Geophysical Research Abstracts
Vol. 19, EGU2017-19438-1, 2017
EGU General Assembly 2017

A comparative analysis to quantify the biogeochemical and biogeophysical cooling effects on climate of a white mustard cover crop

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During the COP21, agriculture was recognised as a strategic sector and an opportunity to strengthen climate mitigation. In particular, the "4 per 1000" initiative relies upon solutions that refer to agro-ecology, conservation agriculture, . . . that could lead to increase carbon storage. Among those agro-ecology practices, including cover crops during fallow periods is considered as a fundamental agronomic lever for storing carbon. However, if biogeochemical benefits of cover-crops (CC) have already been addressed, their biogeophysical effects on climate have never been quantified and compared to biogeochemical effects. This comparative study (CC vs. bare soil), quantified and compared biogeochemical (including carbon storage) and biophysical effects (albedo and energy partitioning effect) of CC on climate.

An experimental campaign was performed in 2013 in Southwest France, during the fallow period following a winter-wheat crop (and before a maize). The experimental plot was divided in two: the northern part was maintained in bare soil (BS) while white-mustard (WM) was grown during 3-months on the southern part. On each subplot, continuous measurements of CO_2, latent and sensible fluxes (by eddy covariance) and solar radiation were acquired. Also, N2O emissions were measured by means of automatic chambers on each subplots. Moreover, by using a Life-Cycle-Analysis approach, each component of the greenhouse gas budget (GHGB) was quantified for each subplot, including emissions associated to field operations (FO). To quantify the albedo induced radiative forcing (RFα) caused by the white-mustard, the bare soil subplot was used as a reference state (IPCC, 2007). Finally, the net radiative forcing for each subplot was calculated as the sum of biogeochemical and biogeophysical (albedo effect) radiative forcing.

The white-mustard allowed a net CO_2 fixation of 63 g C-eq.m-^{2}, corresponding to 20% of the net annual CO_2 flux that year (-332 g C-eq.m-^{2}). Through the WM seeds, the amount of C imported to the field increased by 2 g C-eq.m-^{2}. As the white-mustard was buried and used as green manure for the next cash crop, the amount of C exported (when harvesting winter-wheat) was unchanged. Thus, the WM improved the NECB and reinforced the sink effect by 65 g C-eq.m-^{2}. Nevertheless, growing a CC leads to additional emissions associated to FO. They represented only 3 g C-eq.m-^{2} and can therefore be considered negligible. However, N2O emissions were reduced during the WM development. Finally, the GHGB of the WM subplot (-73 g C-eq.m-^{2}) was a significant sink while the GHGB of the BS subplot was close to neutral (-12 g C-eq.m-^{2}). By increasing surface albedo, the WM induced a biogeophysical cooling effect (-81 g C-eq.m-^{2}) equivalent to the GHGB of the WM subplot. In other words, the white-mustard cooling effect (compared to bare soil) is doubled if both biogeochemical and RFα are considered. This cooling effect was reinforced by the 53% increase in latent heat flux during the WM development. Finally, we estimated that the albedo cooling effect could be increased by 5-fold by maintaining the WM during 6-months. We conclude that through both biogeochemical and biogeophysical effects, cover crops represent a strong mitigation potential.