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Conservation agriculture to promote inland biofuel production in Italy: An economic assessment of rapeseed straight vegetable oil as a self-supply agricultural biofuel

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A B S T R A C T

In order to reach the national target in the use of renewable energy in the transport sector, about 55% of the biodiesel consumed in Italy is imported. However, imported biofuel is currently debated since large-scale production has entailed different environmental and socioeconomic problems. Sustainability in biofuel production is a priority for the European Union and with the new Common Agricultural Policy 2014–2020 (CAP) this priority could become an opportunity through access to aids for the adoption of sustainable agricultural practices.

Considering the importance to promote small-scale biofuel production, this study aimed to assess the economic feasibility of rapeseed straight vegetable oil (SVO) use as a self-supply agricultural biofuel in Italian context, assuming that rapeseed is cultivated by using practices of conservation agriculture. The financial support of the new CAP was considered, and alternative hypotheses were assumed to promote the SVO supply chains. The economic analysis shows that EU aids can help to promote inland biofuel production, ensuring positive profits for farmers (with a net present value up to 181 thousand €), thereby reducing the risk connected to investments, mainly due to the fluctuation of some key variables, like diesel price. Moreover, results highlight the importance of establishing farmers' associations: given the high cost of the initial investment, the absence of an agreement for the creation of an optimum-sized supply chains might make those investments non profitable. Agricultural policy is therefore helpful to promote sustainable biofuel production, making the supply chains independent and self-sufficient over time. In this context, to ensure a sustainable biofuel production, beside the provision of support to the initial investments, it is also important to consider in the future biofuel policy scenario the possibility to incentive energy crop cultivation by promoting conservation agricultural practices (e.g., crop diversification, crop rotation, minimum tillage).

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1. Introduction

In recent years, energy from biomass has been increasingly promoted as an alternative to fossil energy sources. In the European Union (EU), the Renewable Energy Directive (RED) has set an overall binding target to source 20% of the EU energy needs from renewable sources by 2020 (European Union, 2009). EU policymakers claim to pursue several objectives with this policy: greenhouse gas (GHG) emission reduction, positive contributions to energy security and income generation in rural areas (Demirbas, 2009). As part of the overall target, each member state has to achieve at least 10% of their transport fuel consumption from renewable sources, including biofuels. In Italy, due to tax credits and national requirements to blend a minimum biofuel share into conventional fuels, the share of renewable energy in the transport sector grew from 1% in 2006 to 6.4% in 2015 (Eurostat, 2017a). The main source of biofuel used in Italy is biodiesel (98% of total consumption): the inland production was 500.3 thousand *toe* in 2015,

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while the imports were 55% of the total volume of biofuel consumed.

However, the extent of GHG savings/emissions of imported biofuel or biofuel made from imported raw materials is currently strongly debated (Hélaine et al., 2013). Indirect Land Use Change (ILUC) is the main concern about large-scale biofuel production (Tokgoz and Laborde, 2014; Wise et al., 2014). Biofuels made from food crops might also increase competition for food and, indirectly, for resources with food production. This might lead to adverse effects on prices and availability of food, feed and bio-based materials (Wise et al., 2014). For these reasons, second generation biofuels are becoming of specific interest because they are mainly based on biomass residues and non-arable land areas. Despite this, currently there are no signs that they will become technologically mature and cost-effective in the next decades to fully substitute first generation biofuels before 2030 (Ajanovic and Haas, 2014; Festel et al., 2014). There are also many uncertainties in the GHG implications of residue removal, particularly regarding changes in soil organic carbon (SOC) and nutrient off-take (Heyne and Harvey, 2013; Whittaker et al., 2014).

In this context, small-scale production, particularly of rapeseed Straight Vegetable Oil (SVO) used as self-supply agricultural biofuel, could be a possible solution to avoid/overcome all problems linked to large-scale biofuel production (Baquero et al., 2011; Esteban et al., 2011; Fore et al., 2011). SVO can be produced in small-scale in local cooperatives through pressing, filtering and conditioning processes, which are much simpler than the ones required for biodiesel production, with a reduction in fuel production costs and GHG emissions. It can be used in a non-modified diesel engine just by adding a small heat exchanger in conjunction with other minor modifications in the fuel intake system (Mat et al., 2018; No, 2017). Moreover, during mechanical pressing of the seeds, in addition to achieving low-cost fuel, a protein-rich rapeseed cake is produced. Usually used in animal feed (Iriarte et al., 2012), it represents an added value that can be used within the farm or sold, thereby helping to diversify farm income, to close the cycle using raw materials and products in the same territory and to reduce the impact on land use.

Nevertheless, one last concern about SVO production remains: the sustainability concerning the agricultural practices used for rapeseed production. There is growing evidence to suggest that the current agricultural systems, not only for biofuel production but also for food, have negative effects on the environment. Such systems in all parts of the world will have to make improvements, taking into account production processes that respect the environment and use 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 model of agriculture combined with practices of Conservation Agriculture (CA) based on minimal soil disturbance, permanent soil cover and crop diversity (Basch, 2012; Vastola et al., 2017). The use of CA practices is not only a priority, but it could also be an opportunity to promote the production of biofuels in Europe. The new Common Agricultural Policy 2014–2020 provides support to the adoption of such “green” practices that could incentive the small-scale SVO production.

Based on the above, the paper aims at assessing the current potential of small-scale supply chains of rapeseed SVO as a self-supply agricultural biofuel in different Italian contexts, by using alternative economic indicators. After describing the CA practices that can be adopted for rapeseed cultivation (section 2), an economic assessment of SVO production in different Italian regions is presented (section 3). Results and discussions are presented in section 4 while final remarks and suggestions for future research are provided in section 5.

2. How to produce rapeseed in a sustainable way?

As rapeseed-based biofuel has good cold flow properties and oxidation stability and fits better within European biofuel standard specifications, rapeseed is the dominant biofuel feedstock in the EU, accounting for 55% of the total production. The rapeseed harvested area was about 6.46 million ha in 2015 with an increase of 5.4% with respect to 2007 (Eurostat, 2017b), basically due to the mandatory use of biofuels in the EU by 2020.

The European target for biofuels has, in fact, generated a general increase in the cultivated areas of all oil crops, reaching 10.8% of total arable land in 2015 (about 11.8 million ha). Therefore, the concern linked to the negative impacts on the change in land use (direct and indirect) led to define a proposal to revise the RED by imposing new sustainability criteria in the production of biofuels (European Commission, 2017). The main criteria states that biofuels may not be made from raw material obtained from land with high biodiversity value (such as primary forests or highly biodiverse grasslands). It also cannot be made from raw materials produced on areas converted from land with previously high carbon stock such as wetlands or forests. As the rapeseed-based biofuel marketed in Europe is produced from raw materials cultivated on existing cropland, it is not considered land use change according to the guidelines on the calculation of soil carbon stock variations associated with direct land use change.

However, concerns remain about the agricultural practices used, considering that production increased by about 32% between 2007 and 2015, more than the correspondent increase of the cultivated areas. Agricultural raw materials produced within the EU, including biofuels, must be produced in compliance with minimum requirements for good agricultural and environmental conditions. These are established according to the common rules for direct support schemes in the Common Agricultural Policy (CAP). However, European studies demonstrate that the current rapeseed cultivation systems lead to a negative impact on the environment (Malça et al., 2014; Palmieri et al., 2014; Queirós et al., 2015). By comparing the different cultivation systems in various European countries (France, Germany, Spain, Poland), these studies show that the choice of fertilizer type has significant implications on the environment mainly related to acidification, eutrophication and photochemical oxidation. Soil carbon change associated with different agricultural management practices significantly contributes to GHG emission intensity of rapeseed production (Malça et al., 2014; Queirós et al., 2015). The same results are found by Palmieri et al. (2014) who carried out an environmental impact analysis of rapeseed production in Italy. Using the Life Cycle Assessment (LCA) method, they showed how practices of intensive farming are responsible for the greatest environmental impact, concluding that the adoption of CA practices (e.g. reduction in fertilizers and use of conservation tillage) is the key issue to reduce the negative impacts of rapeseed production systems.

Among the different CA practices, Baquero et al. (2010) suggest to cultivate rapeseed in crop rotation due to the benefits that come from farm diversification (e.g. the absence of fuel and food competition), in order to promote the SVO production. Crop diversification, as compared to continuous monoculture systems, can be expected to reduce the dependence on external inputs (e.g. fertilizer) through the promotion of nutrient cycling efficiency, the effective use of natural resources, the maintenance of long-term productivity of land, the control of diseases and pests, and consequently increasing crop yields and sustainability of production systems (Davis et al., 2012).

Despite the current absence of a specific support for energy crops in the new CAP, that ensured the cost-effectiveness of Baquero's model, the incentives for the adoption of sustainable agricultural practices of the CAP 2014–2020 could represent a real opportunity to promote the production of biofuels.

Under the so called "greening" of CAP's first pillar, 30% of direct payments is conditional to environmental constraints, forcing the farmers to adopt specific environmental-friendly practices. These include a minimum level of crop diversification with two different crops for farms having a cultivated area between 10 and 30 ha (the main crop must not exceed 75% of the total), and three different crops for surface areas greater than 30 ha (the main crop must not exceed 75% of the total and the two main crops must not exceed 95%). In this context, farmers could be motivated to cultivate rapeseed for SVO production to comply with sustainability criteria.

Farm diversification is not the only CA practice promoted by the EU. Different Rural Development Programs (the second pillar of the CAP) also promote sustainable agricultural practices. In Italy, within RDP measure 10 - "*Agri-environment-climate payments*", many regions have provided support to promote conservation tillage practices (such as minimum tillage) helpful to improve the chemical-physical quality of the soil, fertility and microbiota activity, and at the same time reducing GHG emissions, fertilizer use and production costs without compromising the yields (Vastola et al., 2017).

Given the rapeseed suitability to be cultivated with such practices, we propose a model for rapeseed cultivation in crop rotation (to get the support provided under the first pillar greening) with minimum tillage practices (potentially eligible for support under rural development policy). Adopting the proposed sustainable cultivation model, with almost 3.2 million hectares of arable land (ISTAT, 2017), there are good chances to increase domestic biofuel production in Italy to reach the national target, reducing its imports and also with benefits for farmers. However, an ex-ante economic assessment should be carried out to explore the feasibility of small-scale SVO production, considering the economic incentives affecting farmers' decisions (Cozzi et al., 2015).

3. Economic analysis

3.1. Procedure

The possibility to cultivate agricultural land to produce rapeseed SVO used as self-supply agricultural biofuel depends on the cost-effectiveness of SVO supply chains. To this purpose, some economic indicators were calculated as a reference point for farmers in alternative investments. More specifically, the analysis concerned the calculation of the Net Present Value (NPV) and the Internal Rate of Return (IRR) of the investment (Cozzi et al., 2014; Pappalardo et al., 2017). NPV expresses the future flow of increase in wealth generated by a given investment as compared with the maintenance of the existing situation, discounted to the decision moment:

$$NPV = \sum_{i=0}^{n} \frac{B_i - C_i}{(1+r)^i} \quad (1)$$

where B_i and C_i are, respectively, the benefits and costs in period i; r is the discount rate; and n is the life cycle of investment (in years).

IRR is the discount rate (r') that makes the NPV equal to zero:

$$NPV = \sum_{i=0}^{n} \frac{B_i}{(1+r')^i} - \sum_{i=0}^{n} \frac{C_i}{(1+r')^i} = 0 \quad (2)$$

The cost effectiveness of the investment is verified if $NPV > 0$ and $r' > r$.

At the same time, we also calculated the Payback Period (PBP) (Cozzi et al., 2013; Romano et al., 2013), namely the time in which the initial cash outflow of the investment is expected to be recovered from the cash inflows generated by the investment.

So, the logical procedure followed for the economic evaluation involved the determination of the costs C_i (investment and running costs) (section 3.2) and benefits B_i (revenues generated by the investment) produced by the implementation of the SVO supply chain, as well as the public incentives (section 3.3). In this study, all data collected to calculate costs and benefits, are valued at year 2017 prices.

Italian agricultural systems differ among regions in terms of cultivation costs, productivity and RDP support measures. Furthermore, as emphasized by van Eijck et al. (2014): "Specific case studies are key to more accurate modelling of the biofuel production costs, the profitability for a farmer (by means of net present value calculations) and the identification of alternatives". For such reasons, the analysis was carried out for the main agricultural systems referring to the geographical areas (macro-regions) of the north-west, north-east, central and southern Italy.

According to the obligations under the CAP's first pillar, the optimum cultivation area for rapeseed production in each macro-region (Table 1) has been identified on the basis of crop average yields (t/ha) recorded in each area, and the typology of oil mill selected in the analysis, with a seed processing capacity of 120 kg/h, assuming an operation of 6 h per day for 284 days per year. We also considered the availability of a minimum storage of the seed for the daily processing, a cold pressing facility and the oil and cake meal stored and used by the farmers or the fodder manufacturers of the surrounding areas. Considering that the technical lifetime of the treatment equipment is between 18 and 20 years, we adopted a duration n of the investment equal to 18 years, with a discount rate r equal to 4.5%.

3.2. Cost assessment

Economic costs associated with small-scale on-farm SVO production can be disaggregated into three sections: 1) feedstock cultivation costs, 2) capital costs for the treatment equipment, and 3) operating costs for that equipment.

Data relating to the cultivation costs of rapeseed with minimum tillage practices are shown in Table 2. They represent the average value of the cultivation costs of the different macro-regions, obtained from chambers of commerce and the associations of subcontractors of the main Italian provinces. It is important to point out that, compared to the traditional cultivation practices, the use of minimum tillage leads to a reduction of production costs due to the lack of agricultural operations, such as deep tillage (Vastola et al., 2017).

As for capital costs (Table 3), they are related to the purchase and financing of equipment used in the SVO production process. Such purchases included equipment to extract oil from oilseeds, to process unrefined vegetable oil into SVO, and to store the biofuel for subsequent use.

The capital costs also include a budget of 15,500 € for infrastructural improvements, which could include any combination of costs related to site preparation, electrical modifications, and construction or retrofitting of buildings.

The modification kit for farm tractors to use SVO as self-supply agricultural biofuel is also considered. The total cost (kit, taxes, second fuel tank and installation) is estimated at 10,000 €,

Table 1
Supply chain dimension for each Italian macro-region.

Region	Rapeseed Yields (t/ha)	Rapeseed cultivation area (ha)
North-West	2.9	71
North-East	2.8	73
Centre	2.2	93
South	2.0	102

Table 2
Rapeseed cultivation costs with minimum tillage practices for different Italian macro-region (€/ha).

Cultivation costs [a]	North-West	North-East	Centre	South
Cropping expenses				
Minimum tillage	175	142	125	133
Fertilization pre/post-seeding	80	77	75	66
Pre-weed control	50	50	45	33
Seeding	72	59	65	60
Harvesting - Transportation	170	137	130	130
Total cropping expenses	547	465	440	422
Additional expenses				
Seeds	80	80	80	80
Fertilizers	110	110	110	110
Herbicide	75	75	75	75
Total additional expenses	265	265	265	265
Total cultivation costs	812	730	705	687

[a] Data collected from chambers of commerce and the associations of sub-contractors of the main Italian provinces (mean values, year 2017).

Table 3
Capital and operating costs to produce and use SVO as self-supply agricultural biofuel.

Capital costs	€
Oil extraction equipment [a]	
Oilseed press	28000
Feedstock conditioner	9300
Feedstock storage	11500
Crude oil storage	2000
Feedstock conveyors	1500
Infrastructural improvement	15500
Biofuel processing equipment [a]	
SVO filtration	7700
Biofuel storage	2000
Additional expenses	900
Total SVO production costs	**78400**
SVO engine conversion [a, b]	
Conversion kit (purchase and installation)	5000
Operating costs [a]	**€/L**
Electricity	0.08
Repairs & maintenance	0.03
Labor	0.08

Source: [a] Fore et al. (2011); [b] Baquero et al. (2011).

considering that at least two tractors are to be modified.

The operating costs examined in this study include electricity, labor and repair, based on the results of Fore et al. (2011). Electricity is used in a variety of applications, including feedstock conditioning, oil extraction, and biofuel processing. Specifically, feedstock preparation and oil extraction require electricity for feedstock transfer, feedstock conditioning, and oilseed crushing. Labor allocated to the oil extraction and SVO production processes is primarily related to daily press maintenance (cleaning press heads and oil outlets), press start up (establishing continuous feedstock flow and correct nozzle size), optimizing flow of feedstock through the press (correct pressing speed) and maintaining adequate feedstock supply for the crushing operation. Annual maintenance costs include replacement of oilseed press screws and general maintenance for biofuel processing equipment, including replacement of valves, seals and filters.

3.3. Revenue assessment

The benefits from the investment depend on the use of the straight vegetable oil and the sale of cake meals arising from the rapeseed exploitation and processing. The obtained SVO is assumed to be entirely used to fuel the tractors that work on the farm, so that, on the basis of productivity and the average price of diesel recorded in the different macro-regions, the revenues deriving from the replacement of diesel with SVO are shown in Table 4. Added to these are the revenues obtained from the sale of the cake meal, considering a price equal to 177 €/t (FAO, 2017).

Regarding the CAP (first and second pillar) incentives, both direct payments (first pillar) and RDP aid (second pillar) were considered.

The former is represented by the basic payment plus the greening payment for the sustainable practices that all farmers are obliged to support in order to access direct payments, first of all the diversification of the crop. This support is considered for the entire investment period (18 years) assuming that the policy line taken by the new CAP 2014–2020 is maintained for another two programming periods. For this reason, the internal convergence mechanism is taken into account in order to standardize the value of direct payments throughout the national territory by 2019.

The RDP support for minimum tillage practices is considered only for the regions that activated measure 10, taking into account the differences in amounts, methods and timing of the allocation of the different Rural Development Plans. In these regions, the RDP aid is added to direct payments.

4. Results and discussion

4.1. Economic feasibility

Taking into account the crop yields, the market price of the products obtained, the cultivation costs, the EU support and the storage facilities and seed processing costs for SVO production, the economic results are shown in Table 5.

The table shows the cost-effectiveness indicators of investment (NPV, PBP, IRR) for each macro-region, considering only direct payments (Scenario CAP) and direct payments with the RDP aid

Table 4
Gross and net revenues by 1 hectare of integrated SVO supply chain in different macro-regions.

Products	North-West	North-East	Centre	South
SVO value (€)	628	528	483	414
Cake meal (€)	344	332	261	237
Total gross revenue (€)	**972**	**860**	**744**	**652**
Total net revenue (€)	**160**	**130**	**39**	**−35**
Agricultural diesel price (€/L)	0.70	0.61	0.71	0.67
Rapeseed yields (t/ha)	2.9	2.8	2.2	2.0

Table 5
Economic results for CAP and RDP scenarios: cost-effectiveness indicators of investment.

Scenario	Region	NPV (€×1000)	PBP (years)	IRR (%)
CAP	North West (NW)	122.17	4.7	19.1
	North East (NE)	107.75	5.0	17.6
	Centre (C)	102.82	5.1	17.1
	South (S)	45.35	6.9	10.5
RDP [a]	NW - Piemonte	148.57	3.6	24.1
	NW - Lombardia	155.14	3.5	25.0
	NE - Veneto	181.36	2.6	33.3
	C - Lazio	116.98	4.3	19.6
	S- Basilicata	91.33	3.8	19.3
	S- Calabria	168.73	2.6	33.7

[a] The regions that activated measure 10.1 for each geographical area are reported in detail.

Table 6
Net Present Value by hectare of integrated SVO supply chain and ton of product in different regions.

Scenario	NPV	Region					
		North-west		North-East	Centre	South	
CAP	€/ha		1721	1476	1106	445	
	€/t		593	527	503	222	
RDP		**Piemonte**	**Lombardia**	**Veneto**	**Lazio**	**Basilicata**	**Calabria**
	€/ha	2093	2185	2484	1258	895	1654
	€/t	722	753	887	572	448	827
RDP/CAP	%	22	27	68	14	101	272

(Scenario RDP).

The indicators show the economic feasibility of SVO production chains for agricultural use in Italy, especially in the central and northern regions. In these regions, with only direct payments, we have NPVs over 100 thousand € with a payback period of five years and an IRR greater than 17%.

Of course, access to RDP aid for minimum tillage practices makes the investment more worthwhile in the regions where the RDP measure 10 has been activated. The NPV of the investment almost doubles (181 thousand €) and the PBP is halved (about 3 years) in the case of the Veneto region, where an aid of 325 €/ha is provided, against the 180 €/ha in Lombardy and Piedmont and 130 €/ha in Lazio. Although in these regions the net present value does not increase in a similar way to that recorded for the Veneto region, the support from RDP leads to a general improvement of the economic feasibility of the investment, with PBP values between 3 and a half and 4 years, and IRR between 20% and 25%.

As for the regions of southern Italy, the lowest NPV values are recorded both in the CAP and in the RDP scenario. In the case of the Basilicata region, with only direct payments, we have an NPV equal to less than half of that recorded in the rest of Italy (45 thousand €), with a payback period of almost seven years and an IRR of 10.5%. These results are due to revenues derived from the SVO production that do not cover the cultivation costs (see Table 4), although the latter are lower than those recorded in the rest of Italy (see Table 2). Due to a dry climate, the productions obtained in the southern regions do not make it possible to produce sufficient SVO per hectare, thus obtaining a lower revenue also from the sale of the cake meal. The only way to cover the cultivation costs and to recover the investment costs is guaranteed by direct payments

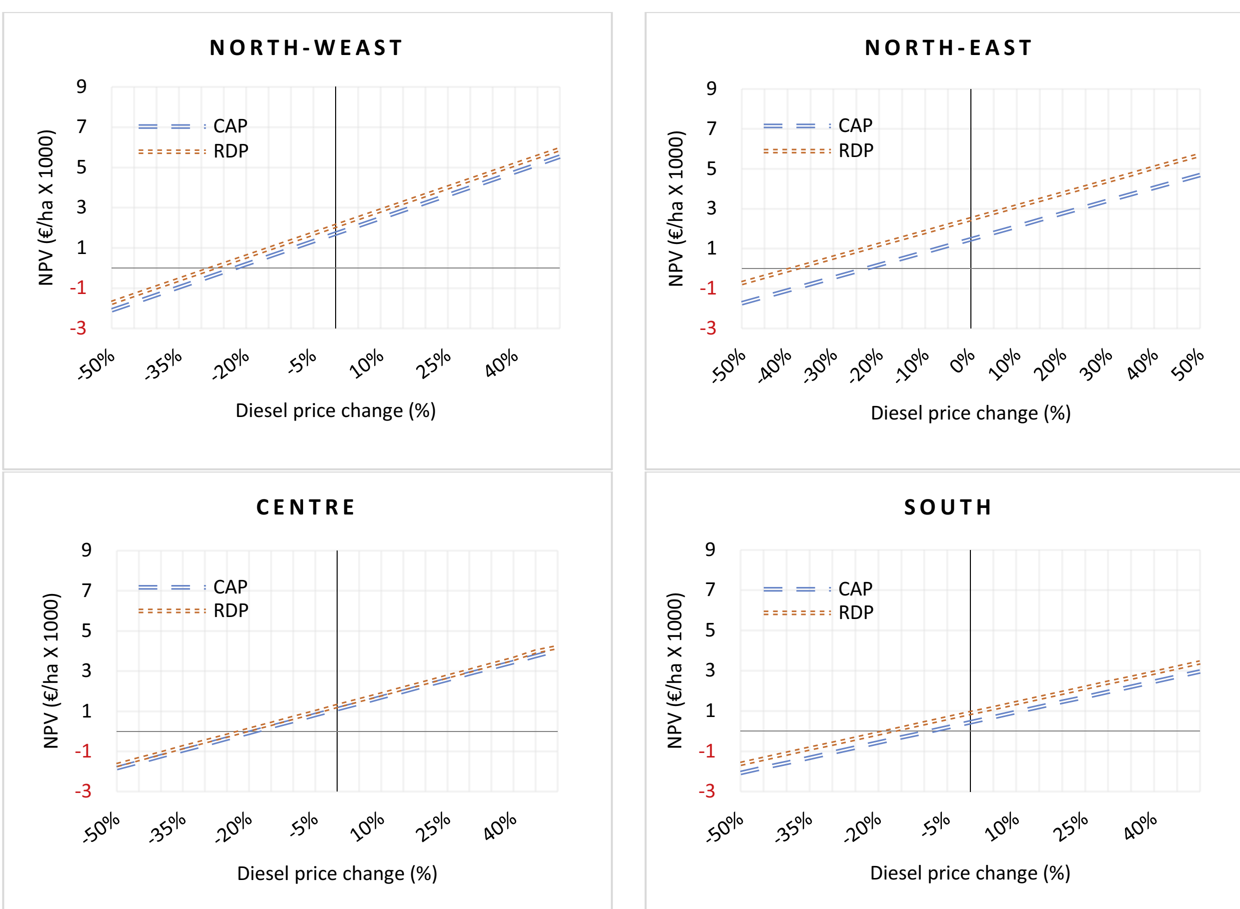

Fig. 1. Sensitivity analysis on Net Present Value (€/ha, ×1000), as a function of change in diesel price (%) for CAP and RDP scenario.

which, in these regions, are generally the only revenue for farmers who direct their production on less specialized crops, such as wheat (Vastola et al., 2017). In these regions, in order to comply with the diversification requirements of the CAP's first pillar, farmers could be led to invest in the SVO production only in the absence of more profitable crops or thanks to further incentives such as RDP aid for minimum tillage practices. For this purpose, the Net Present Value per hectare of area and per ton of product are reported in Table 6 as a reference for farmers.

As shown in Table 6, in regions where RDP support are planned, NPV doubles in the case of the Basilicata region (+101% respect to CAP scenario) or increases fourfold in the case of the Calabria region (+272% respect to CAP scenario), whose RDP aid (equal to 300 €/ha, guaranteed for a period of 7 years) brings the investment (NPV per ton of product) in line with that recorded for the Veneto region (over 800 €/t).

Of course, a general incentive to the deployment of sustainable SVO supply chains, even in the regions with the lowest investment returns, should be the energy security that would derive from the replacement of fossil fuels with biofuels. Farmers could be driven to produce biofuels to protect themselves from the risk associated with the volatility of traditional fuel prices.

Since the fuel price volatility represents not only a strong point but also a threat for the diffusion of such supply chains, the results of the sensitivity of the investments are shown below according to some variables, first of all the price of agricultural diesels.

4.2. Sensitivity analysis

The sensitivity analysis was carried out for the economic scenarios considered (CAP and RDP), observing the effect on the net present value per hectare of surface, induced both by changes in the price of agricultural diesel (increase and reduction compared to the current price) and by reductions in the optimal size of the supply chain recorded in the different regions. In fact, farmers are not always able to reach a collective agreement ensuring the optimal chain dimension for optimizing the use of the SVO production plant. There are no variations in the price of the cake meal thanks to the possibility of signing contracts within supply chain agreements that can guarantee price stabilization.

The results of the analysis are shown in Figs. 1 and 2, where it is possible to observe the magnitude of the investment sensitivity with respect to changes in the diesel price and the size of the supply chain, respectively. It should be noted that for the RDP scenario, the sensitivity analysis was carried out for each macro-region, only focusing on the regions that registered the minimum NPV.

As can be seen from Figs. 1 and 2, the investment is particularly sensitive to changes in the price of agricultural diesel. An increase of diesel price could further stimulate the creation of SVO supply chains throughout Italy (it should be noted, in the CAP scenario, the effect on NPV by increasing the price of diesel in the regions of southern Italy). Conversely its reduction, even slight, could undermine the feasibility of investment in almost all regions in both scenarios.

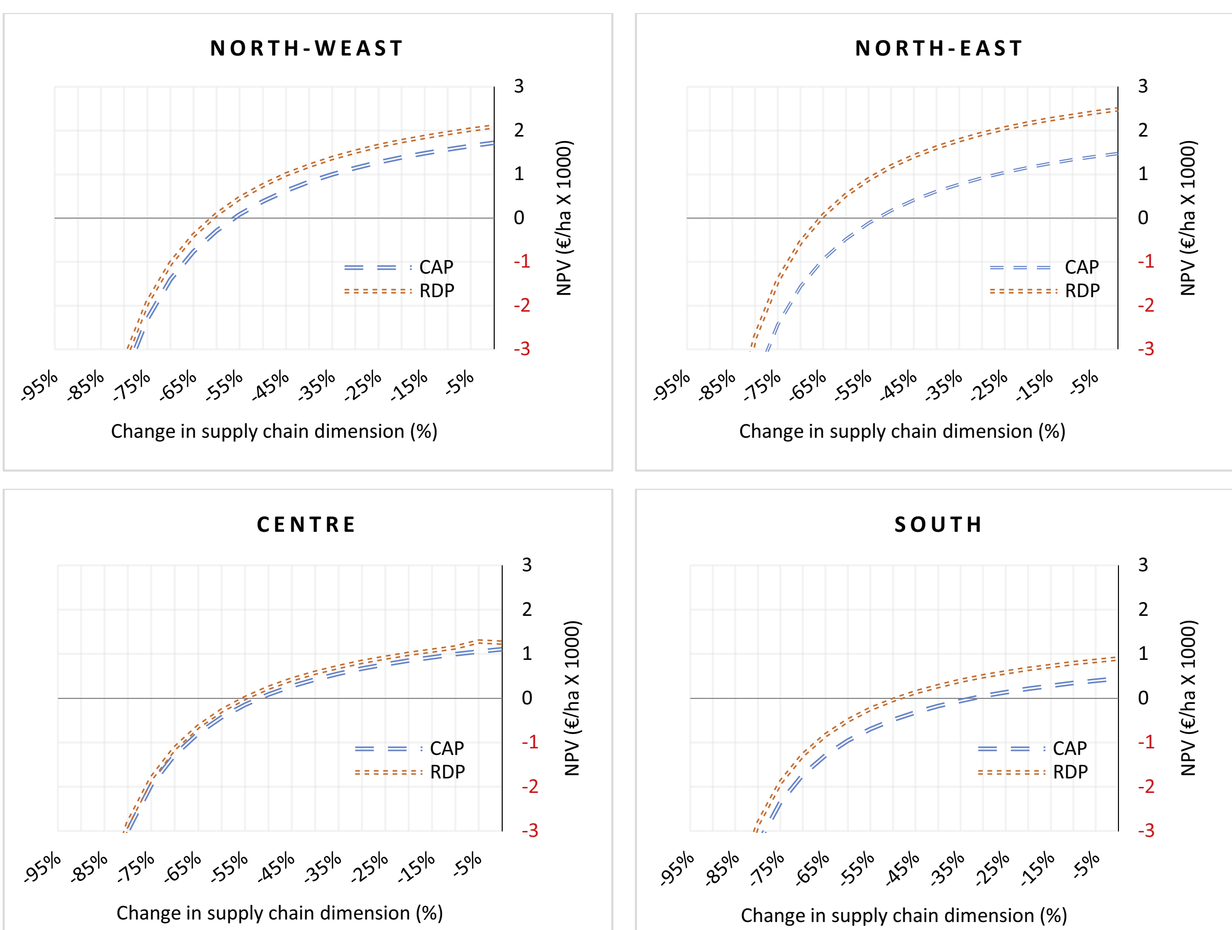

Fig. 2. Sensitivity analysis on Net Present Value (€/ha × 1000), as a function of change in supply chain dimension (%) for CAP and RDP scenario.

Table 7
Economic results for Alternative scenario: cost-effectiveness indicators of investment.

Scenario	Region	NPV (€×1000)	PBP (years)	IRR (%)
Alternative	North West	200.57	0.5	185.8
	North East	186.15	0.6	174.0
	Centre	181.22	0.6	171.9
	South	123.75	0.8	124.7

In the CAP scenario, a reduction from the current price of 20% in the north-west and north-east regions, of 15% in the centre regions, and 5% in the southern regions, leads to negative returns on investment. Of course, access to RDP subsidies (RDP scenario) could partly mitigate this negative effect, particularly for the regions of the north-east and south, ensuring positive returns even up to reductions in the diesel price of 35% and 15%, respectively.

With regard to the sensitivity of the investment compared to increasing reductions in the size of the supply chain, Fig. 2 shows how the regions of southern Italy are particularly sensitive. There are negative returns with reductions larger than 30% compared to the optimal size, against 55%–60% reductions for other regions. In absolute terms, with sizes less than 71 ha for the southern regions, 47 ha for the central regions, 37 ha for the northeastern regions and 32 ha for the north-western regions, net revenues and European aid would not cover the costs associated with the initial investment.

Also, in this case, the RDP aid partly mitigate this negative effect with positive NPV up to 55% reductions for the regions of southern Italy, 55% for the centre, 60% for the north-west and 65% for the north-east.

In this context, in the current European agricultural scenario, farmers could be held back in making new investments in the face of risks linked to high initial costs. In the context of bioenergy, Kulcsar et al. (2016) show that subsidies for plants are important to promote the biofuel development, especially in rural areas. For this reason, in order to assess the weight that the initial costs have on the investment, an alternative scenario is assumed in which, instead of the RDP subsidies, grants are made to support the production costs of the SVO production plants, provided that sustainable agricultural practices are respected. The results of the economic feasibility analysis for the alternative scenario are shown in Table 7, showing the importance of investment support. In this scenario, the best indicators of economic feasibility are recorded with respect to current scenarios, especially in terms of payback period (around one year) and the internal rate of return (over 120%).

Moreover, by assessing the sensitivity of the investments in this scenario, as was done for the two scenarios representing the

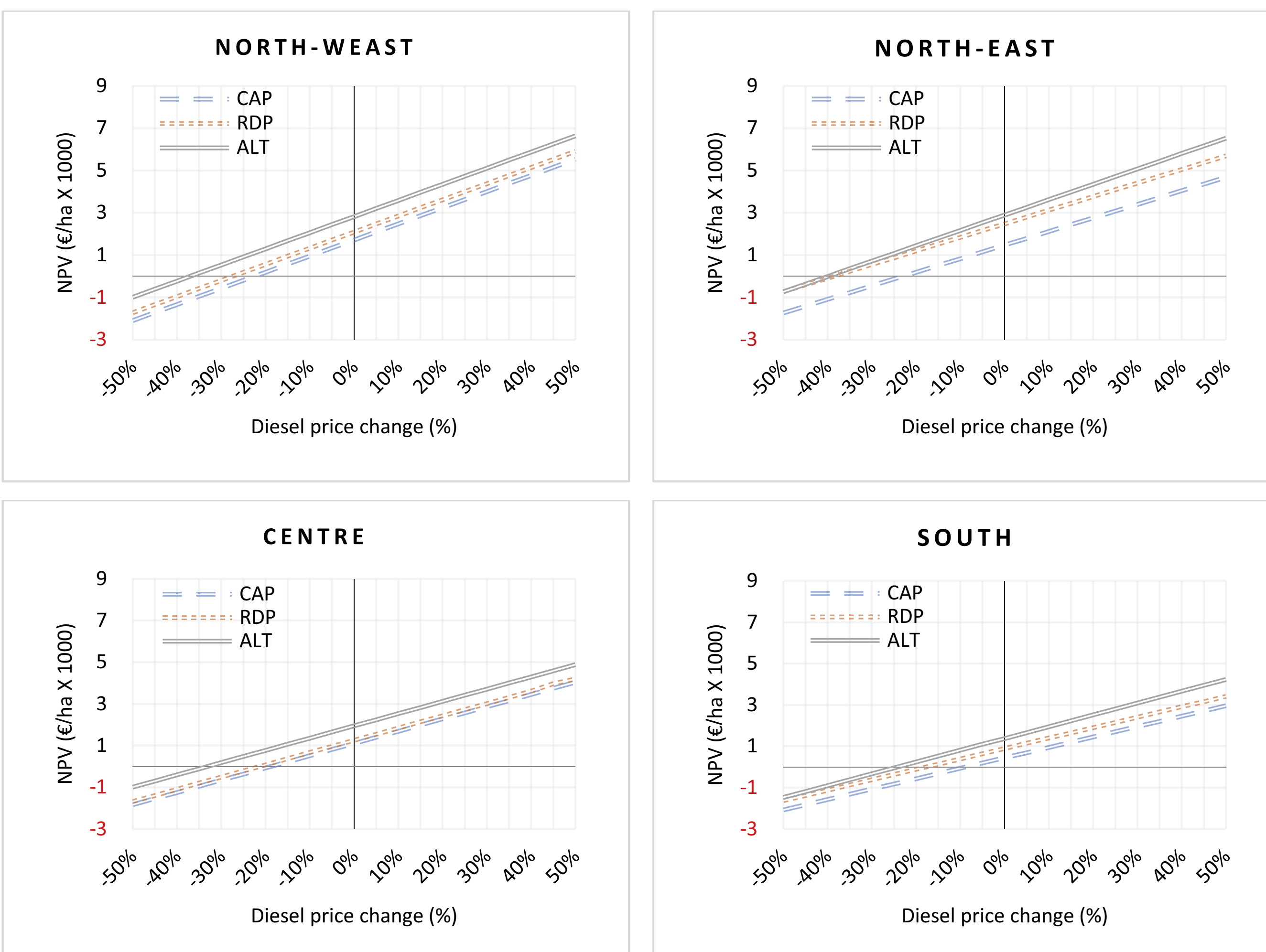

Fig. 3. Sensitivity analysis on Net Present Value (€/ha × 1000), as a function of change in diesel price (%) for Alternative scenario (ALT), respect to CAP and RDP scenario.

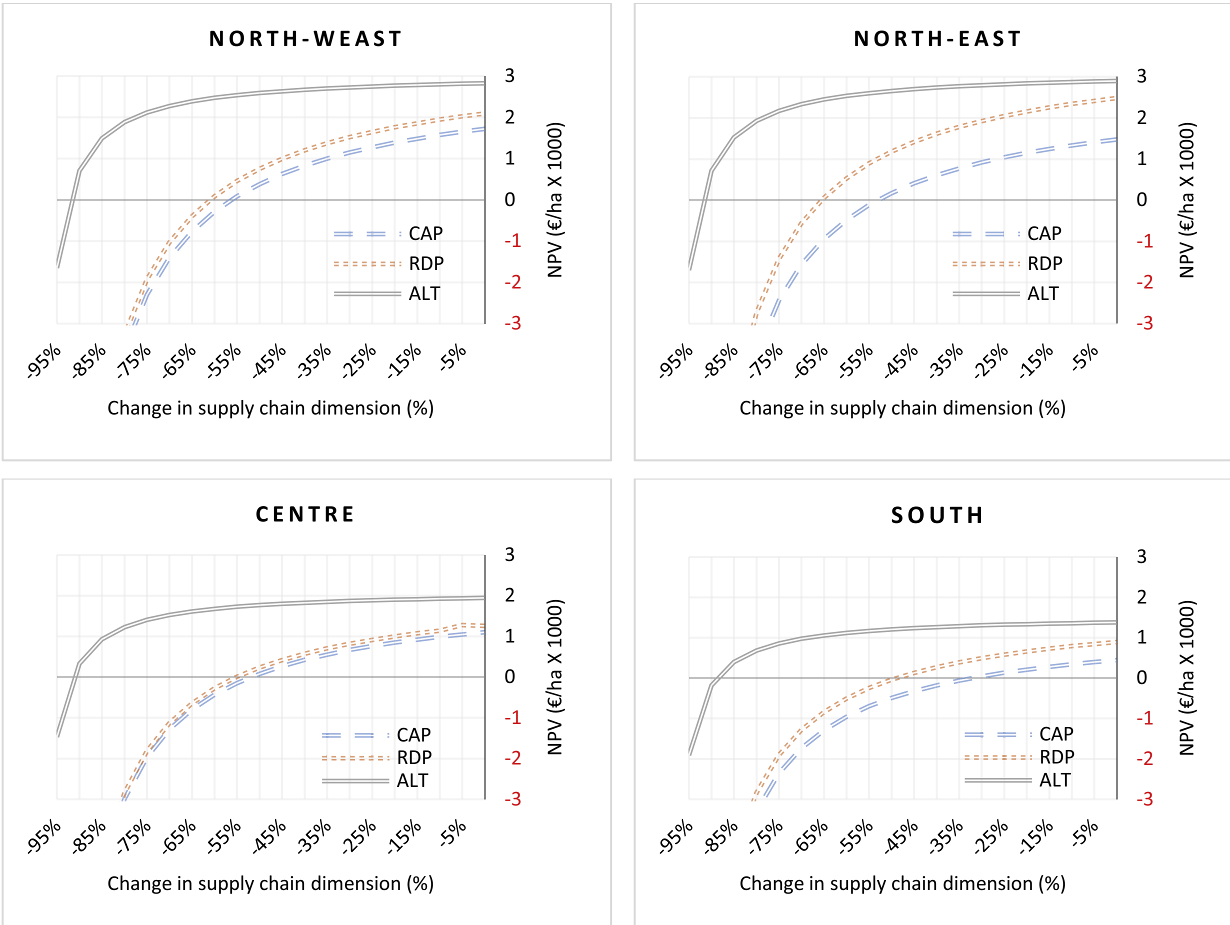

Fig. 4. Sensitivity analysis on Net Present Value (€/ha × 1000), as a function of change in supply chain dimension (%) for Alternative scenario (ALT), respect to CAP and RDP scenario.

current policy, it is possible to observe how the investment suitability is largely improved both in the case of diesel price decrease (Fig. 3) and, especially, in the case of size reductions of the supply chains (Fig. 4).

5. Conclusions

In order to reach the target of biofuels in the transport sector in 2020 and the one already envisaged in 2030, the production of first generation biofuels will continue to play a major role. However, sustainable production models, especially for raw materials, are needed. In this context, conservation agricultural (CA) practices (crop diversification, crop rotation, minimum or no tillage practices, etc.) could be a solution. The importance of such practices is likely to be promoted by the new CAP 2014–2020 through diversification obligations (first pillar) and incentives for sustainable practices (second pillar), representing an opportunity to increase the sustainable production of biofuels.

Rapeseed, the main European energy crop, lends itself to being cultivated in crop rotation with minimum tillage practices with a view to crop diversification on the farms. This cultivation model combined with the Straight Vegetable Oil (SVO) production, used as self-supply agricultural biofuel, could represent an opportunity for sustainable development of the biofuel supply chain, with enormous advantages for farmers, such as energy security and income diversification.

In the present study, an economic analysis was conducted to evaluate the feasibility of increasing the sustainable production of biofuels in Italy through the SVO supply chains. The results confirm this possibility: the proposed model allows farmers to comply with the requirements of crop diversification provided for access to direct payments and, at the same time, the latter ensure the profitability of investments, in particular for the regions of central-northern Italy. In the southern regions, the development of supply chains for the production of SVO is less advantageous due to low yields of the crop and the direct payments alone may not be enough to encourage farmers. In this context, the incentives for the minimum tillage practices envisaged by Measure 10 of the Rural Development Plans represent a further possibility of promoting biofuels by increasing the value of the investment, to the point of making it profitable also in the southern regions, protecting farmers from the risks connected. The sensitivity analysis has in fact highlighted how the realization of the SVO supply chains depends in particular on the price of agricultural diesel and the size of the supply chain itself. A reduction of one or the other could lead to a loss of investment return due to high initial costs, showing, in line with other studies, the importance of supporting investments in order to promote bioenergy, especially in rural areas. On the basis of this, with the aim of pursuing the objectives of promoting rural areas through bioenergy, one could imagine, in view of the new post-2020 CAP programming, support for new SVO production plants, as it already takes place for electricity and heat plants from the different renewable sources within the current RDPs.

The results of the work lead to a further point of reflection. The sustainability of biofuels, already under discussion with the revision of RED, which requires that energy crops are produced on agricultural soils to avoid problems related to changes in land use (both direct and indirect), must be re-evaluated, imagining that future cultivation systems adopt conservation agricultural practices. In particular, given that the main energy crops (rapeseed, maize, cereals) lend themselves to these production models, one could imagine: (i) to cultivate energy crops as secondary and/or tertiary crops, with a view to crop diversification, with the advantage of producing food, feed and fuel within the same farm, with positive effects on farmers' income and on the environment; (ii) to encourage crop rotation (environmental benefits); (iii) to promote the adoption of minimum tillage practices, guaranteeing advantages both for farmers (reduction of production costs, stabilization of production) and environment; (iv) to encourage the distribution of crop residues on the land, combined with the minimum tillage practices, in order to increase the soil organic carbon (SOC).

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