Assessment of management of a golf course by means of sustainability indicators

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Abstract

Golf courses are supposed to produce remarkable negative effects on the environment, due to some techniques involved in their management. To provide data useful for the proper assessment of the agro-environmental sustainability of a golf course, the framework agro-environmental sustainability information system (AESIS) was used, utilizing a set of indicators suitable to evaluate different dimensions of sustainability (physical, ecological, productive and social). The management of areal golf course located in Tuscany (central Italy) was compared to an alternative land use of the same area represented by an ordinary farm based on a sunflower-wheat rotation. Assessment indicators were selected by applying a conceptual model based on ecology theory and were calculated considering site-specific production and pedo-climatic features of the area. Different weighting scenarios were hypothesized in order to have different management options assessed and to carry out a targeted sensitivity analysis. Main results confirmed the significant impact of golf management on some ecological characteristics but the holistic assessment of AESIS approach permitted an overall evaluation that comprised a wide range of different issues. AESIS demonstrated to be a practical and adaptive tool able to perform an efficient comparison of possible land destinations.

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Introduction

Turfs can be used for technical aims, as those related to erosion prevention and to ecological restoration (Linse *et al*., 2001; Geren *et al*., 2009) but they play a major role also in improving the quality of life, especially for amenity and sport purposes (Seppoloni, 2014). In the recent past, great interest has been devoted to research in this field (Seppoloni *et al*., 2015), and many studies have been carried out to increase knowledge on functioning of these surfaces (Volterrani and Magni, 2007). Studies have been dedicated to characterization of different species and varieties in particular environments (Marchione, 2008; Kir *et al*., 2010), but many of them have interested the interventions of management of turf, as these practices can produce efficient utilization of performed techniques (Turgeon, 2008) taking into account the minimization of their impact on the environment (Gaetani *et al*., 2013). Among the main cultural practices with the highest environmental impact, we can include fertilization (Baldi *et al*., 2013) and irrigation (Bowman *et al*., 2002). Fertilization (mainly due to nitrate leaching) is considered one of the most important factor impacting on water quality (Bigelow and Walker, 2008; Trenholm and Sartain, 2010), but many responsibilities are also imputed to excessive use of water (Sevostianova and Leinauer, 2014), and this is of extreme evidence in Mediterranean areas that present hot and dry summers (Seppoloni *et al*., 2015). So the question is basically to combine efficient use of inputs with maintenance of high quality standards of the turf (Easton and Petrovic, 2005) and this is particularly true for golf courses that occupy great surface in rural area (Piano, 2005) that can alternatively devoted to productive crops. To analyze the effect of technical intensification on the agricultural system (such as turfs), a set of specific indicators can be chosen in order to assess how the intensity of management can affect environment and to compare different systems (Ruiz-Martinez *et al*., 2015). In this study we used the agro-environmental sustainability information system (AESIS) (Pacini *et al*., 2009; Pacini *et al*., 2011) to assess the sustainability impact of turf management at the Circolo Golf Ugolino (Florence, Tuscany) and compare results to standard cropping activities of the area. Assessment indicators were selected by applying a conceptual model based on Ecology theory as described in Pacini *et al*. (2010) and calculated considering site-specific production and pedo-climatic features. While the aim of this study is to show how a truly holistic analysis can disclose sometime underestimated aspects of impact assessment of golf activities, the results of the analysis cannot be trivially generalised to the whole sector as they were inferred from a single case-study.

Materials and methods

The *Circolo Golf Ugolino*, the virtual arable farm and site-specific pedo-climatic characteristics

The AESIS was applied to *Circolo Golf Ugolino* (CGU, Impruneta municipality), the most important golf facility of Florence province, also known as the oldest golf club in Italy. Ugolino is located at only 13 km south of Florence city centre (latitude 44° N) in Chianti, an area that focuses primarily on vine production, with lower surfaces devoted to olive production and arable crops, and a consolidated, flourishing agri-touristic activity. The climate of Chianti is Mediterranean, with an average annual rainfall reaching 865 mm in the Impruneta municipality. The CGU facility covers 18.0 ha, including green, collar, tee (1.7 ha), fairway, surround, pre-rough (13.0 ha) and rough (3.3 ha), and is surrounded by 12.0 ha of woodland. Soils of different turf typologies are very different because of their management. The most widespread typology of soil is silty sand according to United States Department of Agriculture (USDA) classification (Giardini, 2012), it occurs in all the surface of golf course dedicated to fairways, and this kind of soil was used for the following elaboration concerning the virtual farm (VF) compared to golf course (see hereafter) (USDA-ARS, 2014a, 2014b). Average steepness of these soils is 5%. On the contrary, on greens the soils are all sandy, with a percentage of sand higher than 90% mainly due to topdressing performed for many years, and an average steepness of 1%. In order to appreciate the extent of the impacts of turf management at Ugolino indicator results were compared with corresponding results of a virtual arable farm hypothesized on the same CGU area and managed with standard practices. VF hence has pedo-climatic characteristics and total area equal to those of CGU and is featured by the internal Tuscany hilly area typical rotation, *i.e.* sunflower-wheat, and by a 1.4 ha ecological focus area as indicated by current norms of the common agricultural policy (CAP) greening.

The agro-environmental sustainability information system approach

In order to assess the sustainability impact of these two alternative land uses in Chianti, *i.e.* turf and arable crops, we used the AESIS. An in-depth description of AESIS is given in Pacini *et al.* (2009, 2011). Here, only major AESIS procedural phases are summarized with the aim to recall the AESIS general features and show how it was applied for the current analysis. The main feature of the indicator framework is the importance given to different spatial scales (farm, site and field), to the production and pedo-climatic factors, and to the holistic view of the agro-ecosystem.

The AESIS was aimed at finding the right balance between a range of different application purposes and the level of complexity of indicators. Agro-environmental indicators can be calculated, simulated with models or directly measured with different levels of detail, in proportion to the aims of the evaluation exercise. The procedural phases to apply the framework are reported in Figure 1.

Phase 1. Definition of the sustainability issues

The AESIS application procedure was initiated with gathering of already available information on the issues related to sustainability in the region and corresponding land use critical points (AESIS sub-phases 1.1 and 1.2). A set of agro-environmental indicators for the quantification of the performance of the management of each environmental and production process in the agro-ecosystem was identified based on a conceptual framework for the evaluation of sustainability of land use options (sub-phase 1.3). The conceptual framework is described in detail in Pacini *et al.* (2010). It is based on the principle that a truly holistic assessment of land use options for farming system diagnosis and design must take into consideration relevant structural and functional properties of agro-ecosystems backing them together with the physical, ecological, productive and social dimensions of sustainability. The framework was already validated and applied to compare alterna-

1. DEFINITION OF THE SUSTAINABILITY ISSUES

1.1. Identify issues related to sustainability
1.2. Identify detailed critical points and connect them to agro-ecosystems
1.3. Choose indicators

2. ALTERNATIVE LAND USE SOLUTIONS

2.1. Settle a comparison layout
2.2. Identify indicator thresholds (or targets)
2.3. Define alternative management systems (*e.g.*, organic, integrated, biodiversity-friendly, best available technologies *etc.*)

3. EVALUATING SOLUTION ALTERNATIVES

3.1. Select calculation methods of indicators proportional to the evaluation purpose
3.2. Measure indicators
3.3. Aggregate indicators and present results

Figure 1. Agro-environmental sustainability information system procedural phases (modified from Pacini *et al.*, 2011).

tive land management options in a Food and Agriculture Organisation (FAO, 2001) worldwide study as described in El-Hage Scialabba *et al*. (2012). The definitions of the agro-ecosystems properties used for sustainability assessment are reported in Figure 2; they were withdrawn from ecology theory and refined according to how they are referred to in this paper. Indicators of functional properties were further grouped into four categories corresponding to ecosystems functions as defined by De Groot *et al.* (2002) and the Millennium Ecosystems Assessment (2005): regulation, habitat, production and information functions.

Phase 2. Alternative land use solutions

The AESIS was developed not only to assess the sustainability of land use options but also to evaluate possible alternatives. The first step of this process consisted of designing a comparison layout where current practices under evaluation were compared with different management systems and with scientifically determined sustainability thresholds (sub-phase 2.1). The thresholds are identified for each single indicator. They are part of the solution to the sustainability problem and determine the extent to which decision-makers change their strategies in order to attain the goals they represent (sub-phase 2.2). In the case of Circolo Golf Ugolino the comparison layout included the comparison with a VF as previously defined (sub-phase 2.3) as well as comparisons of both land use alternatives with thresholds.

Phase 3. Evaluating alternative solutions

In this phase of the evaluation procedure, the calculation methods of the indicators were selected following a criterion of proportionality to the evaluation purpose (sub-phase 3.1). For instance, indicator processing methods for policy auditing have to be applied to a large number of farms and as such may be based on simple presence/absence observations, whereas some indicators for research and policy planning are calculated for selected representative farms by applying complex, ecological-environmental models with high data input requirements. In the two land use options under survey we chose to apply a combination of in-field observations and simulation modelling.

Finally, indicators were measured (sub-phase 3.2), subsequently aggregated and results were presented (sub-phase 3.3). For the present case-study we integrated indicator results by applying an aggregation framework already validated and applied for sustainability impact assessment at European (EU) and regional levels as in Paracchini *et al*. (2011). The framework includes land use functions producing ecosystems services and goods and aggregates corresponding indicators based on a multi-criteria linear additive model and sustainability ranges used for indicator normalisation. Indicator aggregation was performed under three different weighting scenarios so to carry out a targeted sensitivity analysis: i) scenario with complete compensation allowed among all of the indicators; ii) scenario considering only classical agronomic-environmental indicators belonging to the physical dimension (soil erosion, environmental pesticide risks, nitrogen leaching, water use), with complete compensation allowed among all of the indicators; iii) scenario with weights attached to sustainability dimensions decided a priori and dimensions considered to be equally weighted, with compensation allowed within a single sustainability dimension, but not among the dimensions, as suggested by Munda (2004).

Results and discussion

In the next sections, the results of the case-study application are presented by following the AESIS process, as reported in Figure 1, for most significant steps.

Phase 1. Definition of the sustainability issues

The definition of local sustainability issues was initiated from the review of the regional situation given by the 2014 report on the state of the environment in Tuscany (Regione Toscana, 2015; sub-phase 1.1). In subphase 1.2 we have extrapolated detailed critical points for the agricultural sector from general sustainability issues in Tuscany, as follows. This phase is fundamental to reach a good compromise between

Structural properties

- *Diversity* is given by the number of different components and processes present in the system and their relative abundance. It includes among others biodiversity of genes, species and ecosystems, as well as the diversity of income sources and knowledge, traditional and scientific.
- *Coherence* provides measures of the numbers and strengths of the connections and flows among components and processes within the system. It considers ecological balance, economic integration and household labour, and seeks to minimize trade-offs and maximize synergies.
- *Connectedness* is similar to coherence, but concerns the connections with components outside the agroecosystem. It includes, among others, trans-boundary pollution and the production system connectivity with external waterways and habitats; integration of farm business in the supply chain and independence from exogenous factors; and the participation of producers in social networks and institutions.

Functional properties

- *Capacity* is the average performance level of a state variable in the system, *e.g.*, the quantity of production of foods, biofuels, fibres, timber and other ecosystem goods and services that can be obtained from a unit of inputs (water, land, biodiversity, energy, nutrients and labour).
- *Stability* is the capability of the system to remain close to stable states of equilibrium when facing *normal* variations, and is reflected in the frequency and amplitude of fluctuations in the state variables.
- *Resilience* refers to the aptitude of the system to maintain its performance defined by capacity and stability after a disturbance or long-term or permanent changes in its environment or internal conditions, including both environmental and macro-economic risks.

Figure 2. Agro-ecosystem properties of the conceptual framework for sustainability assessment of land use options (modified from El-Hage Scialabba *et al.*, 2014).

the will to keep a holistic perspective of agro-ecosystem functioning and the need to concentrate on problems at stake under current pedo-climatic and production conditions.

According to the report, 30% of agricultural land is subject to erosion phenomena, of which 13% is classified at high erodibility potential. Because erosion is highly affected by stable pedological conditions, corresponding trends are mainly attributable to agronomic practices including, *e.g.*, cover cropping, hydraulic systems and management of crop residues. Considering pesticides in food and water, although all samples in the last reporting period were found to be regular, 35% of food, 25% of surface water and 9% of underground water samples showed pesticide residues. The level of pollution from macrodescriptors indicator, including among other information on phosphorous, dissolved oxygen, ammoniacal and nitrate nitrogen, indicated potential eutrophication in 25% of surface waters. The 58% of underground water bodies were found to be in poor chemical state or at risk due to nitrogen substances originated from agricultural activities. These data witness the importance of soil erosion, pesticide risks, water eutrophication and quality in the abiotic domain of regional agro-ecosystems.

Although the Tuscany report on the state of the environment does not take into account biodiversity in agricultural land, its importance in the ecological domain of agro-ecosystems is transversally acknowledged throughout all states of EU with special reference to the ecological focus areas of the greening payment of the 2014-20 CAP.

Besides EU, region and sometimes-even local (*e.g.*, water availability) critical points in the environmental (abiotic and ecological) domains of agro-ecosystems, there are production and social issues that are potentially conflictual and need to be contextualised in the present exercise on golf activities in order to keep a holistic perspective for integrated sustainability assessment. In a world with 850 million under-nourished people, in a country that is not self-sufficient for food, is it sustainable to allocate land for recreation instead of for food production? In a country with total and youth unemployment rates of 12 and 40%, respectively, is it (un)sustainable to renounce to portions of food production and environmental health in exchange for jobs?

Identification of environmental critical points relevant for the agricultural sector in the region are reinforced by the potential impact due to fertilization, irrigation and pest management intensive techniques adopted at CGU (Table 1). Thereafter, corresponding measurable indicators were chosen (Figure 3) based on the conceptual framework in

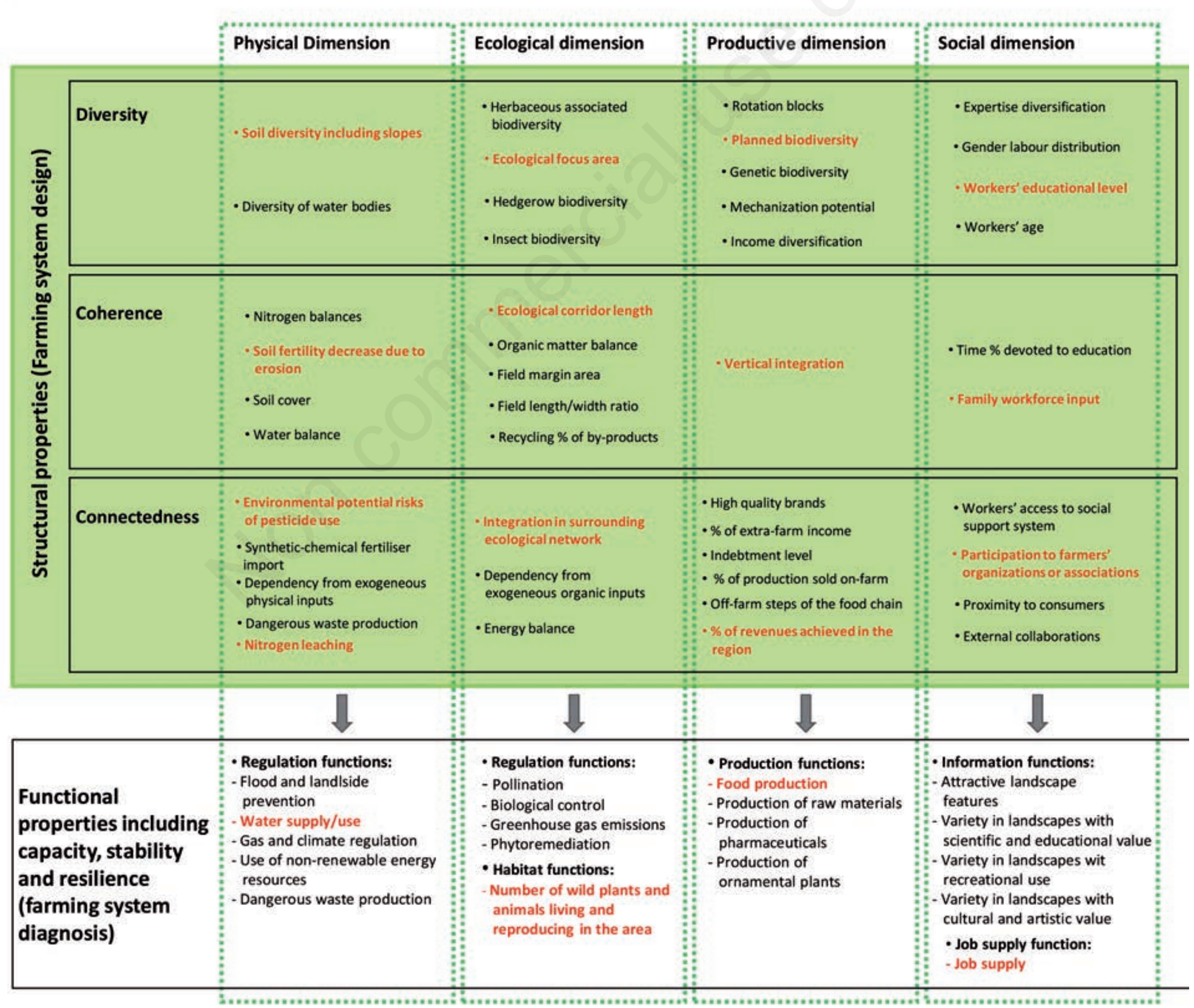

Figure 3. Agro-Environmental Sustainability Information System sub-phase 1.3 *choose indicators*. Indicators selected for further analysis are reported in red bold. Indicators of functional properties were additionally grouped into categories corresponding to ecosystems functions as defined by De Groot (2002) and the Millennium Ecosystems Assessment (2005), and a function of job supply.

Figure 2 (sub-phase 1.3). In the first instance, authors chose a number of indicators covering the whole of agro-ecosystem properties and dimensions based on scientific and expert knowledge. In this step it was important to privilege indicators having a direct link with sustainability issues and detailed critical points previously identified. However, additional indicators apparently disconnected with them were chosen in order to keep a holistic perspective and account for potential trade-offs among sustainability dimensions and properties.

Indicators of functional properties were further grouped into the four Millennium Ecosystems Assessment categories. Given the outstanding relevance of job placement in times of economic crisis, we also included an indicator representing the function of job supply that can be enforced by rural enterprises.

Ideally, an exhaustive set, made of hundreds of indicators, would supply a perfect representation of the agro-ecosystems under study, but probably this would happen at an unbearable cost. Hence, following the proportionality principle, and considering the scale of the analysis, only one indicator for each combination of agroecosystem property and sustainability dimension (physical, ecological, productive and social) was selected for further analysis. To simplify the application of the conceptual framework and keep the total number of indicators close to cost-effective standards, the three functional properties were assembled in one group and only one indicator was selected as representative for each sustainability dimension. In this way we were able to decrease as much as possible the total number of indicators (16) while keeping a holistic perspective. Exceptionally, two indicators were chosen for physical connectedness (*i.e.*, environmental potential risks of pesticide use and nitrogen pollution) in order to account for both these two aspects as highlighted by phases 1.1 and 1.2, which made the total number of selected indicators amount to 17.

In a nutshell, concepts leading the phase of indicator selection were: i) ability to represent agro-ecosystem properties, sustainability dimensions (holistic perspective); ii) ability to represent ecosystems functions; iii) EU proportionality principle (cost-effectiveness); and iv) avoid double-counting. Concerning point iv), double counting is a recurrent problem in financial information systems and its importance is broadly acknowledged but can hold relevance also in sustainability assessment, *e.g.*, we did not select energy indicators and greenhouse gas emissions due to their high correlation with nitrogen pollution (synthetic-chemical fertilisers have a high energy content and their production causes emissions) and soil erosion indicators (soil erosion depends among other factors from energy consuming tillage operations, also causing emissions). The same rationale applies to pollination and bio-control on the one hand and ecological focus area on the other. Sub-phase 1.3 has strong implications in terms of the final results of the analysis as choosing one indicator instead than another can bias sustainability assessment. Under this perspective, it is important that the selection of indicators is as much as possible objective, not driven by biasing elements such as data availability, land use consolidated patterns and preferences, *etc*.; in our case we used a theoretically-based conceptual framework without considering at this stage sustainability assessment layout and data availability. As a result of this procedure, we anticipate further selection of the list of 17 indicators in the following AESIS steps.

Phase 2. Alternative land use solutions

The sustainability issue at stake is if golf is a sustainable land use option for Tuscan inland hilly areas. To verify that, we designed a comparison layout including a virtual arable farm (see description in the

Table 1. Ordinary fertilization, irrigation and pest management programs performed on different sections of golf course.

Turf area	Area (ha)	Fertilization N (kg 100 m^{-2})	P_2O_5 (kg 100 m^{-2})	K_2O (kg 100 m^{-2})	Number of interventions per year	Irrigation mm	Number of interventions per year	Pest management Type of active ingredient (pest in table note)
Greens/ collars	1	1.88	0.96	1.83	20	435	135	Propiconazole,* prochloraz,°
Tees	0.7	1.82	0.30	0.88	6	410	135	clorpirifos-metile#
Fairways/ surrounds	13	1.36	0	0.40	4	330	115	Dicamba, mecocrop§

*Dollar spot (*Sclerotinia homeocarpa*); °fusariosis (*Fusarium spp.*); #crane fly and owlet moths, (*Tipulidae* and *Noctuidae spp.*, respectively) in green, collars and tees; §weeds in fairways and surrounds.

Table 2. Sustainability thresholds, targets and ranges.

Indicator	Sustainability threshold/target	Type	Source*	Sustainability range
Soil erosion	1.4 t ha^{-1}	Max	(a)	1.4-5.0
Environmental potential risks of pesticide use	16 EPRIP score/ha^{-1}	Max	(b)	0-16
Nitrogen leaching	27 kg ha^{-1}	Max	(c)	10-27
Water use	107 mm	Max	(d)	0-107
Ecological focus area	5%	Min	(e)	5-50
Ecological corridor length	60 m ha^{-1}	Min	(f)	60-120
Planned biodiversity	4 rotation blocks	Min	(e)	4-8
Portion of revenues achieved from local end users	50%	Min	(g)	50-100
Food production	4.657 Gcal ha^{-1} AAU	Min	(h)	4.657-9.314
Job supply	13.5 ha^{-1} AAU/LU°	Max	(i)	1.0-13.5

*Source legend: (a) Verheijen *et al.*, 2009; (b) Trevisan *et al.*, 1999, EU Directive 91/414; (c) calculated from the limit for drinking water of 50 mg/L of EU Directive 91/676, considering local pedo-climatic conditions; (d) based on groundwater recharge calculated from Civita, 1994; (e) Vereijken, 1999, CAP green payment requirement; (f) Schotman, 1988; (g) settled by the authors; (h) calculated based on human energy requirements (FAO, 2001) and Italian agricultural area used; (i) calculated based on labour intensity for arable crops from ISTAT (2013); °following the European System of Accounts. EPRIP, environmental potential risk indicator for pesticides; AAU, agricultural area used; LU, labour unit.

methodology section) as a reference of the area (sub-phase 2.1). This comparison layout implied further selection of indicators. The indicator of soil diversity was discarded because the VF was hypothesized on the same land of CGU, neutralising corresponding results. Social indicators of education, family workforce and participation to farmers' organizations, as well as vertical integration (production dimension), were impossible to be estimated for the specific type of the VF, *i.e.* an arable farm of 30 ha in inland Tuscany hilly areas. Integration in surrounding ecological network depends on singular entrepreneurial choices and was also impossible to be estimated. Number of wild plants and animals living and reproducing in the area could not be calculated because of the same reason of previous indicators, and probably would not be worthy anyway to be measured for such a small stretch of land. Although these indicators were cancelled for following AESIS steps, we still claim their importance both in terms of transparency of the indicator selection process and overall results discussion, and in terms of pointing out the limitations to be posed to the extent of application of the analysis. Besides the farm comparison, comparisons of single land use options with environmental, production and social sustainability thresholds/targets were settled concerning the ten indicators left (Table 2, sub-phase 2.2).

Phase 3. Evaluating alternative solutions

In this phase, calculation methods of indicators were selected that met the requirements of the present type of application purpose (sub-phase 3.1). One procedure was selected for each indicator selected in sub-phases 1.3 and 2.1. The indicator method sources, as well as the descriptions are shown in Table 3.

Table 3. Calculation methods of indicators.

Indicator	Method	Method source
Soil erosion	Revised universal soil loss equation (RUSLE) module in CROPSYST model	Stöckle *et al.,* 2003; USDA-ARS, 2014a
Environmental potential risks of pesticide use	Environmental potential risk indicator for pesticides (EPRIP) yardstick	Trevisan *et al.*, 2009
Nitrogen leaching	CROPSYST model	Stöckle *et al.*, 2003
Water use	Water used for irrigation	UN-Water, 2014
Ecological focus area	Fallow land, terraces, agro-forestry areas, perimetric wood areas, crops, afforestation land, cover crops, nitrogen-fixing crops excluded buffer strips	EU Regulation 1307/2013
Ecological corridor length	Length of hedges and grass strips (including rough)	Vereijken, 1999
Planned biodiversity	Number of rotation blocks	Vereijken, 1999
Portion of revenues achieved from local end users	Calculated from CGU records and estimated based on expert-knowledge	Elaborated from the authors
Food production	Calculated based on energy content of sunflower and wheat grains retrieved from USDA national nutrient database for standard reference	USDA-ARS, 2014b
Job supply	Calculated from CGU records and labour intensity of arable crops	ISTAT, 2013

CGU, Circolo Golf Ugolino; USDA, United States Department of Agriculture.

Table 4. Results of indicators and aggregation under three different weighting scenarios

Indicator	Value		TV	Weighted, normalised score					
				Scenario a)*		Scenario b)°		Scenario c)#	
	CGU	VF		CGU	VF	CGU	VF	CGU	VF
Soil erosion (t ha^{-1})	1.6	5.0	1.4	–0.05	–1.01	–0.05	–1.01	–0.01	–0.25
Environmental potential risks of pesticide use (EPRIP score ha^{-1})	4.0	4.5	16	0.75	0.72	0.75	0.72	0.19	0.18
Nitrogen leaching (kg N ha^{-1})	117	49	27	–5.29	–1.26	–5.29	–1.26	–1.32	–0.32
Water use (mm)	380	0	107	–2.55	1.00	–2.55	1.00	–0.64	0.25
Physical dimension				–7.14	–0.55	–7.14	–0.55	–1.78	–0.14
Ecological focus area (%total area)	40	5	5	0.78	0.00	n.c.	n.c.	0.39	0.00
Ecological corridor length (m ha^{-1})	110	0	60	0.83	–1.00	n.c.	n.c.	0.42	–0.50
Planned biodiversity (no. rotation blocks)	1	2	4	–0.75	–0.50	n.c.	n.c.	–0.25	–0.17
Ecological dimension				0.86	–1.5	0.00	0.00	0.56	–0.67
Portion of revenues achieved from local end users (%)	40	0	50	–0.20	–1.00	n.c.	n.c.	–0.10	–0.50
Food production (Gcal ha^{-1})	0.0	6.4	4.7	–1.00	0.37	n.c.	n.c.	–0.50	0.19
Production dimension				–1.2	–0.63	0.00	0.00	–0.60	–0.31
Job supply (AAU LU^{-1})	3.8	33.3	13.5	0.78	–1.58	n.c.	n.c.	0.78	–1.58
Social dimension				0.78	–1.58	0.00	0.00	0.78	–1.58
Sustainability aggregated index (no.)				–6.70	–4.26	–7.14	–0.55	–1.04	–2.70

TV, threshold value; CGU, Circolo Golf Ugolino; VF, virtual farm; EPRIP, environmental potential risk indicator for pesticides; n.c., not considered; AAU, agricultural area used; LU, labour unit. *Scenario with complete compensation allowed among all of the indicators; °scenario considering only classical agronomic-environmental indicators belonging to the physical dimension (soil erosion, environmental pesticide risks, nitrogen leaching, water use), with complete compensation allowed among all of the indicators; #scenario with weighs attached to sustainability dimensions decided a priori and dimensions considered to be equally weighted, with compensation allowed within a single sustainability dimension, but not among the dimensions.

Indicators were measured and relevant results are shown in Table 4 (sub-phase 3.2). The golf course achieved sustainable performances for 4 of 10 indicators including environmental pesticide risks, ecological focus area and corridors, and job supply. The arable crop system achieved sustainable performances also for 4 of 10 indicators including environmental pesticide risks, water use, ecological focus area and food production. VF modelled results of soil erosion, environmental potential risk indicator for pesticides (EPRIP) and nitrogen leaching are in line with a number of studies carried out in Tuscany under comparable production and pedo-climatic conditions (Pacini *et al*., 2011; Merante *et al*., 2015; Pacini *et al*., 2015).

Concerning direct comparisons of CGU with VF, CGU achieved better performances for 6 of 10 indicators, including soil erosion (1.6 and 5.0 t ha^{-1}, respectively), due to permanent soil cover by grassland, EPRIP (4.0 and 4.5 EPRIP score ha^{-1}), ecological focus area (40 and 5%), due to specific importance given at Ugolino golf course to ecological infrastructures, ecological corridor length (110 and 0 m ha^{-1}), due to extended CGU rough sectors, portion of revenues achieved from local end users (40 and 0%) and job supply (3.8 and 33.3 agricultural area used labour $unit^{-1}$).

CGU showed very low performances in terms of nitrogen leaching (117 kg N ha^{-1}, +239% and +433% as compared to VF and threshold, respectively) and water use (380 mm, +355% as compared to threshold) and this is in line with environmental concerns as reported in the introduction.

However, when aggregating indicators into one sustainability index (sub-phase 3.3, Table 4), because of notably negative performances in terms of nitrogen leaching and water use, the golf course index was found to be 36% lower than the sustainability index of the virtual arable farm (weighting scenario a), –6.74 *vs* –4.26, respectively). This difference reached the considerable level of 92% under weighting scenario b, when only classical environmental-agronomic indicators of the physical dimension were considered (–7.14 *vs* –0.55, respectively). Results reversed when imposing equal weights to the four sustainability dimensions (weighting scenario c), which allowed positive performances of the golf course in terms of ecological and social dimensions (+0.56 and +0.78, respectively) to consistently compensate negative results in terms of physical and production dimensions (–1.78 and –0.60, respectively). This was possible only because of the relative reduction of the impact of nitrogen leaching (from –5.29 to –1.32) and water use (from –2.55 to 0.64).

Our approach reflect the importance of an overall assessment of all components (ecological, recreational, socioeconomic, *etc*.) that affect management of a golf course and in this way it is consistent with findings of Dai *et al*. (2016), who pointed out that ecological benefits produced by golf course are higher than dis-services, in terms of financial accounting. These ecological services can also be enhanced by particular management reserved to rough areas that can play an important role in conservation of particular environments with typical plants and to improve pollination activity (Dobbs and Potter, 2016).

Conclusions

Our work produced interesting comparison between two very different kinds of land use that have been characterized under different options. The comparison performed by means of an overall approach framework (AESIS) demonstrated to be efficient in pointing out benefits and negative aspects linked to the two alternatives here examined.

In particular, from a methodological point of view, AESIS framework proved to be a practical and adaptive tool that during our work was used under three scenario characterized by different features. Modularity of AESIS permitted in this way several simulations with different weights that produced different results in the comparison. Thus, it is important to stress that the framework does not follow a rigid scheme but it can rely on different indicators to be chosen according to different aims. This can be an efficient method to compare possible land destination options, a case that can happen in a planning committee of a municipality to which is assigned the duty to deliver the permission for a golf course construction.

Considering results of the study, golf course showed to have a significant impact on some physical-environmental characteristics but on the other side it performed in a better way than the alternative ordinary farm in some features concerning both ecological-environmental and socioeconomic domains, confirming that a proper assessment of sustainability can be performed only with a holistic approach that comprises a wide range of different issues.

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