the most important problems in managing agriculture and an issue linked to the challenges set by climate change.

As mentioned in the results section, conservation systems bring a reduction in average crop yields, whose size depends on the soil, climate and crop conditions.

From our point of view and according to other researches, of primary relevance is the effort to make farmers aware that the possible loss of profit (e.g. the purchase of specialized technologies; application of herbicides and/or time needed to improve management skills) in the short run will be compensated after the transition period. Moreover, the adoption of conservation agriculture techniques should be linked to educational/technical assistance to accompany business choices in order to make them profitable in the medium-long run.

The private profitability of this farming system should be supported, in the short run, by EU policy system providing incentives to single producers so that transitional risks can be minimised. The payment system should be added to the conventional agricultural system (i.e. greening system of payments of the CAP first pillar). At the same time, a widespread activity of public communication towards farmers have to be implemented, to make them aware of the advantages of CA techniques, for example, as in our case study, of the technical superiority of *no tillage* in the medium-long run.

Additionally, to support the transition period towards CA the decision makers can use the link between Good Agricultural Environmental Conditions (established in 2003 and with reduced tillage farming included) and the present CAP subsidies (granted by the second pillar).

Despite the collective benefits that could be achieved with the diffusion of CA they are still widely unrecognized by European decision makers. EU policy makers have to recognized the positive benefits of CA and devise a way to pay them as ecosystem services (Hodge et al., 2015), as it already happens in Canada and Brazil communities. The ecosystem approach actually represents an opportunity to reshape political interventions towards a more holistic model, in which the traditional productive service of farming is placed side by side to cultural, social and recreational ones.

Moreover, it should be taken into account the role of CA in terms of provision of public goods – i.e. the soil productivity and fertility preservation have a public impact in terms of food security – as well as of a number of environmental advantages (the climate change mitigation through carbon sequestration in the soil; the enhancement of below and aboveground biodiversity; the reduced CO_2 emission through less fuel consumption, the reduced use of agrochemicals, etc.). CA benefits should make consumers highly supportive of a transition to conservation agriculture practices.

We recommend for creating a system of environmental voluntary certifications in order to have the collective benefits generated by CA recognized by the market. In fact, the use of a quality label should be exploited by farmers as a viable solution to escape from commodity prices fluctuations, while society would benefit in terms of a wider supply of more environmental sustainable products.

As a concluding remark, we suggest to increase research and development activity devoted to more environmental friendly practices and/or technologies − e.g. the use of relatively cheap drones with advanced sensors and imaging capabilities that give farmers new ways to increase yields and reduce crop damage.

The authors consider it desirable to emphasise the need for extending the application to larger and more diversified portions of land and to different crops.

Acknowledgments

Authors thank the anonymous reviewers and the editor for helpful comments that have improved the article.

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