

## **A new tool to assess the winegrowing sustainability**

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### **ABSTRACT**

The wine industry is an important sector of the Italian economy, and is fed by environment primary inputs and contribute to energy resources demand. At the same time, the wine sector is one of the best identified components of Italian rural environment and agricultural landscape. The Italian Ministry for Environment, Land and sea launched in July 2011 a National pilot project to estimate the wine-sector sustainability performance, in collaboration with three research Centers of the University of Turin, Piacenza and Perugia.

In this framework, to assess the sustainability of agronomic management of the vineyard an ICT tool that measures the environmental impact of pests, fertilization and soil management has been developed. Concerning the disease management, the tool uses a calculation procedure to assess the potential environmental risk of pesticides at the farm level. About fertilizers, the tool calculates the risk of damaging effects of the distribution of nitrogen, phosphorus and potassium as a function of the soil characteristics and needs of the vineyard and evaluates the effect of cultivation on the evolution of organic matter, based on the ratio between the quantity entered in the ground with fertilizers, cover crops and crop residues and the recommended levels. The use of agricultural machineries causes the compaction of soil and influences the activity of plants and of soil's microflora. For this assessment, in the model are considered the values of rainfall, the percentage of surface covered by cover crops and vines, the machinery used and the number of steps per year. The water runoff is also evaluated, according to the type of soil, the agronomic management, the slope and the rainfall. The final evaluation relates the indicators calculated in different forms; for providing an overall judgment fuzzy logic is used. According to the traditional definition of sustainability which has environmental, economic, and social dimensions, socio-economic aspects have to be introduced in the sustainability assessment. For this reason a tool box kit, called "territory", of qualitative indicators has been developed to include in the sustainability evaluation all aspects that make wine production one of the best identified component of Italian "culture" of rural environment and agricultural landscape management and protection, associated to food safety and consumer's health. The tool box kit investigates the winegrowing farms on strategies, policies and measures adopted in the management of biodiversity, landscape, social aspects (field, winery and office workers, local community, consumers, suppliers) and economic aspects (territory and community investment). All the selected Indicators have been developed through multi-stakeholder processes, and those designated as "Core" are generally applicable Indicators and are assumed to be relevant for most of the national winegrowing farms. All farms have to pay off the "core" indicators to participate at the National project.

The two indicators will be included, along with tools for the calculation of Carbon and Water footprint in a suite of assessment that will be available to all companies who wish to assess their own sustainability performance, on the website [www.viticolturasostenibile.org](http://www.viticolturasostenibile.org).

**Key words:** sustainability, winegrowing, pest management, territory, Italy

## 1. INTRODUCTION

The wine industry is one of the most important sector of the Italian economy, and is fed by environmental primary inputs, contributing to energy resources demand. Agricultural practices, such as application of fertilizer, use of plant protection products, irrigation, and soil management, vary between the different management systems but in any case they maintain always an important influence on the environment.

In the last few years, different environmental indicators has been developed for the viticulture sector, however most of them are limited to the assessment of one or only a few phases of vine management, such as the application of pesticides or fertilization, ignoring the other major agronomic practices.

The Italian Ministry for Environment, Land and Sea in cooperation with three research Centres (Agroinnova, Opera, CRB) and nine Wine companies selected according to geographical and product criteria (F.lli Gancia & Co, Marchesi Antinori, Tasca d'Almerita, Venica&Venica, Planeta, Mastroberardino, Castello Monte Vibiano Vecchio, Masi Agricola, Michele Chiarlo), launched in July 2011 a National pilot project to estimate the wine-sector sustainability performance.

The different indicators were created following the indications given by the 128/2009 CE Directive on the sustainable use of pesticides in agriculture and the guidelines set by the O.I.V. (International Organisation of vine and wine) by the resolutions CST 1-2004 and 1-2008 and reaffirmed in the 2009-2012 strategic plan. According to O.I.V.guidelines, the environmental risk assessment should consider: the site selection (for new vineyards/ wineries), biodiversity, variety selection (for new vineyards), solid waste, soil management, energy consumption, water management, air quality, wastewater, adjacent land use, human resource management and agrochemical use.

An ICT tool has been developed to measures the environmental impact of pesticides, fertilization and soil management practices, and to assess the sustainability of the vineyard trough the evaluation of agronomic management and its impact on the landscape quality.

In addition to Environmental aspects, the definition of sustainability consider also an economic, and a social dimensions. To integrate those aspects into the project it has been developed a tool box kit, called "territory", that include in the sustainability evaluation different qualitative indicators. Those two indicators will be integrated with the Carbon and Water footprint tools in a suite of assessment where most of the input data are shared.

This paper describes an expert System using software that assesses in a holistic way the environmental impact of the viticulture on soil fertility and landscape ecology and a tool box kit of selected indicators to describe the socio-economic impacts of the company on the territory. The territory is intended as environment in which issues to be addressed are biodiversity and landscape and as community in relation whit workers, local community, bystanders, residents, and consumers.

## 2. THE TOOL FOR VINEYARD MANAGEMENT ASSESSMENT

This tool has been built on EIOVI, a previous model developed and tested for an Organic Viticulture system. EIOVI (Environmental Impact of Organic Viticulture Indicator) was developed by the Institute of Agricultural and Environmental Chemistry at the Catholic University of Piacenza within the EU FP6 Project Orwine (Fragoulis *et al.*, 2009), and his structure was already close to the aims of this project.

The development of the new model has been carried out in parallel with the indicators of Water and Carbon Footprint. Those indicators share often the same inputs, in this way the entire system can be used and maintained by the company personnel.

The different input variables are associated to the available maps at national or local level, and the results are displayed on a webGIS cartography that allows an intuitive visualization and the interaction with different data, allowing the modification of the different inputs to complete or extend the available information. The association with webGIS cartography allows the results

visualization at different particle scales, that allow the operator to have the company situation immediately under control. In order to facilitate the Vineyard operator, and to relate the different modules to the real field activity, the OIV indication were reorganized into six modules:

1. plant protection
2. fertilization
3. soil organic carbon management
4. soil management - compaction
5. soil management – water runoff
6. biodiversity

Since, usually, in a vineyard the agricultural operation are not uniform throughout the different vineyard or grape types, to improve the analysis quality, the operator can define different management units homogenous through agricultural activities. The software allows the association of the year of assessment with any Company or vineyard, and will keep a database with the previous year's data.

This choice is related to the fact that:

1. vineyards management changes every year, so it must be possible to update the input data (where necessary) to make a new assessment,
2. sustainability means a continuous improvement and therefore it is important to keep track of the evolution of the companies.

At the end, for each evaluation, the software produce a report that contain a summary of all the processes and their results, which ensure traceability, reproducibility and data storage.

## **2.1 Pest and disease management**

Concerning pest and disease management, the tool uses a calculation procedure to assess the potential environmental risk of pesticides at the farm level. It is based on EPRIP, an indicator of the environmental potential risk of pesticides (Padovani et al., 2004; Trevisan et al., 2009) and uses the concept of the exposure toxicity ratio (ETR), the ratio between a predicted environmental concentration (PEC) and a toxicological end point. The definition of PEC depends on: - the product's chemical and physical properties; - the intervention strategies (number of applications and interval between the different treatments); - the environmental context.

The ETR is calculated for each environmental compartments exposed to a risk: ground water; surface water; air and soil. Toxicological effects on humans, aquatic and soil organisms are taken into account. The ETR are converted into risk score using a scale from 1 to 5 by placing a threshold value of 2 for sensitive areas, such as water wells and populated areas and 4 for non-sensitive areas. The ETR for surface waters, is calculated by comparing the potential risk caused by the drift ( $PEC_{drift}$ ) and the runoff ( $PEC_{runoff}$ ) maximum value, taking into account the lower toxicity towards algae, Daphnia and fishes. The assessment of  $PEC_{drift}$  follow the model EuDriftCalculator, implemented in the FOCUS Surface Water Scenarios (FOCUS, 2001). The model EuDriftCalculator take into account the size of the water body and the phenological stage of the vines, and it's corrected by a mitigation factor, according on the precautions taken by the operator, such as anti-drift nozzles or drift-recovery sprayers.

The  $PEC_{runoff}$  is calculated as function of applied dose, phenological stage of the plant, drift losses, soil slope, distance from the water body and fraction of crop protection product that can runoff, calculated assuming three days rain after the treatment.

The  $PEC_{soil}$ , so as detailed in the final report of the Soil Modelling Work Group of FOCUS (FOCUS, 1997), is a function of application schemes (application rate, number of applications and interval between applications), soil properties (bulk density) and substance properties (DT50, disappearance time for 50% of the product). The predicted concentration in soil compared with the earthworm LD50 (lethal dose for 50% of the population).

For ground water the PEC calculation method is based on the approach used in the EPRIP indicator, that use the leaching quantity index which is a function of substance properties (Koc, DT50, and Kh), application rate, crop stage at the application, soil properties (sand and clay content, bulk

density, and organic carbon content), hydro geological properties (depth of ground water table and ground water level), and meteorological properties (average annual precipitation). The ETR is the ratio between PEC and the groundwater Legal Limit.

The  $PEC_{air}$  is calculated using a fugacity approach. The dilution rate in the air is based on wind speed and height of mixing, which depend on atmospheric stability and air dispersion. The predicted concentration is compared with the rats inhalation LD50.

## **2.2 Fertilizer management indicator (FMI)**

Since mineral elements are involved in different quality factors synthesis, the production quality can be influenced by the use of mineral fertilizers. But for their use should also be taken into account the risk of potentially harmful effects such as nutrients excess in the soil, water bodies contamination and biodiversity changes. Therefore, the model has three sub-indicators that evaluate the major macro-nutrients contributions, the use of nitrogen (N), phosphorus (P), and potassium (K).

These three sub-indicators are in connection with soil organic matter; bulk density; N,  $P_2O_5$  and  $K_2O$  fertilizer (or compost) content, and application rate. The vines demand of nutrients depends on expected yield and variety; for this reason their nutrient requirements should be taken into account before fertilization practices. For nitrogen, the total available amount is calculated as the sum of organic and mineral fertilization nitrogen. For mineral fertilization the nitrogen amount is directly related to the amount of fertilizer used; instead for organic fertilization, the available nitrogen depends on the amount of organic matter used, the organic matter nitrogen content, the availability coefficient and the year of intervention.

## **2.3 Soil organic carbon management**

The soil organic matter has favourable effects on structure, micro-flora and on carbon storage. The Fertilization management define the fertilizer distribution, but is also used to define the set of techniques (fertilization, irrigation, organic matter intake and processing) that preserve the soil fertility. Organic N in compost is not immediately available due to the time needed for organic matter microbial mineralization. The C/N ratio of organic material influences microbial activity. Higher is the ratio, and more the N limits the microbial decomposition of organic matter. When composts with a C/N ratios higher than 20:1 are added to soil, all the mineral N and any kind of mineralized organic N is used by microbes, reducing the N availability for plants. Thus, the C/N ratio of compost is an important factor in the plant-available N calculation. Availability coefficients are used to calculate plant-available N and to predict field mineralization.

In the case of the use of cover crop, its nutritional demand must be added to the vineyard demand (Bowman et al., 2007). On the other hand, N-fixing plants such as legumes contribute to soil N availability, and this is also taken into account in the case as such plants are used as cover crop. The indicator evaluates the effect of management practices on the evolution of soil organic matter and, consequently, on soil fertility. The calculation of the indicator is based on the relationship between soil organic matter inputs and organic fertilizers, compost, cover crop, crop residues, and vineyard recommended levels (Bockstaller et al., 1997).

The fertility indicator takes into account the type of cover crop (legumes, grasses, other, or mixture), the type biomass, the percentage of the vineyard covered and the use of manure or compost in the last years.

## **2.4 Soil management to avoid compaction**

In a Vineyard agricultural machineries are often used with a great number of transit (pest control, fertilization, soil and canopy management). It is estimated that in a vineyard in which up to 10 pesticides treatments are carried out, there are about 20 passages of tractors with different machines.

This great number of transit affects soil compaction and, consequently, root and soil microbial activity, it's therefore important to assess the soil management (with grass cover or not) considering those parameters. In the model three different factors have been considered for the evaluation of the soil

compaction: the action of the swing rain, the transit of agricultural machinery and the susceptibility of the soil as a function of its physical and hydrological characteristics. For the rain, the indicator takes into account the average monthly rainfall and the degree of soil covered by the grass and vine, considering the training system and the phenological stage.

For the transit of agricultural machinery, the indicator takes into account the weight of the machines, the wheel contact area and the number of passages per year. The parameters of evaluation reward the farmers who carry out a smaller number of passages in the field and who use machines that reduce the soil compaction.

Concerning the soil susceptibility, the indicator is based on the concept of compaction stress. The compaction stress is the limit of compaction in which the soil has an elastic deformation without variations in porosity and in its functions (Horn and Fleige, 2003). This limit is related to soil physical characteristics, water and organic matter content, and to the kind of soil management, like coverage and number of tillages.

## **2.5 Soil management to avoid run off**

Soil erosion is one of the major problems in vineyards, especially on slope soils. Since a large part of Italian viticulture is carried out on hilly soils or in low mountain areas, the evaluation of this parameter is very important. On these soils, in fact, the soil losses caused by erosion, can exceed 15 tons per year per hectare of vineyard. Due to the importance of the Italian landscape quality safeguard, the sustainability analysis must take into account good practices and soil management activities that control water runoff.

The indicator depends on: - previous indicators; - soil management practices; - the presence and the type of grass cover; - the climatic characteristics of the area; - the use of agricultural machinery.

The indicator of erosion is based on the coefficient "C" of the RUSLE. The index is calculated at farm level as the average of the individual values at the field level. (Wall et al., 2002).

## **2.6 Biodiversity management**

The vineyard landscape is extremely important in Italy and in some cases (Langhe, Eastern Hills of Friuli, Collio) is already under public protection or is recognized as a World Heritage Site. Furthermore, in some areas it is one of the elements of tourist appeal.

The assessment of biodiversity within a vineyard depends on two main factors: the abundance, which is the number of present species, and the distribution uniformity. The evaluation of those factors seems too difficult for a not specialized operator, and one of the goals of this project was to produce a tool that can be used by all companies operators that want to use it. For this reason, to simplify the evaluation, the indicator takes into account the presence of areas with natural vegetation, in the farm and / or adjacent to the vineyards, based on the assumption that the presence of these areas represents an important sink of useful flora and fauna.

In the report then evaluated the percentage of vineyard area covered by permanent grass, natural or artificial, such as the embankments of the terraces, and also the extension of natural or planted wooded areas.

In addition, the indicator takes into account the care that the company has in the management of those areas, considering the relationship between the times allocated to the management of the vineyards and the time involved in the maintenance of other areas, this data permit to have an assessment of the involvement in the protection of biodiversity.

## **2.7 Fuzzy Expert System**

The six different modules of this toolbox kit, give six different results that have also different units of measures. Those results cannot so easily merged to obtain an overall judgment, and to provide a solution to this problem several options available in literature were investigated. The most suitable option was the use of the fuzzy logic approach that was already successfully tested in the EIOVI indicator and was profitably used in different sustainability models.

The fuzzy logic is used to define a relationships between different data in compliance with a set of attributes. In the classical sets theory, an element belongs or does not belong to a set. This means that the membership function can only have two values: 0 (non-membership) and 1 (membership). The fuzzy set theory define the element membership degree in a set with a functions that can assume any value from 0.0 to 1.0. The 0.0 value represents a complete non-membership; the 1.0 value represents a complete membership; all the values between represent a partial membership. For each Agronomic practice it has been defined a value between 0 and 1, according to membership subset F (favorable) or U (unfavorable).

The different modules were calculated using the Sugeno's inference method (Sugeno, 1985). The limit values ( $\alpha$  and  $\gamma$ ) beyond which the index is certainly F or U have been also attributed, based on criteria drawn from the literature or on expert judgment.

For pest and disease management, the model calculates the probability that a certain threshold of danger, associated with the use of pesticides in a given environmental context, is exceeded. The alpha and gamma values are then related to the probability to exceed these thresholds. For fertilization management, the alpha and gamma values are related to the ratio between the amount of element supplied to the soil and the amount of element removed. The soil organic carbon management model draws up an Organic Matter availability assessment in the vineyard, the alpha and gamma values rewards practices that preserve and increase the soil organic matter.

For the soil compaction assessment, the indicator is the result of three sub-indicators, one for the swing rain effect, one for the use of agricultural machinery and one related to soil susceptibility.

The Indicator rewards with the alpha parameter those winegrower that use farming techniques to reduce the action of the rain (green cover and training systems) and who carry out a limited number of passages, and penalize with the gamma parameter those winegrowers that have bare ground and that carry out a lot of passages . For the soil compaction susceptibility, the parameters  $\alpha$  and  $\gamma$  identify two pre-compression stress limit values.

For soil management related to the prevention of water runoff, the indicator rewards farmers that favours the coverage of the soil and penalizes those who till the inter-row.

For the biodiversity management, the indicator rewards the winegrower that maintain or increase the natural areas sinks for useful flora and fauna.

The aggregation process has been achieved by combining weighted fuzzy values. Through a process of defuzzification, the total value of fuzzy analysis has been transformed into a sustainability judgment, converted in a range from A to E.

The model was developed in three representative companies in different Italian soil and climatic conditions, the remaining six companies were used to assess the robustness of the model. To reduce the uncertainty of the model a step-down strategy has been adopted (Dubus et al., 2003). The data collection in the first three companies allowed the evaluation of farm data availability, and the collected data were also compared with literature data or aggregated data received from the local authority. This approach revealed the quality of the different data sources, allowing the evaluation of uncertainty. The outputs of the model were discussed with vineyard manager and a panel of expert, to identify errors related to subcomponents and model shortcomings, to perform the calibration of the fuzzy judgment.

### **3. THE TOOL FOR TERRITORY ASSESSMENT**

The economic and social sustainability is an integral part of the proposed plan, according to the most common definitions of sustainable development. The triple bottom line (also known as people, planet, profit or "the three pillars" (Goethe institute, 2008) captures an expanded spectrum of values and criteria for measuring organizational success: economic, ecological, and social.

Therefore a tool box kit of indicators is proposed to evaluate the socio-economic sustainability of the involved farms. The tool-box kit contains qualitative and quantitative indicators related to four main topics: biodiversity, landscape, economic and social activity. The territory indicator is inspired by the Global Reporting Iniziative approach to the sustainability reporting and ISO 26000 approach the

corporate social responsibility. the international models on winegrowing sustainability have also been considered on the developing of the indicator.

Qualitative and quantitative information make up the two types of discoverable information. Quantitative is generally the easiest to understand and manipulate since it is based on numbers and hard facts. When information can't be measured or reproduced, then it is typically qualitative. In fact qualitative indicators are non-numerical factors for determining level of progress towards a specific goal.

The four sections that compose territory indicator are briefly described below.

### **3.1 Biodiversity**

This aspect is included also in vineyard indicator. In territory aspects related to biodiversity are dealt with the use of qualitative or semi quantitative indicators. The questions investigate issues relating to the management of areas of high natural content, management of protected species, the strategy and the company's commitment to preserving and implementing the farm biodiversity.

### **3.2 Landscape**

In this section questions investigate issues relating to the location of the vineyards with respect to recognized areas of excellence, the contrast to neglecting of rural buildings, the harmonious integration in the landscape of new stables, vineyards, roads, lighting. Awards are presented to winegrowing companies that contribute to enrich the landscape not only through the vineyards but also through other related buildings and activities.

### **3.3 Economic activity**

The questions of this section assess the economic impact of winegrowing company on the local community and territory. The use of resources, goods, people and services available on the territory makes it possible to ensure the territory itself a mode of shared and long-lasting development.

### **3.4 Social activity**

This section evaluates the impact of the farm activity on the human resources intended as workers and operators, consumers, residents and bystander. Questions related to health and safety of all categories of people involved are proposed. Items related to formation, education, participation, recruitment, retribution of all kind of workers and operators are included. The participation, at different level, of company to the local community activities is also assessed in this section of the tool box-kit.

The compilation of the tool box kit of indicators does not furnish a score of sustainability related to the proposed aspects. Some criteria are defined "core", for these ones a minimum level in the answer is required. This minimum level is assumed by literature, or by national data bases. Generally is required at the company to be better than the corresponding "core" value found in literature. Some "core" criteria could anyway be not applicable in the company. In this case the fact that the criterion is not applicable makes it not "core".

The territory indicator is in the VIVA sustainable wine the only for which the fulfilment of minimum criterion is required. All applicable core aspects have to be fulfilled in order to follow the complete evaluation of the sustainability through the other three environmental indicators.

## **4. RESULTS/CONCLUSIONS**

The two indicators will be included, along with tools for the calculation of Carbon and Water footprint in a suite of assessment that will be available to all companies who wish to assess their own sustainability performance, on the website [www.viticolturasostenibile.org](http://www.viticolturasostenibile.org) .

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