ENVIRONMENTAL, ECONOMIC AND SOCIO-INSTITUTIONAL CONTEXT OF THE SUSTAINABILITY INDEX: EVIDENCE FROM ITALY

Maria Annunziata Longo *, Paolo Tenuta **

* Regione Calabria, Italy
** *Corresponding author*, University of Calabria, Italy
Contact details: University of Calabria, Via Pietro Bucci, 87036 Arcavacata, Rende CS, Italy

OPEN ACCESS

How to cite this paper: Longo, M. A., & Tenuta, P. (2020). Environmental, economic and socio-institutional context of the sustainability index: Evidence from Italy [Special issue]. *Corporate Ownership & Control, 18*(1), 355-369. http://doi.org/10.22495/cocv18i1siart10

ISSN Online: 1810-3057
ISSN Print: 1727-9232

Received: 26.08.2020
Accepted: 20.11.2020

JEL Classification: Q01, Q05, M140
DOI: 10.22495/cocv18i1siart10

Abstract

The aim of this study is to define a methodology for assessing sustainability at different levels of detail. For the definition of the conditions of sustainability, the approach known as the triple bottom line was used. The study developed concerns the identification of a set of environmental, economic, and socio-institutional indicators and the elaboration of the same in a synthetic analysis index, organized in a hierarchical structure. An index for measuring irrigation sustainability has been built. This index, called the Sustainable Irrigation Index (SII), allows monitoring and assessment of the sustainability of irrigation activities and policies, at various territorial analysis scales, varying from the regional to the agricultural company. We proceeded with the creation of a multi-criteria spatial decision support system (GIS-based). The implementation of the index took place using the GIS IDRISI software. Finally, the index was applied to the concrete case of a Province of the Calabria region.

Keywords: Sustainable Development, Sustainable Governance, Sustainable Regional Development, Environmental Economics, Triple Bottom Line, Index, Indicator, Natural Resource Management

Authors' individual contribution: Conceptualization – M.A.L.; Methodology – P.T.; Formal Analysis – M.A.L.; Resources – M.A.L.; Writing – M.A.L.; Supervision – P.T.

Declaration of conflicting interests: The Authors declare that there is no conflict of interest.

1. INTRODUCTION

The present study fits into a rather significant picture in which the world scenario shows a situation of progressive shortage of water resources. Irrigation is essential for agricultural production, the scarcity of water resources represents one of the main limiting factors for economic and civil development and represents a brake on agricultural development worldwide. The growing imbalance between fresh water needs and availability requires integrated planning of water resources at the level of the river basin. Italy is one of the European countries with the highest rate of used agricultural area irrigated, with the consequence that about 84% of Italian gross agricultural production derives from the irrigated territories.

The increase in the percentage of the population living in urban environments and the spread of habits and hygienic-sanitary structures of high quality will cause, over time, an increase in the water needs per capita. From this point of view, it is essential to implement policies to counter the scarcity of water resources, both from a quantitative point of view, limiting waste and optimizing its taxation with alternative and competing uses, and qualitatively, affecting punctual and widespread sources of investigation.

The availability of water resources is particularly critical in the Mediterranean area, so all agriculture, which consumes the greatest amount of resources, is required to reinterpret its role in water management and above all to do it in a sustainable way.

Various indications relating to the evaluation of agricultural sustainability are presented in the literature, albeit in the majority of cases mainly oriented towards a single perspective (less, instead, compared to irrigated sustainability, currently being researched). The few studies available, however, often analyze only one point of view (e.g., the corporate one) or are limited to a single thematic aspect (for example the economic one).

The assessments are taken in this work and the basis of the sustainability study are as follows:

- The sustainability analysis is multi-criteria and interdisciplinary. The assessment is based on environmental, economic, and socio-institutional considerations.
- Sustainability is "measurable". It is necessary to build models capable of representing, monitoring, and evaluating sustainability through sets of indicators comparable over time and space, built to guide decision-making processes through an integrated approach. This is mainly related to the fact that the policies undertaken by organizations are warned if clearly measurable results are achieved.
- The main objective of the assessment is to direct management towards sustainability criteria. This means to analyze and to evaluate current management, identify any "correctable" weaknesses, and propose improvement strategies, which take into account the interactions between environmental conditions and economic, social, and political aspects.

Table 1. Research phases

Step 1	*Step 2*	*Step 3*	*Step 4*	*Step 5*
Analysis of the state of art relating to definitions, models, indicators, and sustainability indices.	Breakdown of the complex problem based on the identification of the elementary indicators, the conditions of absolute unsustainability (excluding conditions), and the ranges of sustainability values.	Structuring of a synthetic index of irrigation sustainability (SII, Sustainable Irrigation Index), based on the aggregation of indicators into themes and sub-themes and on the structuring of the territorial levels of analysis.	Muticriterial – multi-objective and spatial processing of data collected through the application of the GIS IDRISI software, with comparative analysis of alternatives through the application of the analytical hierarchy process (AHP) method.	Application of the SII to a case study.

Note: This table shows the steps that led from the analysis of the literature to the implementation of the SII.

The approach considered most effective to manage the problem of assessing irrigation sustainability is, as mentioned, multi-criteria and multi-objective, since it allows managing the issue of assessing sustainability with the classic methods of decision support systems (DSS), IT systems capable of making the use of information immediate and efficient. The multi-criteria evaluation methodologies play a central role in the evaluation of sustainability since they allow to face complex problems by evaluating all the variables involved individually but in an integrated way, attributing to each one its own relative importance. IDRISI software was used for the implementation of the SDSS, based on the integration between the GIS spatial analysis and the multi-criteria analysis technique based on the theory of AHP analytical hierarchical processes. The aim of AHP methods is to transform preferences of the decision-maker, expressed qualitatively, into quantitative quantities (criteria weights), expressed in numerical form. For the evaluation of the weights to be attributed to the individual criteria, the scale proposed by Saaty was used, based on the comparison in pairs of the same criteria, on the construction of a matrix of weights, and the final verification of a consistency index. To assess irrigation sustainability, an index (SII) was constructed, divided into 3 dimensions or perspectives (environmental, economic, and socio-institutional), 11 themes, 42 sub-themes, about 300 indicators.

Indicators are the simplest element of analysis. The SII takes into account the subjects responsible for irrigation management: region, Consortia, companies. The SII, variable between 0 and 1, can fall into five ranges ranging from "permanent unsustainability" to "high sustainability". It also makes it possible to identify categories of weakness, to propose specific and targeted interventions, and, therefore, to increase sustainability.

Table 2. The application of the index to the three territorial levels of analysis

Expedited level (or regional)	*Level of detail*	*Level of extreme detail*
Based on existing information, aimed at providing an indication of the sustainability of large-scale irrigation management, supporting the preliminary planning of new interventions, guiding strategic political choices related to irrigation agriculture.	At the Consorzio di Bonifica scale, based in part on existing information and in part on direct surveys, aimed at assessing the sustainability of consortium irrigation management, supporting feasibility studies for new projects, improving the management of current irrigation systems, plan future interventions (structural and otherwise).	On a company scale, based on specific investigations and detailed mappings and aimed at assessing the sustainability of the company's irrigation management, identifying any critical points and proposing specific corrections at the company level (e.g., change of crops or irrigation method), carry out a detailed analysis of irrigation sustainability at the consortium level, plan punctual interventions.

Note: This table shows the possible applications of the SII and its usefulness in the three levels of analysis.

The current study, therefore, aims to contribute to increasing the knowledge available through models capable of representing, monitoring, and assessing sustainability through sets of indicators comparable over time and space, built to guide decision-making processes through an integrated approach. The SII, in particular, allows you to schematically identify the weak points of irrigation management and to propose appropriate corrective solutions. The application highlighted several positives: first of all, the use of simple, flexible, and easily understandable indicators facilitates the application of the index. Precisely the use of indicators, as a tool to support decisions, is spreading increasingly among public administrations, above all because it allows you to monitor the progress of policies, to easily make spatial and temporal comparisons, to promptly take corrective measures. The development, in particular, of irrigation sustainability indicators proposed in this study, referring to social, economic, and environmental aspects and their interactions, allows a broad spectrum analysis and an overview of the contribution of irrigation to sustainable development. The integrated analysis of the three dimensions contributes, in fact, to overcome the problems generated by a partial approach, for individual dimensions, which is not consistent with the principles of sustainable development. The fact that these indicators are grouped in a synthetic analysis index allows for easier reading and interpretation of the data. The administration that uses the SII can thus identify economic, social, and/or environmental weaknesses and propose corrections, but also identify possible actions through which to improve the effectiveness of irrigation policies with regard to sustainability objectives, or monitor the progress made over time in the various areas and to disseminate sustainability issues, raising awareness of the economic, institutional and social subjects involved.

In Sections 2 and 3 of the following work, are reported the literature review, the main methodological approaches adopted by a series of models managed by national and international agencies to evaluate the various aspects of sustainability and the research methodology. Sections 4 and 5 illustrates the research results. Section 6 contains the conclusions.

2. LITERATURE REVIEW

In the literature, there are various indications relating to the assessment of sustainability, albeit in most cases oriented mainly towards a single perspective (environmental, social, or economic), less, instead, compared to irrigated sustainability, currently being researched. The available studies, however, often analyze only one point of view (e.g., the corporate one) or are limited to a single thematic aspect (e.g., the economic one). This is because some interventions by international bodies have encouraged companies to increase the information provided externally to demonstrate their voluntary assumption of social responsibilities so that consumers and investors can take them into account for their decisions (Ricci, Siboni, & Nardo, 2014). From this point of view, it has become essential to be able to represent one's own sustainable development. For several years there has been widespread awareness of the impossibility of traditional economic reporting systems to represent the full complexity that characterizes all organisations (Lev, 2001; Andriessen & Tiessen, 2001; Pike, Rylander, & Roos, 2001). The informative limit of economic documents is highlighted by the impossibility of supporting the stakeholders' opinion on the set of performances achieved by the company (Kaptein & Wempe, 2002). The Enron and Parlamat cases have accelerated a process in place for several decades in which the information contained in the compulsory accounting documents have lost relevance (Collins, 2001; Francis, Schipper, & Vincent, 2002; Klein & Marquardt, 2006; Lev & Zarowin, 1999); this stimulated the request for additional information (Wasley & Wu, 2006). The need to observe simultaneously the effects of any company transaction on the overall performance, in accordance with the stakeholder view, drove managers to extend the scope of observation toward the triple bottom line (Clarkson, 1995; Davenport, 2000). Only monitoring its performance in the extended sense allows the company's sustainability to be measured and managed (Funk, 2003; Kiernan, 2001; Wheeler, Colbert, & Freeman, 2003).

2.1. Literature review on the notion of sustainability and sustainable development

It is a common perception of how the model of economic growth adopted by the industrial revolution to date is environmentally and socially unsustainable. The issues related to the sustainability of development, included in the constitutional principles of the European Union, have evolved since the 1960s with the birth of the first environmental associations. One of the clearest and most evident characteristics of sustainable development is the multidisciplinary approach: it combines environmental, economic, and social problems. This type of approach, also known as the triple bottom line, was proposed by the World Commission on Environment and Development (WCED), called to develop strategies to guide sustainable urbanization processes. WCED bases its vision of sustainable development on the analysis of three dimensions: economic, social, and environmental. Agenda 21 added to these also the institutional dimension understood as the ability to ensure conditions of stability, democracy, participation, information, training, and justice. In the literature there are numerous definitions of sustainability, sometimes even conflicting: the most common ones are summarized below and a review of the main models used by the international community for the assessment of sustainability itself is illustrated. The first complete definition of sustainability is contained in the "Our Common Future" report, drawn up in 1987 by the WCED (Brundtland Commission). Development is defined as sustainable that "guarantees the needs of current generations without compromising the possibility that future generations will be able to satisfy their own". Development is defined as sustainable if it is capable of generating situations of substantial equilibrium between the three spheres: social, economic, environmental, or, if you prefer, if the so-called equilibrium rule of the three "E" is valid: ecology, equity, economics. A more complete vision of sustainable development was provided, in 1991, by the World Conservation Union, UN

Environment Program, and World Wide Fund for Nature, which identifies it as "an improvement in the quality of life, without exceeding the carrying capacity of the ecosystems of support, on which it depends". In the same year, economist Hermann Daly provided a further vision of sustainability. Sustainable is the development that meets three general conditions: the consumption of renewable resources does not exceed the relative regeneration rate; the consumption of non-renewable resources is compensated by the production of an equal amount of renewable resources which in the long term are able to replace them; the release of pollutants into the environment does not exceed the absorption capacity of natural receptors. In 1994, the International Council for Local Environmental Initiatives (ICLEI) provided a further definition of sustainable development: "Development that offers basic environmental, social and economic services to all members of a community, without threatening the operability of natural, built and social systems on which the supply of these services depends". In 2001, UNESCO expanded the concept of sustainable development by indicating that "cultural diversity is as necessary for humanity as biodiversity for nature (...) cultural diversity is one of the roots of development understood not only as growth economic but also as a means to lead a more satisfying existence on an intellectual, emotional, moral and spiritual level". Finally, the approach provided by Agenda 21 includes, however, the institutional approach. In other words, sustainable development is based on an efficient integration between non-degraded natural ecosystems, advanced technologies, and conscious and responsible social and cultural systems (Rapisarda, 2005).

The assessment of the sustainability of development can be expressed according to two formulations (Munda, Nijkamp, & Rietveld, 1992):

1) Strong ecological sustainability: it is the most prudent one, lined up in favor of measures aimed at avoiding those environmental changes that produce irreversible losses of the natural heritage of the ecosphere and to compensate for irreversible losses. Sustainable economic development is therefore what combines a growth of human-produced capital (*C*), the maintenance of a natural capital (*N*) at least not less than that inherited. The condition of strong sustainability, therefore, can be expressed thus (Pearce, Barbier, & Markandya, 1990):

$$\Delta(C) \geq 0 \cap \Delta(N) \geq 0 \quad (1)$$

2) Weak ecological sustainability: it is the riskiest and most confident in the ability of future generations to successfully face the environmental consequences of our actions. In other words, development is sustainable, with wealth growing in such a way as to allow us to face the consequences of the inevitable reduction in the degree of naturalness. The weak sustainability condition, therefore, is as follows (Bojö, Mäler, & Unemo, 1990):

$$\Delta(C + N) \geq 0 \quad (2)$$

where, *C* must be greater than zero, while *N* can take negative values. The consequences of negative *N* can be accepted thanks to the rates of *C* intended to introduce corrective factors capable of maintaining favorable living conditions for humanity.

In summary, weak sustainability implies the maintenance of the total amount of capital, admitting the substitutability between the different forms of capital. Strong sustainability, on the other hand, considers the conservation of capital as a whole, that is, for those non-replaceable forms of capital such as natural capital, the maintenance of the so-called "critical natural capital" (Pearce, 1993).

2.2. Literature review on measuring sustainability

The need to assess sustainability in an increasingly objective and clear manner has pushed the scientific world into an effort to create models capable of measuring, representing, and monitoring sustainability through sets of indicators. These sets are built to guide decision-making processes through an integrated approach of economic, environmental, and social indicators. The reasons for this are to be found in the fact that the policies undertaken by organizations are felt if measurable results are achieved. It is, therefore, useful to use economic, social, and environmental indicators comparable over time and space. The development of indicators, through the use of analysis models, allows reaching indices, representative of a given phenomenon. There are several structures for developing a sustainability indicator: the basic domain (e.g., economy), basic objective (e.g., economic prosperity), sectoral target (e.g., building value), identification of a problem (e.g., building disorder), causal (cause-effect functions), a combination of previous structures (Maclaren, 1996).

Based on the chosen approach, different solutions are adopted in the construction of indicators. One is to develop a single compound index, the second is to develop a set of indicators, while the third is to use the notion of "capital stock" as a unifying concept for selecting indicators (Winston & Pareja-Eastaway, 2006). There is a further question related to the choice of indicators: they are often descriptive of a goal, scientifically valid, and measurable. However, the territory is dynamic and there are sites of conflict or cooperation between political actors, where the actors try to exercise their strength, to assert their role, to achieve their political objectives (Astleithner, Hamedinger, Holman, & Rydin, 2004). Where opposing views exist, different indicators can be used to confirm different views of sustainable development. The selection of indicators at the national level, therefore, becomes a political choice "through this choice, governments give meaning to their priorities, make commitments to be put in place and indicate that they are ready to respond to their electorate of the possible failure of the process" (Stevens, 2005, p. 6). In this process, an important role is assumed by the multi-criteria evaluation methodologies that allow facing complex problems by evaluating all the variables involved individually but in an integrated way, attributing to each of them their own relative importance (Boggia, 2007). There are numerous parametric models developed by international bodies for measuring the sustainability performance of the various countries (Maiolo, Martirano, Morrone, & Pantusa, 2006). These models, although constructed to be applied to the measurement of the sustainability of states, can be used, by changing the indicators, for any type of organization. In addition to the specific indicators, there are others which, although they develop in a prevailing dimension (economic, social, or environmental), still take into account the more global definition of sustainability. For example, classic economic indicators are GDP and the employment rate but, in Europe, some indices have been developed, described below, aimed at integrating economic and environmental aspects (NAMEA matrix and SERIEE accounts), which therefore exceed the single economic dimension (Tenuta, 2009). The identification of the indicators and indices to be used changes according to the spatial level of analysis. It is, therefore, possible to make a further distinction between indicators and sustainability indicators at a territorial level and indicators and sustainability indices on a single organization scale.

The former is used on a large scale (for example at the national level) to evaluate the policies of a state, the latter instead are used by individual organizations (e.g., local authority, company, NGO, or other) to evaluate their performance. At the individual organization level, documents such as integrated reports can be used. The assessment of sustainability carried out at a territorial level (international, national, territorial, or sectoral) implies the analysis of indicators, the development of indices, and the use of different models with respect to the analysis carried out at the individual organization level.

Table 3. Tools for measuring and assessing sustainability

Economic indices and indicators	***Social indices and indicators***	***Environmental indices and indicators***	***Sustainability indices and indicators***
• Satellite accounts (SERIEE); • NAMEA matrix; • ISEW (Index of Sustainable Economic Welfare).	• HDI (Human Development Index); • HPI (Human Poverty Index); • GEM and GDI - gender indices.	• PSR (OECD); • DPSIR (EEA); • EPI 2006 and 2008 (Environmental Performance Index).	• ESI (Environmental Sustainability Index 2005); • Dashboard of sustainability; • European Common Indicators; • UNCSD; • Monet; • ISSI; • US-IWG-SDI; • World Development Indicators; • PPI (Policy Performance Index); • SDI (Sustainable Development Indicators).

Note: This table shows the numerous experiences conducted at an international level in order to identify increasingly significant controls and increasingly representative sustainability indices.

The goal of measuring sustainability can take place according to two distinct approaches:

- the identification of indicators and the development of synthetic indices, which bring together the complexity of sustainability in one or at least a few variables;
- the development of more or less extensive sets of indicators that include sectoral (environmental, economic, and social) indicators.

Numerous experiences have been conducted internationally in order to identify increasingly significant indicators and increasingly representative indices of sustainability.

The Environmental Sustainability Index (ESI) is based on a set of five components and twenty-one very general indicators, each of which combines from 2 to 6 variables for a total of 67 more specific variables. A high ESI value corresponds to a positive level of environmental sustainability.

The Dashboard of Sustainability is software that summarizes complex relationships between the economic, environmental, and social factors of sustainability. The Dashboard on the basis of a defined set of indicators allows visualizing with a summary parameter the level of sustainability of the development of a specific territorial reality. Through this software, a synthetic picture is obtained which describes the reality and quality of life of a nation, region, province, municipality. The Dashboard of Sustainability goes beyond the one-sidedness of GDP or other one-dimensional indicators of well-being and makes the complexity and multidimensionality of the concept of development sustainability explicit (Jesinghaus, 2005).

The European Common Indicators identified are 10, plus the ecological footprint added in a subsequent review of the project, and refer in particular to sustainability in urban realities. The goal is to measure the approach or departure from a sustainable model (Rapisarda, 2005).

The United Nations Commission on Sustainable Development (UNCSD) was established to follow the implementation of Agenda 21. In 1996 it presented the first guide on methodologies and a model of indicators of sustainable development. This model, revised in 2001, is based on a set of 58 indicators of sustainable development. This model is divided into themes and sub-themes grouped into four pillars: social, environmental, economic, and institutional, for a total of 15 themes, 38 sub-themes, and 58 indicators (Maiolo et al., 2006).

Monet is a Swiss project that aims to develop a monitoring system for the Swiss sustainable development strategy. The model consists of more than 100 distinct indicators in the social, environmental, and economic spheres (Maiolo et al., 2006).

The ISSI is an aggregate index created by the Italian Institute for Sustainable Development to quantify the improvements compared to sustainable development. ISSI represents a single indicator capable of integrating the three components of sustainable development, economy, society, and environment in which there is no list or core set of indicators (Federico & Barbabella, 2008).

The US Intergovernmental Working Group (US-IWG-SDI) has identified a series of indicators through which it has designed a model for measuring sustainable development for the United

States. The selected indicators are represented by an ecometer, a sociometer, and an ambientometer (Maiolo et al., 2006).

The World Development Indicators is a database by the World Bank in which data are collected for almost all countries in the world and the improvements made in achieving the Millennium Development Goals are highlighted analytically. The indicators used are around 1000 ordered in more than 80 tables and grouped in 6 sections and represent in an integrated way the social and economic conditions of the population, the financial situation of the various countries, the state of natural resources, the environment, and energy.

The Policy Performance Index was developed on the initiative of the European Union with the aim of replacing traditional indicators such as GDP, the unemployment rate, and inflation in measuring the results of individual countries with a performance index of the programmatic lines composed of three economic, social and environmental sub-indices.

The Sustainable Development Indicators (SDI) have been identified in compliance with the sustainable development strategy of the European Union. The set of indicators consisting of 12 themes, 45 sub-themes, and 98 analytical indicators represents a good starting point for pursuing the European Union's Sustainable Development Strategy.

2.3. Literature review on measuring agricultural and irrigation sustainability

In the literature there are numerous studies related to agricultural sustainability, many less are those related to irrigation sustainability, currently in development. The first studies on sustainability were carried out by the United Nations immediately after the Conference for the Environment and Development held in 1992. Over time this activity has been enriched with important contributions and the multidimensional articulation of agricultural sustainability has been increasingly outlined. The crucial points of agricultural sustainability are the following (Pretty, 2008):

1. Realize integrated biological and ecological processes.
2. Minimize the use of non-renewable resources.
3. Increase the knowledge of farmers.
4. Make productive use of people's skills to work together to solve common problems related to the environment and agriculture.

Irrigation should be sustainable when the inevitable impact on agricultural soils, water resources, and other aspects is such as to respect the quality of the environment and satisfy the demand for food in an economically and socially fair manner (Wichelns & Oster, 2006). In other words, irrigation sustainability means a system capable of continuing to use irrigation resources and ensuring their maintenance for future generations. To be sustainable, irrigation and drainage must be conducted efficiently, so as not to degrade the quality of soil, water, and other natural resources that contribute to both agricultural production and the quality of the environment (Oster & Wichelns, 2003). The general principles on which a definition of sustainable use of water can be set have been formulated in a series of international documents, from chapter 18 of Agenda 21 to the Dublin conference in 1992, to the 5th EU Framework Program of Environmental Action, at the Johannesburg summit (2002) and the Kyoto World Water forum (2003). In the perspective adopted by these documents, the sustainable use of water resources concerns both the maintenance of capital for future generations (ecological sustainability), the efficient allocation of a scarce resource (economic sustainability), and the fair sharing and accessibility for all of a fundamental resource for life and economic development (social sustainability) (Solanes & Gonzalez-Villareal, 1999; Kahlenborn & Kraemer, 1997). The reorganization of irrigation systems can be a key element in the search for a sustainable structure for the regional water resource system, since controlling irrigation water means controlling almost all of the water circulation. To obtain this result, it is essential on the one hand to activate policies to mitigate the causes of climate change and on the other to adapt to the effects, moving from the "old" demand policy to the "new" season of managing the available water resource, based on the reduction of consumption, on the increase in available water resources and efficiency in uses, and on a radical revision of the tariff system to encourage savings and penalize waste.

3. RESEARCH METHODOLOGY

With the aim of directing irrigation management towards sustainability criteria, this study provides a methodology for assessing the sustainability of irrigation resource management at various territorial scales of investigation. The study concerns the identification of a set of indicators, hierarchically aggregated into sub-themes and themes, and the elaboration of the same in a synthetic analysis index, defined as SII.

Table 4. The construction of the SII

Definition of the subjects responsible for irrigation management.	Breakdown of the complex problem (assessing the level of irrigation sustainability), based on the identification of the elementary indicators, the conditions of absolute unsustainability (excluding conditions), and the ranges of sustainability values.	Structuring of a synthetic index of irrigation sustainability (SII), based on the hierarchical aggregation of indicators in themes and sub-themes and on the structuring of spatial levels of analysis.	Muticriterial – multi-objective and spatial processing of data collected through the application of the GIS IDRISI software, with comparative analysis of alternatives through the application of the analytical hierarchy process (AHP) method.

Note: This table shows the construction steps of the SII.

For the implementation of the index, it is necessary to define, for each perspective, the significant indicators, the exclusionary conditions, i.e., those of absolute unsustainability, the values of sustainability and unsustainability for each indicator. In fact, to evaluate the progress of a process, it is essential to have measurable indicators that, combined, lead to the construction of a synthetic, simple, and flexible index, capable of monitoring the process and improving its management. The SII allows for the monitoring and assessment of the sustainability of irrigation activities and policies, at different scales of analysis, varying from the regional to that of the farm. It is based on the implementation of a multi-criteria spatial decision support system (GIS-based). The multi-criteria analysis methods allow you to make comparative assessments, to classify a series of alternatives using a set of decision rules, and to identify the best compromise solutions, allowing you to evaluate all the variables involved individually, but in an integrated way, attributing to each of them its own relative importance.

Table 5. The hypotheses underlying the study

The sustainability analysis is multi-criteria and interdisciplinary: the assessment must be based on environmental, social, economic, and political considerations (triple bottom line approach).	The assessment is based on characteristics (environmental, social, and economic) existing at the moment or easily foreseeable.	Each indicator is considered independently of the others. That is, the interactions between the different indicators are not considered.	Some factors that influence sustainability are permanent (e.g., temperature, precipitation, macroscopic soil characteristics, etc.), others correctable at certain costs (e.g., crops, salinity, social and economic characteristics, corporate irrigation methods, etc.), which can be determined.	In the analysis, the "null" hypothesis must also be taken into account, i.e., taking into account, in the long term, the environmental, social, and economic effects that "non-irrigation" would entail on different types of soil. This would mean continuing to produce what was there before watering, possibly including the costs of reclamation, erosion control, soil arrangement, etc. This aspect is particularly relevant in the planning of new interventions.

Note: This table shows the fundamental hypotheses behind the study.

The actors of irrigation management, i.e., those who, each as far as they are concerned, have at heart the adoption of adequate and sustainable solutions, are public bodies, i.e., political subjects, managing bodies, generally coinciding with the Consortia of Remediation, and farmers (Schultz, 2001). Frequently there is a difficulty in communicating between the different levels: public bodies often pay insufficient attention to understanding farmers' objectives in their agricultural policies. This can lead to unexpected effects on crop choice, irrigation strategies, and impacts on society. As explained by van Schilfgaarde (1994) "the view from the top may be very different from the view from the bottom" (p. 207). This means that planners do not field crops and do not water. These activities and the corresponding choices are up to farmers, who may or may not have the same objectives as planners (Schultz, 2001). Taking into account the above considerations, the SII has been structured in such a way that it can be applied differently by the three responsible parties:

1) The region, which is the public body responsible for legislation and management of the water cycle.

2) Reclamation Consortia, which are the resource management bodies.

3) Farms, which are the ultimate users of the resource.

The calculation of the SII, variable between 0 and 1, takes place using the following expression:

$$SII = ENV \times SOC \times ECO \tag{3}$$

The three partial indices, all variables between 0 and 1, have the same weight in the calculation of the SII. *ENV*, *SOC*, and *ECO* correspond to the three dimensions or perspectives of analysis. Each of them is hierarchically divided into themes, sub-themes, and indicators. The sustainability classification indicates the level of irrigation sustainability, based on environmental, social, and economic reasons. The classification is organized into 5 levels (from permanent unsustainability to high sustainability). For intermediate classes it is also possible to insert the "limiting" sub-theme, that is, the one with the lowest sustainability value, intervening on which the global level of sustainability can be improved.

The meaning of each class reported is as follows:

1) Class S3 – High sustainability: irrigation management is carried out correctly, respecting the environment, economic efficiency, and social principles. There are no particular aspects to improve. There may be minor limitations.

2) Class S2 – Medium sustainability: irrigation sustainability is good but some aspects can be improved. Moderate limitations may be present.

3) Class S1 – Low sustainability: irrigation management is sustainable but it is necessary to intervene on the weaknesses to prevent unsustainability. In fact, the reported limitations can also be significant.

4) Class NS1 – Marginal or low unsustainability: irrigation management is currently unsustainable but for causes that can be removed at a certain cost. We can speak of "temporary unsustainability".

5) Class NS2 – Permanent unsustainability: irrigation management is not sustainable so action must be taken to avoid continuing to cope with a particularly critical situation from an environmental, economic, or social point of view.

Table 6. Sustainability classification

Categories	Classes	Class description	SII values	Sub-theme
S (Sustainable)	S3	High sustainability	0.75 < SII < 1	-
	S2	Medium sustainability	0.50 < SII < 0.75	Axx Exx Sxx
	S1	Low sustainability	0.25 < SII < 0.50	Axx Exx Sxx
NS (Unsustainable)	NS1	Marginal unsustainability	0 < SII < 0.25	Axx Exx Sxx
	NS2	Permanent unsustainability	SII = 0	-

Note: This table shows the sustainability level of irrigation. The classification is organized into 5 levels (from permanent unsustainability to high.

The limiting causes of sustainability are indicated by a letter that corresponds to the sub-theme that reaches critical levels. It is necessary to specify that the analysis allows identifying the "weak" indicator, that is the one with the lowest sustainability value based on the predetermined ranges. However, since it can be compensated by the values of the other indicators falling in the same sub-theme, in the general classification it was preferred to refer to the sub-theme and not to the limiting indicator. Only in the event that the indicator falls under one of the exclusion conditions, it cannot obviously be compensated. This is reflected in the unsustainable values of the SII. The sectors (or perspectives), consistently with the classic definitions of sustainability, are three: environmental, economic, and socio-institutional. Each sector (identified in other models also with the terms of size or pillar or scope) is structured into basic themes, sub-themes, and indicators. Although the importance of the use of indicators is universally recognized, a number of open questions remain the identification of adequate criteria for choosing the indicators, the definition of significant reference values and/or targets, the relationship between the indicators and the territorial, environmental, cultural and social context in which the activity takes place, the collection, and processing of data.

More generally, sustainability indicators are a tool for monitoring and assessing the sustainability of activities and policies. They are generally considered to be a vehicle for synthesizing, or simplifying, and communicating information on phenomena that are relevant for policymakers (Moxey, Whitby, & Lowe, 1998).

The selection and efficacy of the sustainability indicators are based on some factors, established by the Canadian International Institute for Sustainable Development, which is widely used and used by various bodies: significance, relevance for the reality in question; scientific solidity; reproducibility; measurability, and convenience; comprehensibility; consistency and reliability. For each theme relating to a dimension, a basic objective was identified in advance, on the basis of which the indicators were subsequently selected. An attempt was also made, as far as possible, to take into account the indicators proposed by the European Commission for the evaluation of agricultural policies and by other international institutions and organizations, above all for the possibility of making any international comparisons. In addition, the account was taken of the availability of data at a territorial level and the simplicity of the indicators, trying to privilege precisely the most transparent and immediate ones, to facilitate the application of the index and the immediacy of the information. As regards the temporal dimension, an attempt was made to consider indicators with time series of the maximum possible length.

The appropriate length of the time series depends on the type of indicator. In some cases, the time series available are shorter than the appropriate length. This occurred above all in the case of environmental indicators that concern issues that have only recently been considered important by the community. In such cases, it was preferred to include the indicators in the model, in order to establish an initial reference level that allows the evaluation of trends in the future. Many of the indicators used, especially with regard to the economic and social perspectives, are imported from other disciplinary areas and are used in the context of the assessment of sustainability by attributing them different values. Further investigations will allow identifying more specific indicators for irrigation. Having set the fundamental objectives for each theme, the significant indicators were selected, grouped into homogeneous sub-themes. The following should be noted that the inclusion of indicators in a specific dimension or perspective is a non-rigid technical choice, linked to interpretations and analysis perspectives. It is therefore possible that some indicators, included in a certain theme, may also fall within others. In this study, we have tried to use indicators that are as close as possible to the target set for each theme. Furthermore, the indicators selected for each sub-theme were validated and checked by specialists of the respective subjects. In fact, various professionals (engineers, agronomists, economists, sociologists) were involved in the study, some from public bodies, others from the University. It should be stressed that the contribution of the various professionals has become necessary, in addition to the validation of the indicators, also in the data collection phase. For the validation of each indicator, the following questions were asked to the specialists (FAO, 1985):

- What is the information to be collected?
- Why is it necessary?
- Where or how can it be detected?
- Is it worth trying to find that data, or, in other words, is the cost of finding worth the information?

The definition of targets, threshold values, or reference levels that allow an assessment of the significance or trend towards sustainability is complex. In some cases there are threshold values recognized at the national or international level, such as a standard of law (e.g., concentration values of the main chemical pollutants to be controlled in surface fresh water), in other cases, however, it is necessary to take into account the context in which we operate and the specific objectives that we intend to achieve.

In most cases, it is difficult to attribute net values, to which corresponds "sustainability" or "unsustainability". In practice, there is a transition range, delimited by a typical value (target) and a critical value (Bos et al., 2007). In many cases even the definition of typical value and critical value is impossible, so it is advisable to adopt a continuous preferability scale, in which the minimum and maximum values are defined on the basis of the most frequent values found in literature or measured in reality. Those conditions that make irrigation unsustainable from an environmental, economic, or social point of view are considered to be excluded. For each of these perspectives, in fact, there are essential conditions for the definition of irrigation sustainability.

Table 7. The exclusion conditions adopted in this study

Environmental perspective	***Economic perspective***	***Social perspective***
Land use incompatible with irrigated agriculture and/or a slope greater than 30%.	Condemnation of the tenants, with a final judgment, for economic-financial offenses.	Use of child labor and/or failure to respect workers' health and safety conditions.

Note: This table shows the conditions that make irrigation unsustainable from an environmental, economic, or social point of view.

If these conditions are verified, procedures can be applied to the method and the calculation of the irrigation sustainability index through the selected indicators. The application of the SII can take place at three different territorial levels of analysis: regional, consortium, and business. The application at each level has different objectives and is based on different numbers and types of indicators. The application of the SII at the first level (regional scale) of analysis intends to meet the following objectives: provide an indication of the sustainability of large-scale irrigation management, support the preliminary planning of new interventions, and direct strategic political choices relating to irrigated agriculture.

The application is large-scale (1:250,000 – 1:100,000) and can take place by taking as reference vast areas, such as the provincial or regional one. The application at the first level can be considered expeditious: it was preferred to select simple and easily available indicators, even at the cost of losing some elements of evaluation, in an attempt to create a flexible and immediate application tool. The analysis is based on the following information: macroscopic characteristics of the territory, land use and capacity, irrigation needs, water availability and derived flow rates, social characterization of the territory, agricultural characterization of the territory (presence of recognized less favored areas or quality districts), land characterization (average company size, the prevalent form of management, etc.), evaluation of regional irrigation policies: volume of investments and type of structural interventions related to irrigation interventions, type of non-structural measures adopted to prevent and limit the damage related to drought and water scarcity.

At level 1, the analysis is mainly based on existing information and data for each perspective. The following are considered: 4 themes, 11 sub-themes, and 51 indicators. The application at level 2 (consortium scale) is detailed and is connected to the remediation consortia. The scale of the survey varies between 1:100,000 and 1:10,000. The analysis achieved the objectives of assessing the consortium's irrigation management sustainability, supporting feasibility studies for new projects, improving the management of current irrigation systems, and planning future interventions (structural and otherwise).

Reference is made to existing information for the environmental perspective and direct collection of consortium data. All the economic and social information relating to the Reclamation Consortia is added to the information relating to the level 1 application. In particular the macroscopic characteristics of the territory and physical-chemical properties of the soils, land use and capacity, characteristics of irrigation networks, meteo-hydrological characterization of the territory (climatic aspects, irrigation requirements, water availability and derived flows, hydrogeological risk, historical information), criticalities related to the environmental impoverishment of the territory induced by irrigation, regional and consortium economic characteristics, social, agricultural and land characterization of the territory, evaluation of regional and consortium irrigation policies.

The analysis is based on 9 themes, 31 sub-themes, and 165 indicators. The company-scale analysis is the complete level of extreme detail. The analysis scale is at most 1:10,000. The objectives of the analysis are the following assessing the sustainability of corporate irrigation management, identify any critical points and propose specific corrections at the company level (e.g., crop change or irrigation method), carry out a detailed analysis of irrigation sustainability at the consortium level, and plan punctual interventions.

Level 3 analysis is based on existing information, specific investigations on environmental parameters, detailed maps of crops and irrigation methods, economic and financial analysis of the company, direct detection of social indicators. In particular on the macroscopic characteristics of the territory and physical-chemical properties of the soils, land use and capacity, cultivated crops, irrigation requirements, quality of irrigation water, characteristics of irrigation networks, meteorological and hydrological characterization of the territory (climatic aspects, irrigation requirements, water availability and derived flows, hydrogeological risk, historical information), criticalities related to the environmental impoverishment of the territory induced by irrigation, regional, consortium and business economic characteristics, social, agricultural and land characterization of the territory, evaluation of regional, consortium and company irrigation policies.

The level 3 analysis is based on 11 themes, 42 sub-themes, and 315 indicators.

Table 8. Themes and sub-themes to be analyzed at level 3

Dimensions or perspectives	*Theme*	*Sub-theme*	
Environmental	A.1. Agricultural and agronomic aspects	A.1.1	Topography
		A.1.2	Physico-chemical characteristics of the soil
		A.1.3	Land use and capacity of use
		A.1.4	Crops and crop requirements
		A.1.5	Quality of irrigation water
	A.2. Irrigation systems	A.2.1	General characterization
		A.2.2	Intake works
		A.2.3	Adduction works
		A.2.4	Accumulation/compensation systems
		A.2.5	Distribution networks
		A.2.6	Comitial networks
	A.3. Weather – hydrological aspects	A.3.1	Climate factors
		A.3.2	Requirements, availability, and derived flow rates
		A.3.3	Historical information on drought and water scarcity
		A.3.4	Hydrogeological risk
	A.4. Related aspects	A.4.1	Environmental depletion
Economic	B.1. Public body (Region)	B.1.1	Structural interventions
		B.1.2	Quality of structural interventions
	B.2. Management bodies (Reclamation consortia)	B.2.1	Outputs
		B.2.2	revenue
		B.2.3	Productivity indicators
		B.2.4	Spending indicators
	B.3. Companies	B.3.1	Outputs
		B.3.2	revenue
		B.3.3	Productivity indicators
		B.3.4	Legality
Social and institutional	C.1. Territory	C.1.1	Social characterization
		C.1.2	Agricultural characterization
		C.1.3	Land composition
	C.2. Public body (Region)	C.2.1	Irrigated policies
		C.2.2	Certifications and budgets
		C.2.3	Agricultural strategic plan for drought
	C.3. Management bodies (Reclamation Consortia)	C.3.1	Occupation
		C.3.2	Health & Safety
		C.3.3	Tariff systems, certifications, and budgets
		C.3.4	Interventions that affect the development of agriculture
		C.3.5	Agricultural management plan for drought
	C.4. Companies	C.4.1	General features
		C.4.2	Agricultural agronomic techniques
		C.4.3	Occupation
		C.4.4	Health & Safety
		C.4.5	Marketing, certifications, and budgets

Note: This table shows the level 3 analysis which is based on 11 themes, 42 sub-themes, and 315 indicators.

A spatial decision support system (SDSS) has been created for the implementation of the SII. In the case of geographical decision-making problems, integration of decision support systems and GIS is necessary. The SDSS has been structured through the integration of a geographic information system (GIS) with a series of multi-criteria analysis techniques applied to spatial data, in order to derive some representative quantities of irrigation sustainability. The territorial information processed, coinciding with the basic indicators, was returned both in graphic format (thematic cartography) and in alphanumeric format (integrated database). For the weighted aggregation of the elementary indicators, both with respect to their typology and the mathematical structure of combination, reference was made to multiple criteria decision aid (MCDA) multicriteria techniques, based on an analytical hierarchy process (AHP) approach. These techniques have been implemented within the DSS through calculation algorithms capable of providing a measure of the consistency level of the assumptions assumed for the aggregation models. The methodology implemented was therefore aimed at developing a spatial DSS that makes it possible to configure and compare a series of physical scenarios, each of which is representative of a combination of factors and/or characteristics of the natural environment (Colosimo, Biafore, & Mandicino, 1997).

The advantages in the application of an SDSS are significant and connected above all to the fact that it overcomes the spatial limits linked to the application of a simple decision support system and allows greater manageability of aggregated data at a territorial level. We have already mentioned multi-criteria analysis: it is a methodology derived from the disciplines of operational research and decision theory. It allows you to tackle complex problems by evaluating all the variables involved individually, but in an integrated way, giving each of them its own relative importance (Wolfslehner, Vacik, & Lexer, 2005). The multicriteria evaluation methods allow to face comparative evaluations and to classify a series of alternatives using a set of decision rules.

The evaluation is based on the comparison between the values assumed by all the indicators for each of the alternatives, obtaining as a final result a classification of the alternatives themselves according to the degree of achievement of the objectives set, in the presence of defined priorities.

The AHP method, introduced by Saaty (1990), is one of the most flexible multi-criteria analysis techniques. The versatility of this method is remarkable, in fact in the literature there are applications of this method in numerous fields (Vaidya & Kumar, 2006), from medicine to politics, to industry, to engineering, to the social. The ability of the AHP method to analyze different decision factors based only on the contribution of decision-makers makes the method particularly flexible and valid especially in the case of applications to complex socio-economic problems, in which social, cultural, and other issues must be incorporated non-economic factors (Alphonce, 1996). Numerous applications of the AHP method are available in the literature for issues related to the environment and, in particular, to agriculture. Alphonce (1996) applied the AHP method for solving specific problems related to agriculture in developing countries. Montazar and Behbahani (2007) applied AHP for the selection of an "optimized" irrigation system. The goal was to develop and evaluate an understandable model for selecting an irrigation system based on different criteria, parameters, of a physical, socio-economic and environmental nature, as well as related to the efficiency of the systems, with the aim of improving the exploitation of resources natural in agriculture. Wolfslehner et al. (2005) applied the AHP method to the assessment of forest sustainability. However, there are many case studies developed over time, just as evidence of the validity of the method. The method is able to easily introduce different factors, qualitative and quantitative, into a decision support system, breaking down a complex problem into a hierarchical structure, in which each level is composed of specific elements. The advantages of applying the AHP method are different (Vaidya & Kumar, 2006):

- allows you to easily manage qualitative and quantitative information;
- manages to incorporate the consent of the various interest groups. Generally, this occurs through the administration of a questionnaire for the comparison of each element;
- allows the formalization of subjective issues of the decision-making process, making the relative weight of each evaluation criterion transparent and therefore facilitating communication.

One of the central questions in the application of the AHP method is the determination of the weights of the criteria and, consequently, of the final evaluation of the alternatives compared to the criteria set.

Since the real weights are unknown, they must be approximated. To do this, the AHP method is based on the evaluation, numerical or verbal, of a sequence of comparison in pairs of two criteria or two alternatives. Numerical evaluations can take values in the scale 1-9, while verbal evaluations are brought back to the same scale of values through a conversion.

Table 9. The AHP method

1/9	*1/7*	*1/5*	*1/3*	*1*	*3*	*5*	*7*	*9*
extremely	very strongly	strongly	moderately	equally	moderately	strongly	very strongly	extremely
Less important					More important			

Note: This table shows how numerical evaluations can take values in the scale 1-9, while verbal evaluations are brought back to the same scale of values through a conversion.

Several studies have attempted to introduce scales of logarithmic values, geometric relationships, negative numbers, etc., nevertheless always coming to the conclusion that the most acceptable values were those of the 1-9 scale (Bodin & Gass, 2003). The scale of values 1-9, therefore, has been shown to be the most suitable measurement scale for approximating unknown weights in multi-criteria analysis problems.

Table 10. The meaning of the nine comparisons

Importance	*Definition*	*Explanation*
1	Equal importance	Two elements contribute in the same way to achieving the goal.
3	Slight dominance	Experience or judgment slightly favors one element or another.
5	Strong dominance	Experience or judgment strongly favor one element over the other.
7	Demonstrated dominance	The dominance of an element is demonstrated in practice.
9	Absolute dominance	The obvious preference of one element over the other is clearly manifested in the highest possible order.
1, 4, 6, 8	Intermediate values	Intermediate or compromise situation between the previous classes.

Note: This table shows the meaning of the nine comparisons.

In the calculation of the SII, the AHP method was used for optimization. The structuring of the problem, as amply illustrated, took place by hierarchically dividing the information into 11 themes, 42 sub-themes, and 315 indicators. The application of the AHP method took place initially for each sub-theme. Where the number of indicators of the sub-theme was greater than nine, partial application of the method for homogeneous semi-groupings was carried out. The method was then applied in cascade by themes and dimensions, obtaining the relative weights with the cyclical application of the procedure.

For the comparison of the indicators, measured in different units of measurement, it was necessary to calculate a normalized linear distance:

$$R(x) = \frac{R(i) - R(min)}{R(max) - R(min)} \tag{4}$$

wherein, *R(i)* is the value of the factor considered, *R(min)* and *R(max)* are equal, respectively, to the minimum and maximum values of the factor. The best value is the one that comes closest to an ideal point. Each element (indicator first, sub-theme and theme then) was, therefore, the subject of a comparison with the other elements to calculate the relative weights. As mentioned, all the comparisons for the attribution of the weights took place in pairs. In the application of the SII, the comparison system and the rating scale proposed by Saaty (1980) were used. Overall, the application of the method involved the evaluation of matrices of variable dimensions up to a maximum of 9 x 9. For each of them, the consistency index was calculated and, in the case of values greater than 0.1, the relative weights have been re-allocated. To establish the weights, experts from the Region, Consortia, and companies were consulted, privileging those with specific professional skills. The application of the multi-criteria model has made it possible to obtain a series of maps with the spatial distribution of values for each element (indicator, sub-theme, theme, size).

Table 11. Advantages and criticality of the SII

The advantages of applying the SII	*The critical issues found*
Allows you to identify weak points, both in terms of limiting element (indicator, sub-theme, or theme), and in spatial terms, that is, identifying the area in which the lowest sustainability values are recorded.	Computational costs: the complete application of the index, at the three levels of analysis, involves the processing of many maps. The management of these data is binding in the use of specific software.
Allows comparison of multiple alternatives. This ensures that the solution adopted is not only sustainable but the best among sustainable alternatives.	Since the maps are processed in raster format, the processing times are rather long, especially when aggregating by sub-themes and themes.
Allows monitoring over time. Sustainability assessment is an iterative process over time and space. It is, in fact, subject to subsequent in-depth analysis in the level of spatial analysis but also to subsequent temporal analyzes to monitor the sustainability variation of the choices made. The iteration occurs by varying and updating the base maps and applying the procedure from time to time.	Not all indicators have the same importance: above all in the social dimension, elements taken from global sustainability models have been introduced but distant from the territorial reality examined. Although this is taken into account with the introduction of weights, the consequent computational burden must still be taken into account.
The empirical analysis, at the different levels of detail, allowed to verify the substantial coherence of the SII index at the different analysis levels, to provide a cognitive framework about the socio-economic and environmental context of the province of Cosenza, and to evaluate irrigation sustainability for each of the subjects responsible for irrigation in the area under investigation.	The third level of analysis is probably too expensive: the possibility of simplifying some aspects should be considered, even at the expense of the loss of some information.
The aggregation of indicators in a summary analysis index is complex but useful and necessary for assessing sustainability, since, in addition to simplifying information, it makes it easily accessible for decision-makers.	
It can also provide useful information during the evaluation phase because it provides elements of comparative analysis useful for choosing the most suitable interventions to be carried out in the area.	
It is easily updated in the indicators, in the sense that, being clearly defined what the set of indicators is, the SII is flexible and modifiable as the values of the company and the political priorities change, and with the expansion of knowledge. This is possible precisely because it is an index characterized by transparency in the logical passages and by the re-traceability of the passages made.	
The SII has been structured in such a way as to be applied independently by public administrations, Reclamation Consortia, and companies.	
The index allows not only to make the comparison between different realities, but also the distance from the achievement of regulatory, institutional, or legislative targets.	

Note: This table shows the advantages and critical points highlighted in the application of the SII.

4. RESEARCH RESULTS

In this study, the SII was applied to the first level of analysis (of a province of the Calabria region). The characterization of the Calabrian agricultural system was then provided, highlighting the fragility and potential of rural areas and companies in general and the management of irrigation resources in particular.

Table 12. The main documents used for the application of the SII

Environmental indicators	*Social indicators*	*Economic indicators*
• Soil charter 1:250.000, ARSSA (Regional Agency for Development and Services in Agriculture); • The irrigation needs of the Calabria - ARSSA region; • Cadastre of irrigation systems, URBI (Regional Union for Remediation and Irrigation); • Guidelines: Land evaluation for irrigated agriculture, FAO soils bulletin 55.	• The 6th General Census of Agriculture, ISTAT; • Indicators for Italian agriculture, INEA.	For data relating to the Region: • direct survey through questionnaire; • PSR 2014-2020; • POR 2014-2020.

Note: This table shows the main documents used for the application of the SII.

For the modeling of the physical environment, we used GIS IDRISI. Through this software, the necessary processing was carried out for the preparation of the thematic cartography and the implementation of the SDSS. The first level analysis is based on 4 themes, 11 sub-themes, and 51 indicators. The assessment of irrigation sustainability at the first level of analysis is based on the elaboration of the cartographies that only in the overall context can be illustrated in this work.

For the calculation of the SII, therefore, a raster map was built for each criterion. The criteria were divided into two types: constraints or factors. In the case of constraints, the map is of the boolean type which associates 0 with the occurrence of the condition, 1 otherwise, and which represents the limitations to irrigation practice. In the case of the factors, i.e., the elements that can be used for the decision and which allow a preference to be given to the various choices, standardization was first performed and then the aggregation weights were calculated. Standardization is made necessary by the fact that each factor is expressed in different units of measurement and values. To make it comparable with the others, each factor has been traced back to the 0-255 scale as this range constitutes the maximum possible differentiation with byte type data, required by the application of the GIS IDRISI software. The value 255 indicates the greater preference or desirability of a factor, 0 instead constitutes the worst value. The standardization of quantitative factors is carried out by applying fuzzy logic, according to which a condition, in addition to being true (value 1) or false (value 0), can also take intermediate values, indicating the distance from a condition or the other using sigmoidal, linear or J-shaped functions. Then we proceeded to calculate the weights for the aggregation, based on the application of the AHP method. To calculate the weights, the Saaty scale was used and a series of comparison matrices with symmetric pairs were built.

The application ended with the aggregation of data, carried out by means of a weighted average of the standardized factors, for each pixel of the map. The resulting image, multiplied by the constraint maps, made it possible to obtain a measure of aggregate preference on a 0-255 scale. The values obtained were then traced back to the 0-1 scale and then classified into the categories of values reported for the indication of the SII (from low to high see Table 6).

5. DISCUSSION OF RESULTS

In the case in question, the results highlighted levels of sustainability varying from low to medium. The highest values were found in the more flat inland areas which, from an environmental point of view, have more favorable characteristics and in which more investments were made in terms of works. In these areas the values of the index that are found for the environmental dimension are high (0.84), and for the economic dimension, they are medium (0.44), while the values of the economic dimension found in the rest of the territory are they attest to low values (around 0.30).

The values of the index for the social dimension also attest to high values (from 0.50 onwards), highlighting the presence of a weak territory, where it is necessary to support garrison agriculture but in which there are large areas with the production of quality.

6. CONCLUSION

The purpose of this study was to evaluate irrigation sustainability at different territorial levels of analysis. The concept of sustainability in general was then focused on agriculture and irrigation, keeping in mind that there are close links between agriculture and irrigation. The definition of the SII was therefore defined by defining basic assumptions, responsible subjects, sustainability classes, structure and articulation of the index, selection, classification and implementation processes of the indicators, excluding conditions, range of values, territorial levels of analysis, implementation tools. The SII was therefore applied to the various territorial levels of analysis. The SII is divided into 3 dimensions, 11 themes, 42 sub-themes, and 315 indicators and is applicable to three different territorial levels of analysis. The assessment of irrigation sustainability is a multi-criteria, multi-criteria, and multi-objective process, therefore the implementation of the SII took place using GIS-based multi-criteria analysis techniques and building a SDSS. In particular, the weight calculation procedures were implemented by applying the AHP method proposed by Saaty in 1990, based on the comparison in pairs of the criteria and on the construction of a matrix of weights. Overall, with this work, we have tried to define a theoretical and methodological approach useful for analyzing the social, environmental, and economic characteristics and dynamics connected to the management of irrigated resources with a view to sustainability. The effort made was mainly aimed at:

- identify priority objectives for economy, environment, and society, based on community values and objectives;
- identify a set of environmental, economic, and social indicators capable of describing irrigation sustainability effectively and completely;
- define targets and threshold values for each indicator, related to standards, scientific world, political decisions, and calculate the weight of the different elements of sustainability (indicators, sub-themes, and themes);
- define a synthetic index, able to facilitate the reading and interpretation of the different indicators, so as to constitute a tool of real validity for users (public administrations, managing bodies, companies).

In this study, the aggregation took place through multi-criteria analysis and this has favored the maintenance of information potential. In fact, although these methods allow you to manage and control all the indicators, they allow you to evaluate the degree of sustainability by individual size, by theme, by sub-theme, and by indicator and then carry out the analysis of sustainability according to different levels of aggregation. In conclusion, awareness of the agricultural world has increased in recent years of the need to introduce the concept of environmental sustainability with the adoption of environmentally friendly practices. Agriculture can and must participate with a primary role in the actions for the safeguard and defense of the territory, through the correct management and maintenance of the infrastructures, the monitoring, and control of the phenomena of soil degradation, the maintenance of the vegetation cover in the areas at risk of desertification and, above all, through the correct use of irrigation resources. In this perspective, it is necessary to adopt structural and non-structural measures to improve the management of irrigation resources. Collective irrigation systems must be facilitated and encouraged through the reorganization of the districts and the reorganization of irrigation utilities, improving the efficiency of collective irrigation systems through modernization and adaptation of irrigation systems and networks, aimed at containing the inevitable losses of the system and make maintenance less onerous. It is also important to facilitate the multiple uses of irrigation water as required by law as well as the reuse of purified waste water, ensuring the full efficiency of the reservoirs with the consequent recovery of the volume of existing tanks. Implementing forms of sustainable irrigation takes on significant importance if you consider the quantities consumed and the impacts on human life. Monitoring and assessing the impact of irrigation on the economic, social, and environmental systems allow us to verify progress towards the goal of sustainability. Since the first statement of the principles of sustainability, enormous progress has been made and today sustainable development is at the basis of all the development policies of the European Union. Certainly, the process of building sustainability is long and difficult and only the common and shared effort will allow us to achieve the desired results.

The study has the most important limit in its computational burdens. The data processing activities on a total of three levels of analysis involves the reading of about 1500 maps and 72 weight matrices, of variable dimensions up to a maximum of 9 x 9. The management of such data makes the use of specific software.

REFERENCES

1. Alphonce, C. B. (1996). Application of the analytic hierarchy process in agriculture in developing countries. *Agricultural Systems, 53*(1), 97-112. https://doi.org/10.1016/S0308-521X(96)00035-2
2. Andriessen, D., & Tiessen, R. (2001). *Weightless weight: Find your real value in a future of intangible assets.* London, UK: Financial Times Management.
3. Astleithner, F., Hamedinger, A., Holman, A., & Rydin, Y. (2004). Institutions and indicators – The discourse about indicators in the context of sustainability. *Journal of Housing and the Built Environment, 19,* 7-24. https://doi.org/10.1023/B:JOHO.0000017704.49593.00
4. Bodin, L., & Gass, S. I. (2003). On teaching the analytic hierarchy process. *Computers & Operations Research, 30*(10), 1487-1497. https://doi.org/10.1016/S0305-0548(02)00188-0
5. Boggia, A. (2007). Un modello di monitoraggio ambientale e socio-economico per la valutazione della sostenibilità. *Rivista Micron, 7,* 36-39. Retrieved from http://www.arpa.umbria.it/resources/docs/micron%207/MICRON_7_36.pdf
6. Bojö, J., Mäler, K.-G., & Unemo, L. (1990). *Environment and development: An economic approach.* https://doi.org/10.1007/978-94-009-0623-5
7. Bos, M. G., van den Bosch, H., Diemont, H., van Keulen, H., Lahr, J., Meijerink, G, & Verhagen, A. (2007). Quantifying the sustainability of agriculture. *Irrigation Drainage Systems, 21,* 1-15. https://doi.org/10.1007/s10795-006-9014-y
8. Clarkson, M. B. E. (1995). A stakeholder framework for analyzing and evaluating corporate social performance. *The Academy of Management Review, 20*(1), 92-117. https://doi.org/10.2307/258888
9. Collins, J. C. (2001). *Good to great: Why some companies make the leap – And others don't.* London, UK: Random House Business.
10. Colosimo, C., Biafore, M., & Mendicino, G. (1997). Sistemi di supporto alle decisioni per la pianificazione ambientale. *Atti del 17° Corso di aggiornamento giugno 1996.* Editoriale Bios.
11. Davenport, K. (2000). Corporate citizenship: A stakeholder approach for defining corporate social performance and identifying measures for assessing it. *Business and Society, 39*(2), 210-219. https://doi.org/10.1177/000765030003900205
12. Federico, T., & Barbabella, A. (2008). *Indicatori per lo sviluppo sostenibile in Italia* (Relazione Finale del Progetto Nazionale dell'Economia e del Lavoro). Retrieved from https://www.mef.gov.it/ministero/commissioni/ccba/documenti/CNELx20Rapportox20Finalex20Indicatori.pdf
13. Food and Agriculture Organization of the United Nations (FAO). (1985). *Guidelines: Land evaluation for irrigated agriculture – FAO soils bulletin No. 55.* Retrieved from http://www.fao.org/3/X5648E/x5648e00.htm
14. Francis, J., Schipper, K., & Vincent, L. (2002). Earnings announcements and competing information. *Journal of Accounting & Economics, 33*(3), 313-342. https://doi.org/10.1016/S0165-4101(02)00058-7
15. Funk, K. (2003). Sustainability and performance. *MIT Sloan Management Review, 44*(2), 104-105. Retrieved from https://sloanreview.mit.edu/article/sustainability-and-performance/
16. Jesinghaus, J. (2007). MDG Dashboard of Sustainability. *Proceedings of Virtual Indicator Exhibition* (pp. 280-283). Retrieved from https://ec.europa.eu/environment/beyond_gdp/proceedings/bgdp_proceedings_indicatorexhibition.pdf
17. Kahlenborn, W., & Kraemer, A. (1997). Sostenibilità e gestione delle acque in Germania. *Economia delle Fonti di Energia e dell'Ambiente, 40*(3), 23-51. Retrieved from http://www.biblio.liuc.it/scripts/essper/ricerca.asp?tipo=scheda&codice=2002965
18. Kaptein, M., & Wempe, J. (2002). *The balanced company: A theory of corporate integrity.* https://doi.org/10.1093/acprof:oso/9780199255504.001.0001
19. Kiernan, M. J. (2001). Eco-value, sustainability and shareholder value: Driving environmental performance to the bottom line. *Environmental Quality Management, 10*(4), 1-12. https://doi.org/10.1002/tqem.1100
20. Klein, A., & Marquardt, C. A. (2006). Fundamentals of accounting losses. *The Accounting Review, 81*(1), 179-206. https://doi.org/10.2308/accr.2006.81.1.179
21. Lev, B. (2001). Intangibles: Management, measurement, and reporting. Washington, DC: Brookings Institution Press.

22. Lev, B., & Zarowin, P. (1999). The boundaries of financial reporting and how to extend them. *Journal of Accounting Research, 37*(2), 353-385. Retrieved from http://people.stern.nyu.edu/pzarowin/publications/P14_Boundaries_Financial_Reporting_1.pdf
23. Maclaren, V. W. (1996). Urban sustainability reporting. *Journal of American Planning Association, 62*(2), 184-201. https://doi.org/10.1080/01944369608975684
24. Maiolo, M., Martirano, G., Morrone, P., & Pantusa, D. (2006). Assessment criteria for a sustainable management of the water resources, *Water Practice & Technology, 1*(1). https://doi.org/10.2166/wpt.2006.012
25. Montazar, A., & Behbahani, S. M. (2007). Development of an optimised irrigation system selection model using analytical hierarchy process. *Biosystems Engineering, 98*(2), 155-165. https://doi.org/10.1016/j.biosystemseng.2007.06.003
26. Moxey, A., Whitby, M., & Lowe, P. (1998). Agri-environmental indicators: issues and choices. *Land Use Policy, 15*(4), 265-269. https://doi.org/10.1016/S0264-8377(98)00023-4
27. Munda, G., Nijkamp, P., & Rietveld, P. (1992). *Multicriteria evaluation and fuzzy set theory: Applications in planning for sustainability* (Serie Research Memoranda No. 1992-68). Retrieved from https://research.vu.nl/en/publications/multicriteria-evaluation-and-fuzzy-set-theory-applications-in-pla
28. Oster, J. D., & Wichelns, D. (2003). Economic and agronomic strategies to achieve sustainable irrigation. *Irrigation Science, 22,* 107-120. https://doi.org/10.1007/s00271-003-0076-4
29. Pearce, D. (1993). *Economic values and the natural world.* London, UK: The MIT Press.
30. Pearce, D., Barbier, E., & Markandya, A. (1990). *Sustainable development: Economics and environment in the third world.* Washington, DC: Edward Elgar Publishing Limited.
31. Pike, S., Rylander, A., & Roos, G. (2002). Intellectual capital management and disclosure. In C. W. Choo, & N. Bontis (Eds.), *The strategic management of intellectual capital and organizational knowledge* (pp. 657-672). New York, NY: Oxford University Press. Retrieved from https://www.researchgate.net/publication/274392200_Intellectual_capital_management_and_disclosure
32. Pretty, J. N. (2008). Agricultural sustainability: Concepts, principles and evidence. *Philosophical Transactions of the Royal Society: Biological Sciences, 363*(1491), 447-465. https://doi.org/10.1098/rstb.2007.2163
33. Rapisarda, C. (2005). *Per uno sviluppo durevole e sostenibile.* Retrieved from http://docplayer.it/6820191-Per-uno-sviluppo-durevole-e-sostenibile.html
34. Ricci, P., Siboni, B., & Nardo, M.T. (2014). *La rendicontazione di sostenibilità.* Retrieved from https://www.odcec.torino.it/public/convegni/Presentazione%20Ricci%20Rendicontazione%20Torino%2030%20Aprile%202014.pdf
35. Saaty, T. L. (1980). *The analytic hierarchy process.* New York, NY: McGraw-Hill.
36. Saaty, T. L. (1990). How to make a decision: The analytic hierarchy process. *European Journal of Operational Research, 48*(1), 9-26. https://doi.org/10.1016/0377-2217(90)90057-I
37. Schultz, B. (2001). Irrigation, drainage and flood protection in a rapidly changing world. *Irrigation and Drainage, 50*(4), 261-277. https://doi.org/10.1002/ird.35
38. Solanes, M., & Gonzales-Villarreal, F. (1999). *The Dublin principles for water as reflected in a comparative assessment of institutional and legal arrangements for integrated water resources management* (Global Water Partnership, TAC Background Paper No. 3). Retrieved from https://www.researchgate.net/publication/42765749_TAC_BACKGROUND_PAPERS_NO_3_The_Dublin_Principles_for_Water_as_Reflected_in_a_Comparative_Assessment_of_Institutional_and_Legal_Arrangements_for_Integrated_Water_Resources_Management
39. Stevens, C. (2005). Measuring sustainable development. *OECD Statistics Brief, 10.* Retrieved from https://www.oecd.org/sdd/35407580.pdf
40. Tenuta, P. (2009). *Indici e modelli di sostenibilità.* Milan, Italy: Franco Angeli.
41. Vaidya, S. O., & Kumar, S. (2006). Analytic hierarchy process: An overview of applications. *European Journal of Operational Research, 169*(1), 1-29. https://doi.org/10.1016/j.ejor.2004.04.028
42. van Schilfgaarde, J. (1994). Irrigation – A blessing or a curse. *Agriculture Water Management, 25*(3), 203-219. https://doi.org/10.1016/0378-3774(94)90061-2
43. Wasley, C. E., & Wu, J. S. (2006). Why do managers voluntarily issue cash flow forecasts? *Journal of Accounting Research, 44*(2), 389-429. https://doi.org/10.1111/j.1475-679X.2006.00206.x
44. Wheeler, D., Colbert, B., & Freeman, R. E. (2003). Focusing on value: Reconciling corporate social responsibility, sustainability and a stakeholder approach in a network world. *Journal of General Management, 28*(3), 1-28. https://doi.org/10.1177/030630700302800301
45. Wichelns, D., & Oster, J. D. (2006). Sustainable irrigation is necessary and achievable, but direct costs and environmental impacts can be substantial. *Agricultural Water Management, 86*(1-2), 114-127. https://doi.org/10.1016/j.agwat.2006.07.014
46. Winston, N., & Pareja-Eastaway, M. (2006). On indicators of sustainable housing in the European urban contexts. Paper presented at *ENHR Conference "Housing in an expanding Europe: Theory, policy, participation and implementation".* Retrieved from https://www.enhr.net/documents/2006%20Slovenia/W13_winston.pdf
47. Wolfslehner, B., Vacik, H., & Lexer, M. J. (2005). Application of the analytic network process in multi-criteria analysis of sustainable forest management. *Forest Ecology and Management, 207*(1-2), 157-170. https://doi.org/10.1016/j.foreco.2004.10.025