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System Dynamics Model to Design Effective Policy Strategies Aiming at Fostering the Adoption of Conservation Agriculture Practices in Sicily

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This paper presents a study based on System Dynamics Approach (SDA) whose aim is to support policy and decision makers to design effective policy strategies to foster the adoption of conservation agriculture practices in Sicily. The SDA is a methodological tool that can be used to study and manage complex and dynamic systems characterized by feedback mechanisms, which can be relevantly influenced by the policy&decision-making process and its delays. The SDA may help to define, implement and evaluate decision makers choices from the output of systems to stimulations from the outside. Scientific literature provides important experiences in the field of these simulation models, both for the development of ecological agriculture and for the simulation of the impacts of policy scenarios in a certain region/area.
Conservation Agriculture (CA) is a farming system, mainly for arable crops, which helps to achieve goals of sustainable and profitable agriculture. It is currently playing an ever-increasing role in the frame of EU agricultural policies in consideration of the positive impacts it can produce, in terms of sustainable use of natural resources as well as of Climate Change mitigation and adaptation. At farm level, moreover, CA represents a way to combine environmental and sustainability concerns with profitability and competitiveness aspects, in a variety of agroecological zones and farming conditions.
Short-term solutions and immediate benefits always attract farmers more than long-term ones. Unfortunately, the full technical, environmental and economic advantages provided by the adoption of CA can be measured and appreciated by farmers only in the medium and long-term, when its principles (minimum soil disturbance, permanent soil cover crop rotation) are well established within the farming system. This evidence, together with other technical, social and cultural forces, relevantly affects the process of CA adoption at farm level as well as the effectiveness of agricultural policy efforts aiming at this result.
The aim of this study is to validate a Systemic Dynamic Model (SDM) to be used in ex-ante evaluation to address the public action towards the effective achievement of the planned result of supporting the adoption of CA techniques in a certain region.
It seeks answers to strategic questions related to the elements that could influence the effectiveness of the support payment schemes programmed into the sub-measure 10.1 of 2014-2020 Sicily Rural Development Programme (SRDP). The SDA considers relevant variables which affect the application and dissemination of CA techniques among potential beneficiaries whose number is estimated based on sub-measure access conditions and restrictions. For this purpose, the model structure is based on environmental, social and economic issues, e.g. physical and economic farm dimensions, provision of machinery hire, advisory services, reduction of production costs, etc.
Results show that in a long term dynamic context the environmental support payment scheme provided by Measure 10 does not represent the only driving force in the system to guide farmers towards the expected shift from conventional to CA agriculture. What is needed is a deeper integration with other policies (innovation policies) and other interventions, e.g. schemes promoting precision farming, collective investments, advice, training and information.

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1. Introduction

Conservation Agriculture (CA) is a farming system, developed more than 70 years ago in the US mainly for arable crops, which helps to achieve goals of sustainable and profitable agriculture. It is currently playing an ever-increasing role in the frame of EU agricultural policies in consideration of the positive impacts it can produce, in terms of sustainable use of natural resources as well as of Climate Change mitigation and adaptation. At farm level, moreover, CA represents a way to combine environmental and sustainability concerns with profitability and competitiveness aspects, in a variety of agroecological zones and farming conditions, including mitigation of soil erosion, increase in soil organic matter, enhancement of aggregation and aggregate stability, reduction of energy consumption and carbon dioxide emissions, preservation of wildlife habitat and soil biodiversity, and savings in labour and time (Ruisi et al., 2014).
Unfortunately the full technical, environmental and economic advantages provided by the adoption of CA can be measured and appreciated by farmers only in the medium and long-term, when its principles (minimum soil disturbance, permanent soil cover and specific crop rotation targeting weed&pest control) are well established within the farming system. Minimum tillage and sod-seeding considerably reduce the overall impact of farming practices of the soil system and enhance the capability of soil to conserve water, nutrients and organic matter. This implies, as consequence, a higher level of soil biological activity and biodiversity. The CA management is nowadays used, especially for cereal sowing, over 155 millions of hectares all over the world (FAO, 2015), with a large diffusion in South and North America and Australia. In Europe (EU 27) CA is applied on 3.5 millions of hectares (Eurostat SAPM and FSS, 2010) which represent 3.5 % of total arable land area. In Italy the extend of CA is limited to about 380 thousands hectares in Northern regions.There are various reasons for the low rates of use of these techniques in the Mediterranean environments and these are primarily attributable to the lack of policies encouraging their adoption and, probably, also to prejudice on the part of farmers, as their positive effects are often not immediately apparent but can only be seen after a new equilibrium in soil properties has been established (Stubbs et al., 2004). Switching from conventional tillage to CA depends on various aspects related to structural farm characteristics and entrepreneurial skills. It is also highly site-specific and affected by exogenous factors e.g. policies, technological development, research, distribution process, etc. Farm low risk-taker attitude and limited knowledge of the CA techniques are also important aspects in the process of CA adoption at farm level mainly in start-up.
The transition from intensive tillage to conservation tillage entails a complete reorganisation of the production system to take into account any possible interactions among all the system components occurring across space and time (Ruisi et al., 2014). As showed by the results of KASSA project (http://kassa.cirad.fr/), in the European context the switch to CA systems can be achieved through a slow step-by-step process based on the natural habit of NoTill farmers in sharing experiences, results and creating networks (Marandola et al., 2010). In this process, a relevant role in stimulating the adoption of CA practices at European level is actually played by advisors but, moreover, by associations of farmers who are freely working to create networks and sharing experiences among farmers.A strong driver of the process of adoption of CA practices in Italy is currently played by 2014-2020 Rural Development Programmes (RDP), funded by the European Agricultural Fund for Rural development (EAFRD) that envisage a dedicated support scheme for farmers who decide, on voluntary base, to switch from conventional to CA agriculture. As showed in the table 1, nowadays 15 out of 21 RDPs in Italy have scheduled a dedicated payment tool for farmers within the frame of Measure 10 (Agro-environmental-climate payments scheme) (National Rural Network 2014-2020, 2017).

Table 1: Schemes dedicated to CA practices in Italian RDPs

Regional RDP	Name of the support scheme
Abruzzo	10.1.3 - Soil conservation
Basilicata	10.1.4 - Support to conservation agriculture techniques
Calabria	10.1.5 - Soil conservation and increase of soil organic matter
Campania	10.1.2 - Agronomic practices to increase soil organic matter
Emilia Romagna	10.1.4 - Conservation agriculture and soil organic matter
Friuli Venezia Giulia	10.1.1 - Conservation agriculture for arable crops
Lazio	10.1.5 - Conservation agriculture techniques
Lombardia	10.1.4 - Conservation agriculture
Molise	10.1.2 - Conservation agriculture techniques
Piemonte	10.1.3 - Conservation agriculture techniques
Puglia	10.1.3 - Conservation agriculture
Sardegna	10.1.1 - Soil protection actions
Sicilia	10.1.f - Adoption of conservation agriculture techniques
Toscana	10.1.1 - Soil conservation and soil organic matter
Veneto	10.1.1 - Agronomic practices with reduced environmental impact

2. Case study in Sicily

Conservation agriculture was introduced in Sicily around 1990 and for this reason it can be regarded as an innovation or innovative agricultural practice in the regional context.

At the beginning of the new century, holdings adopting CA practices (NoTill) in Sicily were only 7, for a total of 687 hectares of arable land mainly concentred in the area of Palermo and Caltanissetta. These areas are characterized by clay soils and production of durum wheat, with relevant problems of erosion and loss of fertility (Guccione, Schifani, 2001).

In 2010, according to the Istat Agriculture Census, 13,980 hectares of arable land area were under CA (about 2 % of the total arable land area) mainly located in the provinces of Palermo (38.8 %), Trapani (10.2 %) and Enna (15.2 %).

The 2014-2020 Sicily Rural Development Programme (SRDP) envisages a dedicated payment scheme for farmers who voluntary decide to adopt CA practices. This scheme, namely *Operation 10.1.f - Adoption of conservation agriculture techniques*, supports farmers with a surface annual payment (235 euro/ha/year) to compensate for 7-year's time the additional costs and the income forgone due to the respect of specific commitments going beyond the "baseline" commitments envisaged by the CAP (Pillar I).

The target result of this support scheme is 2,240 hectares of surface to be converted under CA practices within year 2023. For this aim, Sicily is also planning to combine the surface-payment scheme with other immaterial actions such as dedicated training, advice and dissemination.

The support scheme *Operation 10.1.f* envisages the following commitments that farmers have to comply with:

- Adoption of NoTill drilling techniques;
- Conservation of crop residues;
- Adoption of more efficient fertilization rates;
- On-going monitoring of weeds.

Farmers should adopt a dedicated crop rotation among winter cereals, legumes and forage crops. Monocultivation of winter cereals is allowed only for 2 years. The minimum farm area to participate as individual farm in this support scheme is 2 hectares and has to represent at least the 10 % of the total arable land of the farm. The participation is facilitated for farmers operating for more than the 50 % of the agricultural land in areas under risk of erosion (more than 6 t/ha/year) in areas under frail and critical risk of desertification according to the regional chart of desertification.

The payment scheme evidently recognizes the role of agriculture and farmers in the management of regional land and in the control of specific environmental problems. Anyway, the switch to CA practices is evidently influenced by many factors, especially the ones related to soil productivity, the overall farm management and the labour-machinery costs. In this sense it is important to clarify that short-term results with the adoption of CA are misleading (Troccoli et al., 2015).

The apparent contradictory results as well as considerable year-to-year variation, reported in several studies, demonstrate how the impacts on crop productivity are highly site-specific (Ruisi et al., 2014).

Other factor that can influence the adoption of CA is the "integrated-farming schemes" which envisages the commitment of adopting NoTill practices when farmers are operating on relevant slopes (more than 30 %) to reduce erosion and conserve soil.

3. Results

The SDA is a methodological tool that can be used to study and manage complex and dynamic systems characterized by feedback mechanisms, which can be relevantly influenced by the policy&decision-making process and its delays (Fiorani, 2009). In this study we present a System Dynamics Model (SDM) we built to explain the relationships between the most relevant determinants which affect switching from conventional agriculture to CA in Sicily in a dynamic perspective influenced by SRDP. According to the experience developed in other circumstances and contexts, we know that the success of CA implementation in a new environment is quite complex to be attained. Indeed, it needs principles transformation in farmers' understanding about farming system, their habit in conducting agricultural practices and also ability to think forward. Due to those change, CA promotion does not always end successfully (Dea Fitri, 2014). There are four hypothetical pathways towards adopting conservation agriculture (Baudron et al., 2007):

1. quick and complete adoption of conservation agriculture in its fullest form;
2. stepwise adoption of conservation agriculture practices, which may or may not lead to complete adoption over time;
3. conservation agriculture practiced during some cycles but not for the whole period;
4. use of conservation agriculture practices stops when incentives are no longer available.

Using the software Vensim PLE 6.4E we build a model based on three different stocks linked each other:

1. area under conventional agriculture (CV) that is equal to 680,690 hectares of arable land area (source: Eurostat SAPM and FSS, 2010);
2. area under CA that is equal to 13,980 hectares of arable land area (source: Eurostat SAPM and FSS, 2010);
3. area under organic farming (OF) that is equal to 111,543 hectares of arable land area (source: Sinab, 2015).

The last one is taken into account because it is a CA competitor since the two agronomic practices are in opposition.

On the basis of our analysis, determinants of CA adoption can be grouped into three broad categories:

- Economic determinants (CV machinery investments, CV machinery costs, CA machinery price, CA machinery market, Provision of machinery hire, Fuel price, Labour cost, Yield from CV, Nitrogen fertilisers price, SRDP 10.1.f payments, SRDP 11 payments);
- Socio-structural determinants (Farmers' age, Farm dimension, Training, Advisory services, Information, Integrated farming);
- Bio-physical determinants (Soil fertility, Drought, Soil erosion, Slope).

Figure 1 provides an overview of the main feedback loops. In order to show the relationships in the model, we used two types of polarity: a positive link was used when the increase of a variable generated an increase in another variable compared to the condition when the first variable did not change; negative link was used when the increase of a variable led another variable to decrease compared to the condition when the first variable did not change.

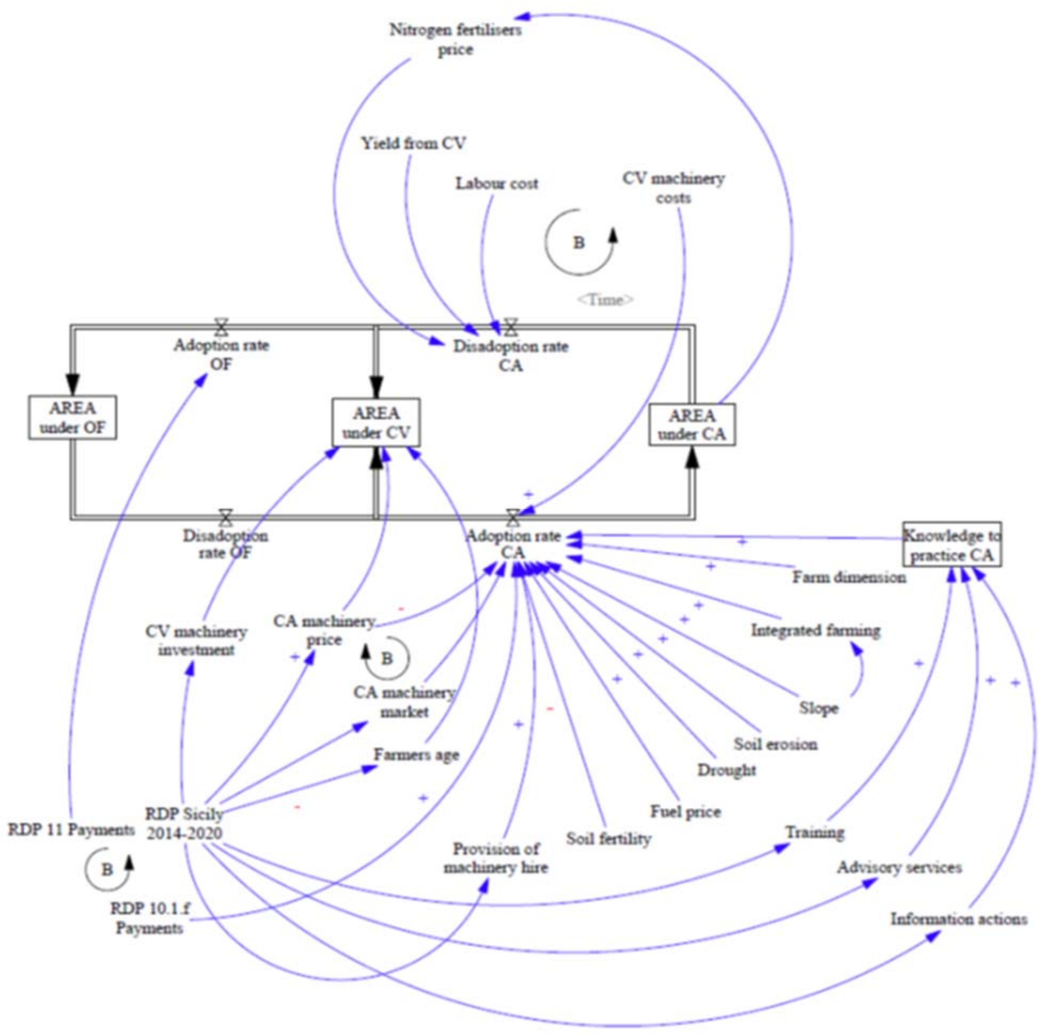

Figure 1: The main feedback loops in the SDM

A balancing loop ("B" in Figure 1) is a cycle in which the effect of a variation in a variable propagates through the loop and returns to the variable a deviation opposite to the initial one. The SDM shows how the determinants acting in CA machinery market and in knowledge transfer (training, advisory services, information actions) positively affect CA adoption rate. Similarly, Integrated farming in arable lands where average slope is more than 30 % and big dimension of farms foster the adoption of CA practices (Sicilian Region - Department of Agriculture, 2017).
In the course of the process (time is a "ghost" variable), after start-up, we suppose that the positive impact of CV machinery costs would be counterbalanced by the labour cost increase due to the more technical complexity of CA practice. The increase in the CA machinery price, caused by the demand growth supported by the Rural development programme of Sicily, would be likewise counterbalanced by a greater competition on CA machinery market. Another balancing loop is caused by the attractiveness of organic farming, supported by measure 11 – Organic farming (art. 29 Reg. EU 1305/2013) through an annual payment of less than 200 euro/ha/year and indirectly by other operations of RDP, which, in the period 2009-2015, led to a significant increase (+45.3 %) of the cereal cultivated area under OF (source: SINAB, 2015).
It is important to highlight that the stock level of CA area would be affected also by other exogenous variables such as insurance scheme, farm financial management, policy decisions, schemes promoting precision farming, other technological development, collective investments, distribution process and environmental education.
A final validation of the SDM presented in this paper could be done by analyzing the performance of the first public call for the *Operation 10.1.f* published by Regional Department of Agriculture in the last month of April.

4. Conclusions

The CA practices could be, in a long term perspective, an effective response to the dual need to increase the profitability of farms by reducing production costs and to contribute to reducing the environmental impact of farming, including, in particular, the waste of land due to erosion.
Enlightenment the factors that may get farmers to switch from a mere phase of interest in CA to an aware choice of change for the CV disadoption is crucial in the process of planning and implementation of operations financed by the rural development policies. The international literature does not provide univocal results in this direction whereas several studies show often conflicting findings (for example the supposed yield reduction during start-up) closely bound to specific site conditions.
The study presented here, confined to the Sicilian reality, does not have the ambition to provide the Authority Manager of RDP punctual suggestions to guide the implementation of the first public call for the Operation 10.1.f - Adoption of conservation agriculture techniques.
However, this paper outlines the basis for a subsequent development of the model in order to verify on one hand the interrelations of the variables identified in the constructed model and on the other hand the effectiveness of policy decisions concerning specific key points such as the priority of intervention (areas under erosion and desertification risks), payment amount, commitment duration, subsides for specific machinery and equipment, adequacy of information and knowledge transfer and last but not least the environmental impacts of the operation. We think to continue the path of study already traced through the results emerging from field studies on beneficiary and non-beneficiary farmers and from Farm Accounting Data Network (FADN) surveys.
The development of a multidisciplinary scientific debate is desirable in order to contribute to better understand the processes and the economic, socio-structural and biophysical variables underpinning the success of this management model for arable cropping systems.

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