# CARBON BALANCE IN A KIWI FRUIT ORCHARD THROUGH THE COMBINATION OF MICROMETEOROLOGICAL EDDY COVARIANCE AND LIFE CYCLE ASSESSMENT APPROACHES

## *BILANCIO DEL CARBONIO IN UN ACTIDINIETO TRAMITE L'APPROCCIO EDDY COVARIANCE E LIFE CYCLE ASSESSMENT*

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**Abstract**

Literature reports that agriculture emits about 14% of the global anthropogenic greenhouse gas, but many uncertainties exist about the quantification of the amount of $CO_2$ captured and sequestered in biomass and soil by the various crop systems. Reliable long-term continuous monitoring of C fluxes are possible via micrometeorological methods, eddy covariance in primis. Emissions through the entire productive year can be, on the other side, inferred by Life Cycle Assessment analysis, based on the approach to calculate the local and global impacts, GHG releases included, due to a production process over its full life cycle. This paper presents a combination of these two techniques in calculating C balance of a kiwifruit orchard grown following a standard farm management practice in Northern Italy.

**Keywords:** kiwifruit, carbon balance, eddy covariance, life cycle anenment.
**Parole chiave:** kiwifruit, bilancio del carbonio, eddy covariance, analisi del ciclo di vita.

**Introduction**

Studies on the mutual complex feedbacks between man-managed vegetation systems and the environment have been progressively increased in the last years. The shortening of not-renewable resources, fossil fuels and water, the need to comprehend better possibile climate change effects and impacts (Olesen *et al.*, 2011), the requirement of undestanding carbon footprint specific of each economic systems, included the agricultural ones (Page, 2011), are only some of the issues now under major debate. Modern agriculture is often claimed as a heavy resource-user and high-impact activity during its whole chain (Xue and Landis, 2010), but important recognition of how farming may positively act in preserving environmental, landscape and social values in the rural society are emerging.

This work aims to quantify the balance between the physiological C absorption at orchard scale and the C emissions due to the man-made orchard management using a Life Cycle Assessment approach.

**Materials and Methods**

The data refer to 10-years old kiwifruit orchard (cv Hayward) located in the Valle del Lamone in Emilia Romagna. Plants were spaced 3x5 apart, and trained at T-shape. The orchard was equipped with an irigation system with 4 microsprinklers (4l/hour) /tree. Orchard management was the one conventionally adopted from kiwi growers in the region, and all the farming operations performed during the year were noted and reported to properly apply LCA.

*Eddy covariance*

A 3.5 m mast set up with a three dimensional sonic anemometer (CSAT-3D, Campbell Sci, USA) and an open path infra-red absorption gas analyser (IRGA) (Li7500, LiCor Inc.,USA) was installed in the orchard. On the same mast, a net radiometer (NR Lite, Campbell Sci., USA) was positioned at the same height to measure the net available energy at the surface. Wind, water vapour, carbon dioxide and temperature were sampled at 10 Hz and stored on a data logger.

Eddy covariance data processing followed the guidelines of the standard EUROFLUX methodology (Aubinet *et al.*, 2000). The half-hour mean flux values were post processed through the mean co-variances between w' and the scalars c', q' and T' (where w is the vertical component of the wind speed vector, c is the $CO_2$ concentration, q is the $H_2O$ concentration and T the air temperature). A data-check was applied together with routines to remove the common errors: running mean to avoid detrending problems, three angle coordinate rotations of the wind vector to remove the effects of instrument tilt or terrain irregularity on the airflow, despiking. Stationarity and surface energy balance closure were also checked.

Several different plots were present in the measurement area. This not homogenous condition is unavoidable in the local scenario, that includes a patchy mosaic of kiwifruits, peaches, wines and annual crops as wheat. We looked for the better location in choosing the orchard, but after that our concern was to assess how the not-homogeneous source-sink distribution could have partly conditioned a proper flux monitoring. Hence, a specific statistical analysis has been done to quantify the annual percentage of flux data coming from plot C and contributing to the total flux.

The major errors in calculating fluxes may occur during the nocturnal stable atmospheric conditions. To minimize this effects the storage of $CO_2$ in the layer below the eddy covariance measurements was estimated by using the time-change in the $CO_2$ concentration measured at the top of the mast. To avoid the underestimation of nocturnal surface exchanges, the night data were inspected to detect invalid values. Such a procedure was preferred to the more usually adopted correction based on established threshold u* value because of the regular structure of the orchard orography and the sparse arrangement of trees.

Data quality check and some occasional failure of the system led to a data coverage of 66% of the whole period. Therefore, a procedure of data gap filling was adopted to compute the annual and monthly NEE (Net Ecosystem Exchange). When the gaps were lower than three consecutive hours, data have been linearly interpolated. In all the other cases, the non-linear regressions method was applied. Missing values of Fc have been calculated by the regression relationships established between Fc and measured temperature (nightime) and radiation (daytime) on monthly bases.
Total carbon exchange terms were estimated both at year scale. The net ecosystem exchange (NEE) was computed from the complete series of the $CO_2$ exchange fluxes measured with eddy covariance and gap-filled using the non linear regression method above described. The ecosystem respiration (ER) was estimated by summing the quality controlled nighttime Re data and the values simulated, for the missing night data, using the monthly Lloyd and Taylor equation.

*LCA*

The evaluation of C emissions deriving from external input linked to the system management was analytically defined through the quantification of all input from the management of the orchard. Emission from embodied energy use have been defined by using SimaPro software, and consulting additional literature. $CO_2$ emission considered direct energy use (petrol, diesel and lubricants), embodied energy contained by all inputs (fertilizers, tractors and implements, irrigation system, fuel production, etc.), and equivalents linked to $N_2O$ emission from the soil.

**Results and discussion**

C annual absorption from the atmosphere due to plant and soil physiological activity and C release to the atmosphere inferred by quantifying C mobilization during the man-made operational orchard management have been quantified
Data, to be discussed and reported later, can be important to test the possibility to use such a combination of independent techniques in assessing reliable impacts of fruit growing in terms of sustainability, and to better understanding the role of agriculture in the new "ecosystem service" vision.

**Literature**


Aubinet, M., Grelle, A., Ibrom, A., *et al.*, 2000. Estimates of the annual net carbon and water exchange of forests: The EURO-FLUX methodology. Adv. Ecol. Res. 30: 113-175.

Olesen J.E., M. Trnka M., Kersebaum K.C. Skjelvåg, A.O. , Seguin B., Peltonen-Sainio,P., Rossi F., J. Kozyra J., Micale M., 2011. Impacts and adaptation of European crop production systems to climate change Europ. J. Agronomy 34, 96-112.

Nardino M., Pernice P. Rossi F., Georgiadis T,., Facini O., Motisi A., Drago D., 2013. Annual and monthly carbon balance in a intensively managed Mediterranean olive orchard. Photosynthetica, 51, 1, 63-74.

Page, G. (2011). "Modeling Carbon Footprints of Organic Orchard Production Systems to Address Carbon Trading: An Approach Based on Life Cycle Assessment. Hortsci. 46(2): 324-327.

Xue X.B., Landis A.E., 2010. Eutrophication potential of food consumption patterns. Environ Sci. Technol., 44 (16), 6450-6456.