360° Green Revolution: 0 greenhouse emissions through environmentally responsible agricultural production

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Paper prepared for presentation at the 119th EAAE Seminar 'Sustainability in the Food Sector: Rethinking the Relationship between the Agro-Food System and the Natural, Social, Economic and Institutional Environments',
Capri, Italy, June, 30th – July, 2nd, 2010

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According to several assessments, agriculture and forestry can play significant roles in mitigation policies as they are also a major sources of GreenHouse Gas (GHG) emissions. In particular farms play a strategic role in environmental preservation and the introduction of new technologies, together with modifications of types of farming and production processes, may decrease the influence of their activities on the environment. This study analyses a pilot project regarding GHG emissions and involves a farm, located in the province of Perugia (Italy), which is the first Italian example of "0 greenhouse emission" certification in accordance with UNI EN ISO 14064 standards. The reduction of GHG emissions generated by land use change and the value of a hypothetical public incentive for environmentally-friendly wine are estimated.

KEYWORDS: GreenHouse Gas (GHG) emissions, ISO 14064, wine

1. Introduction

The Kyoto Protocol aims at mitigating emissions of greenhouse gases (GHGs) into the Earth's atmosphere, in an attempt to limit climatic change, including those due to emissions from the food chain. The report of the International Assessment of Agricultural Knowledge, Science and Technology for Development (IAASTD, 2009) highlights the need to break the vicious circle of obsolete and polluting technologies, which are currently approaching the point of no return. In particular, intensive agriculture, which makes extensive use of chemicals, is one of the main causes of climatic change, and is directly responsible for 10-12% of GHG emissions at global level (Smith *et al.*, 2007). Intensive agriculture is also indirectly responsible for a further 30% of emissions through the conversion of forestland into cultivated land, the production of fertilizers, and the transport and transformation of foods.

In many cases, direct emissions are difficult to mitigate because they are intimately linked with the very nature of production (i.e., the extent of livestock production, presence of irrigation, etc.) although in several cases technical measures can be adopted to mitigate emissions from specific sources. However, considerable potential exists in agriculture for mitigating the effects of climate change. Modifying crop regimes and rotations, increasing the production of renewable energy, reducing tillage and

returning crop residues into the soil are just a few of these options (Wassmann and Vlek, 2004).
Nevertheless as effective options, generally, depend on local conditions - including climate, agricultural practices and socio-economic circumstances - there is no universally applicable list of such options (IPCC, 2007).
Agricultural households and enterprises need to adapt productions and technologies to reduce their GHG emissions, but they do not yet have knowledge of and expertise in handling these processes. Adaptation comes at a price and often requires investments in infrastructure.
Farms play a strategic role in environmental preservation (Cole *et al*., 1997) and the introduction of new technologies, together with modifications of types of farming and production processes, may decrease the influence of their activities on the environment. The introduction of decoupled payments by the European Community and the increasing attention focused on firm's social responsibility have meant that the more innovatively inclined farms try to contribute to the sustainable development. In the last ten years, one objective of these farms has been precisely the reduction in GHG emissions caused by production processes and energy consumption (Flessa H, *et al*., 2002; Rebelo De Mira and Kroeze, 2006).
The pilot project of the Monte Vibiano Vecchio farm, located in the province of Perugia (Italy), is the first Italian example of "0 greenhouse emission" certification in accordance with UNI EN ISO 14064 standards. The farm's "environmentally-friendly" approach has resulted in a reduction of GHG emissions from +286 tons of carbon dioxide milliequivalents in 2004 to -764 in 2008.
The introduction of the ISO 14064 certification has implied changing crop regimes, identifying innovative technologies, constructing monitoring protocols and planning integrated synergic actions which involve several aspects such as production, organization and marketing.

2. Agriculture and GHG emissions

According to several assessments, agriculture and forestry can play significant roles in mitigation policies (FAO, 2006; IPCC, 2007) as they are also a major sources of GHGs (Van Vuuren *et al.,* 2007).
Estimating agricultural emissions is an extremely complex operation, and estimates often are different. For example, Baumert *et al.* (2005) estimated that agricultural activities account for 15% of global GHG emissions leading to climate change, whereas McIntyre *et al.* (2009) estimated about 30%.
According to Smith *et al.* (2007), agriculture accounts for estimated emissions of 5.1 – 6.1 $GtCO_2$-eq/yr in 2005 (10-12% of total global anthropogenic emissions of GHGs). This in particular holds for methane (CH_4) and nitrous oxide (N_2O), both with higher global warming potential

than CO_2, CH_4 contributes 3.3 $GtCO_2$-eq/yr and N_2O 2.8 $GtCO_2$-eq/yr. Of global anthropogenic emissions in 2005, agriculture accounts for about 60% of N_2O and about 50% of CH_4. Methane emissions are primarily caused by livestock production and flooded rice paddies, N_2O emissions are due to the use of organic and inorganic N fertilizers. Lastly, CO_2 emissions are also caused by land use changes and agricultural practices.

Despite large annual exchanges in CO_2 between the atmosphere and agricultural lands, the net flux is estimated to be approximately balanced, with CO_2 emissions around 0.04 $GtCO_2$/yr only (Smith *et al.*, 2007).

According to all authors, a variety of options exists for mitigation of GHG emissions in agriculture. The most prominent options are improved crop and grazing land management (e.g., improved agronomic practices, nutrient use, tillage, and residue management), restoration of organic soils which are drained for crop production, and restoration of degraded land. Lower but still significant mitigation is possible with improved water and rice management; set-asides, land use change (e.g., conversion of cropland to grassland) and agro-forestry as well as improved livestock and manure management. Many mitigation opportunities use current technologies and can be implemented immediately, but technological developments will be a key driving force ensuring the efficacy of additional mitigation measures in the future (Smith *et al.*, 2007).

Some studies emphasize the high degree of uncertainty in their estimates of potential mitigation capability (Cole *et al.*, 1997; Flessa *et al.*, 2002). The major source of uncertainty is the lack of baseline data on land use and GHG fluxes, as regards global estimates of potential mitigation of emissions (Cole *et al.*, 1997). Another significant source of uncertainty is due to integrated analyses of GHG emissions covering the entire production chain and including the life-cycle of agricultural inputs (Flessa *et al.*, 2002). Therefore, there is no universally applicable list of mitigation practices: practices need to be evaluated for individual agricultural systems based on climate, edaphic and even social settings, and historical patterns of land use and management (Smith *et al.*, 2007).

The need to move toward more sustainable patterns of production is more pressing than ever. But farmers will not usually voluntarily adopt GHG mitigation techniques unless they can improve profitability or unless consumers are particularly interested in purchasing “green” products. The awareness of consumers of the environment and their preference for more environmentally-friendly products appears to be growing steadily around the developed world and also in some developing countries (Rashid, 2009). In addition, within the marketing literature, there is growing consensus that the green market is significant and that companies can profit by improving their environmental performance and developing green products (Ottman, 1993; Wiser, 1998; Wüstenhagen and Bilharz, 2006). However, not all green products are successful in attracting customer interest, and customer

surveys of attitudes toward, and even intended purchases of green products often substantially overestimate actual product demand (Kempton, 1993).
As with all products, green products must overcome traditional marketing challenges to increase demand and narrow this gap between stated intentions and purchase behavior. Yet it is also now recognized that there are many obstacles to selling green products which do not arise in traditional product marketing (Wiser, 1998).
A recent survey by Eurobarometer, conducted in order to examine EU citizens' knowledge and levels of concern about sustainable consumption and production, showed that: a) slightly more than 80% of EU citizens felt that a product's impact on the environment is an important point when deciding which products to buy, but only a small majority claimed that, when buying or using products, they are – generally – fully aware or know about the most significant impacts of those products on the environment; b) almost six out of ten interviewees rated environmental impact as more important than a product's brand name in terms of influencing their purchasing decisions, but only a minority rated environmental impact as more important than a product's quality or price; c) information about the total amount of GHG emissions released by a product – i.e. the carbon footprint – was considered to be important and about three out of ten EU citizens believed that the best way to promote environmentally friendly products is to provide better information to consumers. But, at the same time, most of them stated that they do not trust producers' claims about the environmental performance of their own products.
These survey results clearly show that the greatest obstacles to sales are due to the lack of trust in "what is written on the label", the greater importance assigned to product price and quality, and the essential role of information about a topic – the environmental impact – associated with the emission of GHGs.
In the mid-2000s, the International Organization for Standardization (ISO) highlighted the need to standardize the aspects of accounting and verification of GHG processes in order to sustain the credibility, comparability and environmental integrity of already existing and emerging regulatory schemes (international, national and regional) and voluntary schemes for GHG reduction. The method most widely used today to prepare corporative inventories of GHGs is the Corporate Accounting & Reporting Standard (GHG protocol), which was developed under the auspices of the World Resources Institute (WRI) and the World Business Council for Sustainable Development (WBCSD).
The objective of the ISO, in developing standards for accounting and reporting of GHGs, is to supply a set of unequivocal and ascertainable requirements supporting organizations and proposers of GHG reduction projects through a method of quantification, control and verification to ascertain that "one ton of carbon is always one ton of carbon". In particular,

ISO 14064 - GHG supplies governments and enterprises with an instrument of reference, for both quantifying, managing and reduction GHG emissions and facilitating communications to consumers, partly by enhancing the credibility of enterprises.

3. Objectives

This study analyses a pilot project regarding GHG emissions, and involves a farm which received certification according to ISO 14064 standards. The aims of this study were:

1. to estimate the reduction of GHG emissions generated by land use change, improved woodland management, to replace tobacco management with winery ones, to replace diesel fuel tractors with biodiesel ones, use of organic instead of inorganic fertilizer;
2. to illustrate the method for identifying emission sources and minimizing uncertainty associated with calculations to complete the Protocol and Monitoring Report of GHGs;
3. to analyse the mean production cost of a bottle of wine, and to assess the influence of costs in reducing emissions and consolidating the image of the farm on the wine market;
4. to estimate the value of a hypothetical public incentive for farming green product;

4. Materials and methods

4.1. Farming systems

Two farming systems were examined: Farm A, before investments with the old cropping system; Farm B, after investments with the new cropping system. In 2003, over 30% of farm UAA was under tobacco and the farm had some diesel ovens for initial processing of tobacco (capacity: 180 tons). The remaining area was under cereals (45% of total UAA), olive groves (10%) and vineyards (11%) which, having been recently planted, were not yet productive (Table 1). Production of wine came into full swing a few years later, and in 2008 the farm began to use a modern winery, construction of which had begun in 2003, and it was now endowed with more than 271 barriques and 54 tanks, all monitored for maintenance of the proper temperature during the whole process of fermentation. Tobacco production gradually decreased until it was completely abandoned in 2007. The hectares previously under tobacco were replaced by sunflower, cereals and alfalfa. The area under wood was also increased from 160 hectares in 2003 to more than 200 in 2008 (+26%). Therefore, within five years, the farm's

cropping system had changed: in 2003, farm A comprised tobacco, cereals and olive groves, whereas in 2008, farm B had vineyards, cereals and olive groves.
The farmer decided to abandon tobacco growing in 2003 when, according to Franz Fischler's suggestion, the European Commission introduced a reform proposal for the CMO of tobacco, with the aim of fighting tobacco addiction by introducing decoupled payments for the cultivation of tobacco which is usually considered an unethical crop. The reform became effective in 2006, and the maintenance of subsidy payments is to be continued until 2013, by introducing a first partial decoupling from 2006 to 2010 (60% of coupled payments and 40% of decoupled payments), followed by a second decoupling from 2010 to 2013 (50% of coupled payments and 50% of decoupled payments).
Replacing tobacco with vineyards was a bold choice for the farmer, since it led to a considerable reduction in CAP subsidies, the incidence of which on total farm revenue decreased from 53.4% in 2003 to 21.6% in 2008. This choice also implied the need to enter the market of quality wine; consequently, wine turnover increased from 0% in 2003 to 38% in 2008.
These choices were motivated by the following farm strategies:

a) increased environmental responsibility of the farm;
b) increase in quality products such as olive oil and high-quality wines.

These strategies were pursued by: 1) increased attention to farm wood management, aimed at increasing CO_2 absorption; 2) replacement of tractors fuelled by diesel with ones using biodiesel, made from oil crops (1^{st} generation); 3) increasing use of organic instead of inorganic fertilizers. In particular, thanks to changes in the crop system, the use of inorganic fertilizers decreased overall by 42% whereas that of organic ones increased by 18%, especially for vineyards (Table 1).

4.2 Facilities and sources of emissions

The farm's emissions were subdivided into five areas, called *facilities*, where the farm was authorized to implement either financial or operational policies: Winery, Farm Offices, Agricultural Equipment, Fields and Tobacco Ovens. GHG sources and absorbers were associated with each facility. The organization, under the control approach, accounted for 100% of GHG emissions from operations over which it had control. Overall emissions, as required by the ISO 14064 standard, were classified into two categories: a) direct emissions, i.e., emissions from sources owned or controlled by the farm; b) indirect emissions, resulting from the generation of electricity purchased and consumed by the farm.
In detail, the Winery facility included winery buildings and the caretaker's house. Direct emissions were those due to natural gas combustion in the

heating system, wine fermentation and refrigeration gas leaks; indirect emissions were those from consumption of electricity. Farm Offices comprised the administrative structure, offices and a workshop. Accounted emissions derived from natural gas combustion, refrigeration gas leaks and indirect emission from electricity. All equipment necessary for agricultural activities fell under the heading Agricultural Equipment: tractors, harvesters, electric irrigation water pumps etc.. Emissions from combustion of diesel oil and consumption of electricity were quantified.

The Fields facility included all cropland and woodland of the organization. Related GHG emissions were essentially due to the use of nitrogen fertilizers, whether inorganic or organic. Vineyards and woods, considered as sources of CO_2 removal or absorbers, were included in this facility. Lastly, the Tobacco Ovens facility was composed of the ovens used to dry tobacco. Direct emissions from the combustion of natural gas and indirect ones due to the consumption of electricity were also taken into account.

Cultivation of olive groves and the pressing and packing of the resulting oil were not taken into consideration in this analysis, for the following two reasons: 1) cultivation of olive groves and marketing of olive oil were managed by a branch of the farm operating under another, autonomous, regime; 2) this sector is extremely energy-consuming, because of its particular marketing organization: the production and sale of very small single-use bottles, for airline passengers.

4.3 Inventory analysis

GHG accounting and reporting was based on relevance, completeness, consistency, transparency and accuracy.

Methods identified were to minimize the uncertainty associated with the data. It was necessary to record and complete a comprehensive inventory uncertainty assessment, applying the principles and methods presented in Guide to the expression of Uncertainty in Measurement (GUM) (1993).

4.3.1 Indirect emission accounting

Although indirect GHG emissions are the consequence of farm activities, they may occur at sources owned or controlled by another farm. The only source of indirect emissions is electrical energy purchased and consumed by the farm.

According to Intergovernative Panel on Climate Change (IPCC) methodology and based on data availability, CO_2 equivalent emissions from the consumption of electricity were calculated as follows:

$Q = E * F_{EN}$ (Equation 2.1; IPCC, 2006a) [1]

Q: GHG emissions (g CO_2eq);
E: Electric Energy Consumption from Enel Energy invoices [kWh];
F_{EN}: Emission factor [g CO_2eq /kWh].

GHG emissions from electricity consumption were quantified for Winery, Company Offices, Tobacco Ovens and Agricultural Equipment facilities. The emission factors take into account the Italian electricity production mix.

4.3.2 Direct Emissions Accounting

Direct emissions derive, for example, from plants, power systems and vehicles owned or operated by the farm itself. This study examines emissions from the combustion of natural gas and subsidized fuel, wine fermentation, use of nitrogen fertilizers and refrigerating gas leakages in air-conditioning plant.

Natural Gas Combustion
The farm had three delivery points of natural gas: in the Winery, near the Tobacco Ovens, and near the Offices. The general method for estimating emissions from combustion of natural gas was according to the IPCC (2006a), following a tier 1 approach and assuming an oxidation factor of 1:

$$Q_i = S * P.C.I * EF_i * C \qquad [2]$$

where:
Q_i: quantity of substances emitted (kg);
S: fuel consumption provided by Enel (Sm3);
PCI: natural gas calorific value (kJ/Sm3);
C: oxidation factor;
EF_i: emission factor for the substance (56100 kg CO_2/TJ; 0.1 kg N_2O/TJ; 5 kg CH_4/TJ (GUM, 1993));
i: pollutant emitted (CO_2, N_2O or CH_4).

The total quantity of equivalent CO_2 (CO_2eq) in tons was determined by multiplying Q_i calculated emissions for global warming potentials for a time horizon of 100 years (GWP), deducted from Appendix C of ISO 14064-1, as expressed in following equation:

$$CO_2eq = Q_{CO2} * GWP_{CO2} + Q_{N2O} * GWP_{N2O} + Q_{CH4} * GWP_{CH4} \qquad [3]$$

where:
Q_{CO2}: quantity of CO_2 emitted (t);
Q_{N2O}: quantity of emitted N_2O (t);
Q_{CH4}: quantity of CO_2 emitted (t).

Wine fermentation

The calculation method was based on Eq. (4), in which the sugar content of grapes is converted into ethanol, with the release of carbon dioxide:

$$C_6H_{12}O_6 \rightarrow 2\ C_2H_5OH + 2\ CO_2 \quad [4]$$

Emissions were calculated using a model of Forsyt *et al.*, (2008), which requires as input data the total quantity of grapes processed annually (Crush Size), the Typical Press Extraction and the average sugar content expressed in Baume. The model also required data on the possible amount of added juice to optimize fermentation and the residual sugar content in the resulting wine. As the farm produces red wine, it was also necessary to take into account emissions from malo-fermentation, during which malic acid is converted into lactic acid and carbon dioxide. Introducing into the model the quantity of malic acid present in grapes, it can calculate the resulting CO_2 with Eq. (5):

$$CO_2 \text{ produced} = 0.33 \text{ (mass of malic acid)} \quad [5]$$

Use of nitrogen fertilizer

Nitrous oxide emissions, including indirect N_2O emissions and CO_2 emissions from urea-containing fertilizer, were calculated according to the method provided by the IPCC (2006a).

It was therefore essential to evaluate the quantity of organic and inorganic nitrogen used by the farm annually. A separate assessment was carried out for urea because in addition to the direct and indirect emissions of nitrous oxide, it was necessary to consider the amount of carbon fixed during the industrial production process and lost during distribution of urea in the soil.

Simplifying equation 11.1 of IPCC (2006b), direct emissions of nitrous oxide were calculated with Eq. (6):

$$N_2O - N_{DIR} = [(F_{SN} + F_{ON}) * EF_1] \quad [6]$$

where:

F_{SN} : Annual amount of synthetic nitrogen fertilizer applied to soil (kg N/year);

F_{ON} : Annual amount of nitrogen from animal manure, compost, sewage sludge and other organic materials (kgN/year);

EF_1 : Emission factor for N_2O emissions from N inputs [0.01kg N_2O-N (kg N)$^{-1}$].

Indirect emissions from leaching and volatilization were assessed by applying the method described in IPCC (2006a).

Assessment of CO_2 emissions due to the use of urea was carried out with Eq. (7) (equation 11.13; IPCC, 2006a):

$$CO_2 - C_{Emission} = M \cdot EF \qquad [7]$$

Where:
$CO_2 - C_{Emission}$: Annual C emissions from application of urea [tons C (year)$^{-1}$];
M: annual amount of urea used [ton urea (year)$^{-1}$];
EF: emission factor [0.20 ton C (ton urea)$^{-1}$].

Multiplying by 44/12, CO_2-C emissions can be converted into CO_2.
Lastly, the total quantity of CO_2eq was determined by multiplying N_2O and CO_2 emissions for its global warming potential (Eq. 8) for a time horizon of 100 years (GWPI), deduced from Appendix C of ISO 14064-1.

$$CO_2eq = CO_2 * GWP_{CO2} + N_2O_{DIR} * GWP_{N2O} + N_2O_{ATD} * GWP_{N2O} + N_2O_L * GWP_{N2O} \qquad [8]$$

Diesel Oil Combustion
Emissions were calculated from the annual quantities of subsidized diesel fuel, representing accurate data, although not subdivided among various machines. In accordance with the IPCC method (2006a) on the tier 1 approach of mobile sources, emissions of CO_2, N_2O and CH_4 were calculated with Eq. (9):

$$Q_i = F * EF_i \qquad [9]$$

Where:
Q_i: quantity of substances emitted (kg);
F: amount of fuel used (TJ);
EF_i: emission factor (74100 kg CO_2/TJ; 4.15 kg CH_4/TJ; 28.6 kg N_2O/TJ);
i: pollutant emitted (CO_2, N_2O or CH_4).

The total quantity of CO_2eq was determined by multiplying Q_i emissions for its global warming potentials for a time horizon of 100 years (GWP).

4.4 GHG Removals

ISO 14064 defines GHG removal as the total mass of a GHG removed from the atmosphere over a specified period of time, and the GHG sink the physical unit or process which removes a GHG from the atmosphere. In the case of the farm, GHG sinks were represented by the vineyards (about 37 ha) and the woodland owned by the farm (about 205 ha).

Vineyards
The absorption of CO_2 by vineyards was determined by applying the model described in Forsyt *et al.* (2008), which requires as input data the average sugar content at harvest and the quantity of grapes processed annually

(Crush Size). With photosynthesis equation (10), the amount of CO_2 needed to produce sugar is calculated:

$$CO_2 + 12\ H_2O + \text{photons} \rightarrow C_6H_{12}O_6 + 6\ O_2 + 6\ H_2O \qquad [10]$$

However, sugar is only part of the photosynthetic process, so we must also consider the growth of fruit clusters, branches, permanent structures and plant roots. The model assumes that the roots biomass can be approximated as 25% of above ground biomass, with a carbon content of 48%. It is assumed that CO_2 sequestration occurs in fruit, permanent structures, the root system and, partially, in the ground, thanks to the aerobic decomposition of prunings.

Woodland

To assess the net balance between CO_2 emission and removal, the IPCC method is based on the assumption that changes in carbon stocks in the ecosystem primarily occur through exchange of CO_2 between the land surface and the atmosphere. Thus, an increase in carbon stocks over time is equivalent to removing CO_2 from the atmosphere, and a net decrease of the stock to net emissions in the atmosphere. The change in carbon stocks was developed for biomass, and the contributions of litter and soil were excluded, as no data were available on their management. The "Gain Loss" method was used, in which the change in carbon stock is calculated as the difference between carbon fixed in plant biomass during annual growth and carbon removed, as expressed in Eq. (11):

$$\Delta C_B = \Delta C_G - \Delta C_L \qquad [11]$$

where:
ΔCB: annual change in carbon stocks in biomass (tC/year);
ΔCG: annual increase in carbon stocks due to growth of biomass (tC/year);
ΔCL: annual decrease in carbon stocks due to loss of biomass (tC/year).

The annual increase in woodland biomass was calculated applying Eq. (12) (equation 2.9, IPCC 2006b):

$$\Delta C_G = \sum_i (A_i \cdot G_{TOTi} \cdot CF_i) \qquad [12]$$

where:
Ai: area of a woodland type (ha);
G_{TOT} i: average growth of total biomass (t_{dm} (ha year)$^{-1}$);
CF_i: carbon fraction in dry matter (tC/t_{dm});
i: woodland species.

The average annual biomass growth above- and below-ground was obtained with Eq. (13) (IPCC, 2006b):

$$G_{TOTi} = \sum I_V \cdot BCEF_I \cdot (1 + R) \qquad [13]$$

where:
I_V: average net annual increase for a vegetation type (m^3/ha per year$)^{-1}$);
$BCEF_I$: conversion and expansion factor for the conversion of net annual increment in volume to above-ground biomass growth for specific vegetation type (tons of above-ground biomass growth (m^3net annual increment$)^{-1}$);
R: ratio of below-ground biomass to above-ground biomass for a specific vegetation type, in tons d.m. below-ground biomass (ton d.m. above-ground biomass$)^{-1}$.

The data required to implementing this method were extrapolated from detailed reports on the state of woodland owned by the farm, carried out by forestry experts to ensure more detailed calculation and accurate correspondence to reality, thus reducing the uncertainty in the GHG removal assessment.

5. Results

5.1 Emission of CO_2 equivalent

The application of the methods described above allowed us to quantify the emissions produced by the farm and the uncertainty associated with the GHG Inventory. Overall, there was a net reduction in emissions, from -224 t CO_2eq in 2003 to -764 t CO_2eq in 2008 (Tables 2 and 3). This great decrease was mainly due to cultural reconversion during these years. In fact, the production of tobacco had fallen since 2003, and thus so did the consumption of energy required for drying the crop; in 2007, the tobacco owns were closed, leading to a reduction in total farm emissions. A decreasing trend was highlighted in agricultural equipment emissions, particularly in 2008, mainly due to a decrease in fuel consumption and the use of biodiesel in the new tractors. Agricultural Equipment emissions fell from 305 tCO_2eq in 2003 to 120 tCO_2eq in 2008. Offices emissions remained almost constant over the years and did not play an important role in the total inventory.
Regarding the Winery facility, emissions were closely linked to the production of grapes and wine. 2003 was the first year of harvest production was low, and Winery emissions in 2003 therefore only amounted to 33 tCO_2eq. In 2008, they were about 75 tCO_2eq. Fields emissions were essentially due to the use of nitrogen fertilizers and the felling of timber for

firewood in the woods. This facility contained the woodland and vineyards, which is why there were no emission but absorption.

5.2 Environmentally-friendly actions

According to the GHG Inventory and Guide Lines of ISO 14064-2, the farm identified several actions aimed at reducing its own environmental impact. Although its balance sheet was in credit, it continued to invest in actions involving all the sectors related to farm activities: renewable energy, farm transport rationalization, efficiency in energy savings, use organic fertilizers, woodland management, introduction of Green IT measures in offices (e.g., servers on standby, recyclable paper, reduced number of printers). In order to replace cement-asbestos envelopes, integrated photovoltaic panels (incorporated within the outer surface of the farm buildings) were installed, producing a total of 50 kWp of power at peak times. These panels produce about 60% of the farm's energy consumption. The farmer intends to amplify the photovoltaic system, in order to satisfy the overall electric energy requirements of the farm.

The farm was also equipped with a photovoltaic filling station and several electric vehicles for worker transport on the farm. In the filling station, a 7.5 kWp dual axis tracking photovoltaic system produces electric energy, which is then stored in a battery where a vanadium electrolyte keeps it charged, minimizing losses; this energy is used to supply the electric vehicles.

The roofs of the silos where cereals are usually stored, were painted with a special high-albedo paint. Several laboratory tests were carried out to verify the reflective properties of this material, and a certificate was issued, attesting that the roof surfaces of the silos offsets about 25 tons of CO_2 released into the atmosphere. This amount was calculated by mathematical method which assesses both the effect of the Earth's average reflection coefficient on global temperature and the reflecting surface equivalent to one ton of CO_2 released into the atmosphere. In the future, rolling stock will gradually be replaced with 2nd-generation biofuels only, and organic fertilizers will completely replace inorganic ones.

Regarding woodland management, the farmer intends to extend proper management to new woodlands that are currently in a state of abandon.

5.3 Cost analysis

In 2003, the farm made some investments, both to reduce GHG emissions and to extend high-quality production. These investments concerned: a modern winery, the cost of which was approximately 2,400,000 euro; renewal of vineyards (for a total cost of 880,000 euro); substitution of three diesel tractors with three biodiesel models which did not involve any cash outlay but the value of which was estimated at 40,000 euro per biodiesel tractor. Today, the winery has an average productive size of 250,000 bottles of wine per year (production fluctuates from 50 to 60 hectoliters per hectare). Three types of red wine are produced, belonging to three different price ranges: 1) IGT red wine of Umbria, which accounts for 40% of total production (the selling price is 3 euro/bottle); 2) DOC red wine of Umbria, which accounts for another 40% of total production (5 euro/bottle); 3) a premium-quality DOC red wine, which accounts for 20% of total production (15 euro/bottle). The estimated total turnover of the wine sector was 1,550,000 euro, and the average price of one bottle of wine was 6.20 euro. According to the above data and the total cost of investments, including the value of the biodiesel tractors, the share payback charge accounted for 0.57 euro/bottle, assuming an economic life expectancy of 25 years for the winery and the vineyards, and 10 years for the tractors. The total amount of average passive interests was 0.26 euro/bottle, considering a period of 25 years and an interest rate of 4.5%.

The operating costs of the vineyards and the winery amounted to 5.11 euro/bottle, distributed as follows: 1.10 for cultivation, energy, taxes and insurance; 1.97 for processing, packaging and marketing; 2.04 for labour.

In addition to these costs, we examined the costs of actions aimed at reducing GHG emissions. They included: increase in annual cost of partial substitution of inorganic fertilizers with organic ones, increase in annual cost of partial substitution of diesel with biodiesel, costs related to environmental certification (total of 1.3 euro/bottle).

We also considered costs for rent and maintenance of 40 hectares of woodland, which was leased out in order to increase the absorption of CO_2; this cost accounted for 0.03 euro/bottle.

Lastly, our analysis included costs for communications promoting the image of the farm and the environmental certification. These included the cost of the ISO 14064 certification, international promotion events and the purchase of electric vehicles for internal transport. Considering an economic period of five years, these costs amount to 0.15 euro/bottle.

The overall average cost of a bottle of wine was 6.20 euro (which exactly corresponded to the mean selling price of one bottle).

Table 4 lists the percentage of expenditure for each cost item.

Concluding this cost analysis, we emphasize the fact that the environmental image of the farm has been enhanced: from the existence of a 50-Kw photovoltaic plant, costing 380,000 euro, which has annual running costs of 8,000 euro and generates 40,000 euro from sale of energy; a photovoltaic station to fuel electric vehicles, provided on loan for use; and, lastly, the special high-albedo paint coating the cereal silos, which cost about 2,000 euro.

These expenses were not included in the wine production costs, since they are either not directly imputable to that activity (e.g., the special paint), because they were not really spent (e.g., the photovoltaic station to fuel electric vehicles, provided on loan for use) or because they constitute an autonomous cost/benefit activity (e.g., photovoltaic plant).

5.4 The “360° Green Revolution” label

The consumers are informed of the environmental results achieved by the farm through the labels on bottles of wine.

The front label was conceived as a kind of “visiting card”: the farm presents itself as an ecologically responsible company, uses a natural symbol in colour, with the words “360° Green Revolution”, quotes the ISO 14064 certification, and adds its internet site. The back label is clear and concise and, in an eight-line text, briefly describes a radical and innovative project, with the aim of informing the consumers about its ecologically responsible attitude to agricultural production.

An exploratory survey, carried out at the farm's sales point and involving 150 consumers, showed that 85% of the interviewees were prepared to pay a premium price, ranging between 5% and 30% of the purchase price, for two types of red table wine, one IGT and one DOC. The percentage of interviewees fell to 74% for the top-quality DOC wine. This indicates that consumers attribute a stronger link between safeguarding of the environment and repeated purchases (table wine and DOC wine of average price), than between safeguarding the environment and purchases associated with special, and therefore occasional, events.

Asked for their opinion about the “360° Green Revolution” label, 73% of interviewees said they had been attracted by the front label on the bottle, and 81% appreciated the simplicity and clarity of the message. For 79% of the interviewees, the information on the back label was sufficient to indicate that the wine was produced by techniques which respected the environment.

The data emerging from this first exploratory survey, which will hopefully be confirmed in a forthcoming study planned to estimate consumers' willingness to pay by the use of experimental choice analysis , demonstrate that consumers are increasingly sensitive to environmental problems and are prepared to “collaborate” to reduce the environmental damage due to GHG emissions.

The results of this study, in a certain manner, confirm the farmer's conviction that green products are definitely becoming more and more popular on the market and that large international companies in the wine industry are slowly but inexorably heading for a decline, since they have not wished, or known how, to invest in clearly defined measures and actions respecting the environment (see, e.g.,: Cordano *et al.*, 2010; McEwan and Bek, 2009; Hughey *et al.*, 2005).

In addition, the farm costs involved in the farmer's "green commitment" do not necessarily have to fall on consumers, as the cost analysis of the previous section confirms. Added to this is the fact that the farm's red DOC wine won the 2010 *Espresso "Vini d'Italia"* award for the best quality/price ratio.
The next step is to extend environmental criteria over the whole life-cycle of wine.

6. Final remarks

This study shows that a farm can reduce its GHG emissions by changing its style of farming, and by using biodiesel fuel and organic fertilizers in place of diesel fuel and synthetic fertilizers. It can also acquire CO_2 credits by associating efficient woodland management with the above actions.
Mean cost analysis was used to estimate the actual cost of producing a bottle of wine. Reduction of GHG emissions turned out to cost 0.11 euro/bottle, and consolidation of the farm's image on the wine market was estimated to cost 0.15 euro/bottle. These values represent 1,8% and 2,4% of total costs, respectively.
The Common Agricultural Policy could be improved by providing incentives for developing products made by environmentally friendly methods. It will be necessary to established the criteria that these products must meet in order to benefit from incentives, and to estimate the value of these incentives. The case study examined here is a step in this direction.
The method illustrated for identifying GHG emission sources and minimizing the uncertainty associated with the data about calculations for completing Protocol and Monitoring Report of GHG and the ISO 14064 certification are the "criteria" that these products must meet in order to benefit from incentives. The estimated cost of reducing GHG emissions would be the "value" of the incentive. In the case of the farm studied here, it could amount to about 750 euro per hectare of vineyard (0.11 euro/bottle multiplied about 6,800 bottle/ha). This figure is high, but it is clearly far less than the 5,000 euro and more, conceded in the past for tobacco.
Lack of information, insufficient expertise and scarcity of financial and human resources all make it difficult for farms fully to exploit the business opportunities offered by sound environmental management.
Overall, the outlook for GHG mitigation in agriculture suggests that there is significant potential. It will also necessary to support actions to increase consumers' awareness and help them make more informed choices.
Current initiatives indicate that synergy between climate change policies, sustainable development, and improvements in environmental quality can lead the way forward to achieve the mitigation potential in the agricultural sector.

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Tables

Table 1 - Plant production of studied farming systems in cental Italy (hectares)

Cropping system	Farm A - 2003	Farm B - 2008
Tobacco	80.84	
Set-aside	16.00	
Wheat	106.82	91.45
Durum wheat	28.31	77.92
Sunflower		54.34
Meadows		8.40
Olive tree	31.59	41.95
Vineyards	34.84	36.72
Subtotal-crops	298.40	310.78
Woodlands	161.66	204.17
Fallow	59.47	71.09
Farm buildings	2.82	3.88
Other uses	1.88	1.06
Subtotal-other uses	225.83	280.20
Total	524.23	590.98

Fertilization	kg	kg
Inorganic fertilizers (If)	1,419	817
Organic fertilizers (Of)	2	184

Table 2 - Total emissions for facilities, year 2003 (tons)

	Winery	Farm offices	Agriculture equipment	Fields	Tobacco ovens	Total facilities
Direct emissions						
CO_2	17.49	2.51	246.08	0.00	252.38	518.46
N_2O	0.000012	0.000004	0.091833	0.512346	0.000450	0.60
CH_4	0.000596	0.000224	0.013325	-	0.022493	0.04
HCFs	0	0	0	0	0	0
PFCs	0	0	0	0	0	0
SF6	0	0	0	0	0	0
CO_2eq.dir (*)	17.50	2.52	274.83	158.83	252.99	706.67
Indirect emissions						
CO_2eq.indir	15.83	6.17	30.30	0.00	87.63	139.93
CO_2 absorbers						
Absorptions	0.00	0.00	0.00	-1070.60	0.00	-1070.60
Emissions	0.00	0.00	0.00	0.00	0.00	0.00
Total. tons of CO_2 eq.	33.33	8.69	305.13	-911.78	340.62	-224.00

Note (*): To convert emissions of N_2O and CH_4 into CO_2 Eq. total tons emitted were multiplied by GWP: GWP (N_2O) = 310, GWP (CH_4)= 21

Table 3 - Total emissions for facilities, year 2008 (tons)

	Winery	Farm offices	Agriculture equipment	Fields	Tobacco ovens	Total facilities
Direct emissions						
CO_2	36.55	1.85	98.46	60.72	0.00	197.58
N_2O	0.000028	0.000003	0.038003	0.829676	0	0.87
CH_4	0.001412	0.000165	0.005514	-	0	0.01
HCFs	0	0	0	0	0	0
PFCs	0	0	0	0	0	0
SF6	0	0	0	0	0	0
CO_2eq.dir (*)	36.58	1.86	110.36	317.92	0.00	466.72
Indirect emissions						
CO_2eq.indir	38.75	13.56	9.49	0.00	0.00	61.80
CO_2 absorbers						
Absorptions	0.00	0.00	0.00	-1292.52	0.00	-1292.52
Emissions	0.00	0.00	0.00	0.00	0.00	0.00
Total, tons of CO_2 eq.	75.33	15.42	119.84	-974.60	0.00	-764.00

Table 4 – Costs of production of wine, in euro per bottle

Items of cost	euro/bottle	in %
1. Fixed investments	0.83	13.4%
1.a reinstatement charge of winery and vineyards	0.52	8.4%
1.b reinstatement charge of tractors	0.05	0.8%
1.c passive interest charge	0.26	4.2%
2. Operating costs	5.11	82.5%
2.a expenses for vineyard, insurance, energy, taxes	1.10	17.8%
2.b expenses for winery and packaging	1.97	31.7%
2.c labour costs	2.04	32.9%
3. Costs of GHG emission reduction	0.11	1.8%
3.a substitution of inorganic fertilizers, substitution of diesel, environmental certification	0.08	1.3%
3.b rent and maintenance of woodland	0.03	0.5%
4. Costs of communication	0.15	2.4%
4.a environmental certification and promotion	0.09	1.4%
4.b purchase of electric means of transport internal movements	0.06	1.0%
Total	6.20	100%

Acknowledgements

We are particularly grateful to farm's project manager "360° Green Revolution" Stefano Cantelmo, and to Gabriel Walton for her revision of the English text.

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