PhD School on Agriculture, Environment and Bioenergy

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(XXXV cycle, 2019-21)

Project draft

1. Field of interest

AGR/02 - Agronomy and field crops

2. Project title

Carbon sequestration and nitrogen dynamics: Field and modelling study of cover crops

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4. Relevance of the topic and state of the art

Cover crops are agro-ecological service crops cultivated between two cash crops. In temperate climates, they are frequently grown during fall and winter, after a summer cash crop like maize. They are recognized to be able to perform important agro-ecological functions, such as the improvement of soil physical properties, the increase of soil organic matter (Poeplau and Don, 2015), the reduction of nitrate leaching (Tonitto et al., 2006), the enhancement of the nitrogen availability for the successive cash crop (Thorup-Kristensen et al., 2003), and the reduction of weed pressure (Teasdale et al., 2007). Cover crops can also increase the yield of cash crops (Marcilo and Miguez, 2017). Mechanistic simulation models can be used to evaluate cover crop mitigation effects in current versus future climate scenarios. However, the available soil-crop-atmosphere simulation models do not represent adequately the cover crop cultivation and its litter decomposition. In the representation of the cover crop, it is important to describe its termination, which can be performed mechanically or using non-selective herbicides like glyphosate. In specific conditions (e.g., early sowing time), cover crops lose hardening and are damaged by winter frosts, so that termination is no longer necessary. However, a clear framework describing cover crops hardening is lacking; which is limiting the successful implementation of cover crop-related processes in simulation models. Other important agro-ecological processes whose simulation needs to be added in cropping system models are: 1) the decomposition of cover crop litter layer decaying on the soil surface after termination (which reduces water evaporation, and releases or immobilizes nitrogen); and 2) the simultaneous and interacting growth of cover and cash crop when the cover crop is overseeded (i.e. sown before the harvest of cash crops).
The objectives of this PhD project were defined with the purpose of overcoming the lack of knowledge and the limited capability of the available simulation models in representing the cover crop cultivation. The specific objectives are: 1) to improve the understanding of field processes involving cover crop management (winter hardening; intercropping; and surface litter layer decomposition); and 2) to evaluate cover crop effects for climate change mitigation.

5. Layout of the project

5.1. Materials & Methods: da mezza pagina ad una pagina massimo

Three main activities will be carried out during the 3-year period. Details are given below.

5.1.1. The PhD student will define and set a 3-year field experiment aimed at estimating processes related to the development, growth, frost damage, and litter decomposition of two cover crops (e.g. purple vetch and white mustard) in two sites in the Lombardy plain. The observed variables will be: growing degree days of the main development stages; biomass production before winter and at the termination; biomass nitrogen and carbon content at termination; percentage of frost damage (i.e., dead cover crops, %); surface litter decomposition after cover crop termination (i.e., fractions of soil organic carbon at the soil surface and in the top soil two times per year); daily air and topsoil temperature with a weather station to be installed at the field experiment.
At one of the two experimental sites, it is planned to evaluate the biomass production and the litter decomposition of a cover crop (e.g., clover), which will be overseeded in winter wheat and maize, being the most common cash crops in Italy). This experiment will allow evaluating the opportunity of intercropping with a cover crop. In this experiment, the variables related to the possible competition between the cash crop and the cover crop will be observed: development stages, biomass production, height, and leaf area index.

5.1.2. The crop model ARMOSA (Perego et al., 2013) simulates the processes that take place in the soil-plant-atmosphere system. It is a useful tool for quantifying the effect of agronomic management practices, including crop rotation and tillage (ploughing, minimum tillage, sod seeding), on crop and soil-related variables, such as biomass production, grain yield, and soil mineral nitrogen and organic carbon. However, three relevant processes in the cover crop cultivation are not simulated by the current version of the ARMOSA model. Therefore, (1) one of the planned activities will be the implementation of a simulation module for the mathematical description of the soil surface mulch decomposition and the subsequent incorporation of the decomposed materials into the topsoil layer; (2) another improvement will be the addition of the mathematical description of the frost damage, whose prediction is of particular interest in the cover crop cultivation; this module will be first calibrated using the data acquired in the field activities (see 5.1.1.) and from the literature; (3) the third module to be added will simulate intercropping; data observed in the field experiment will be used for the calibration of the module.

5.1.3 The upscaling of the modelling study will be performed at European scale with the crop model ARMOSA with the aim of estimating the effect of the cover crop cultivation on soil carbon sequestration, nitrogen leaching, ammonia and nitrous oxide emissions, and cash crop yield under four scenarios of agronomic management: (1) conventional tillage under a standard crop rotation, (2) conventional tillage and cover crop in the crop rotation, (3) conservation tillage under a standard crop rotation, (4) conservation tillage and cover crop in the crop rotation. The climatic data of future scenarios, which will be available from the EU website Agri4cast, and the LUCAS soil database will be used to characterize the homogenous simulation units. This activity will be performed in the framework of the H2020 LANDSUPPORT project, which aims at quantifying the effect of optimized agronomic practices in the contrasting pedoclimatic conditions of Europe.

Available facilities: Several options are available for the experimental field location (e.g., commercial farms, the Angelo Menozzi University Experimental farm). The DiSAA laboratories are equipped for the planned analyses. Our research team is the developer and the owner of the ARMOSA code.

5.2. Schedule and major steps (3 years):

The schedule of the deliverables (D) and milestones (M) is split into three-month periods; details are given in the following table.

	1st year				2nd year				3rd year			
	1	2	3	4	1	2	3	4	1	2	3	4
M: Set-up of the experimental site	x											
M: Field measurments		x		x		x		x		x		
D: The simulation module of soil surface litter decomposition		x	x									
D: The simulation module of the frost damage			x	x								
D: The simulation module of the intecropping system				x	x							
D: Dataset of the field data						x						
M: Statistical elaboration of the field data							x					
M: Calibration of the three simulation modules								x	x			
D: Submission of a peer-reviewed paper									x			
D: Set of the input data for the European scale modelling analysis										x		
M: Application of the improved ARMOSA model at European scale										x	x	
D: Output of the European scale modelling analysis												x
D: Submission of a peer-reviewed paper												x

6. Available funds (source and amount)

H2020 LANDSUPPORT (Horizon 2020, European Union), 398.590 euro (principal investigator Dr. Alessia Perego).

7. Literature:

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Thorup-Kristensen, K., Magid, J., Jensen, L.S., 2003. Catch crops and green manures as biological tools in nitrogen management in temperate zones, in: Agronomy, B.-A. in (Ed.), . Academic Press, pp. 227–302. doi:10.1016/S0065-2113(02)79005-6

Tonitto, C., David, M.B., Drinkwater, L.E., 2006. Replacing bare fallows with cover crops in fertilizer-intensive cropping systems: A meta-analysis of crop yield and N dynamics. Agriculture, Ecosystems & Environment 112, 58–72. doi:10.1016/j.agee.2005.07.003