



Gender Equality in Soil Science in Italy: Wishful Thinking or Reality?

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Gender equality in Italian soil science is still far from being a reality although an in-depth investigation has never been carried out. In this work we analyse data on women soil scientists working in public research institutions and universities as well as on those affiliated with soil science societies, considering the changes in gender balance with time. We also recall three female pioneers in Italian soil science who played a key role in both research and scientific societies. An analysis of the impact of papers authored by Italian women is finally provided to gauge the contribution of Italian women to soil science in the last 20 years. The results show that the National Research Institutions reached a more equal balance between genders compared to universities. With regard to scientific societies, we observed a strong lack of female inclusion in the first years of the Italian Soil Science Society, founded in 1952, and the Italian Society of Pedology, even if it was founded much later in 1998. The Italian Society of Agricultural Chemistry was less discriminant, likely due to the presence of different sub-disciplines traditionally more open to women, although always far from real equality. With time, in all societies and research institutions we registered a positive trend with a better balance and a pro-active participation of women. However, we observed a persistent loss of highly qualified women resources from the training phase to the beginning of the career as well as under-representation of women in top roles and in the research centre leaderships. However, when we evaluated the scientific production, no statistical differences appear between women and men at all career levels, confirming the key contribution of women to soil science, despite facing major professional difficulties and disparities. These results show that, notwithstanding the marked progress in the number of women entering and working in Italian soil science, beyond the hard numbers, gender equality still remains a challenge and requires greater investments in resources and research toward structural and systemic interventions that may successfully lead to a more gender-balanced society.

Keywords: gender balance, Italian women in soil science, scientific societies, research institutions, authorship

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INTRODUCTION

Gender equality is among the Sustainable Development Goals of the United Nations, and in general, gender issues in society and at working places has been a hot topic in the last years in several countries all over the world. Discrimination in science was addressed as early as in 1983 (Acker, 1983), but still in the year 2000 the situation has not changed much as the scientific community was “shocked by revelations of sexual discrimination” arising from surveys conducted in Sweden and at MIT, United States (Loder, 2000). Recently, Dawson et al. (2021) more specifically examined gender equity in Soil Science in a number of countries. Italy was among those having a lower-than-average proportion of women affiliated to Soil Science Societies (27% with a worldwide average of 32%, and of 38% in Europe).

In Italy, the path towards the concept of equal opportunities began in 1945, later than in other countries (<https://www.mappr.co/thematic-maps/women-rights-of-vote/>), when, with the right to vote extended to all citizens without distinction of sex, the Constitution recognized equality for men and women. The Kingdom of Italy, in fact, ignored the female part that constituted it; for this reason in 1861, shortly after Italian Unification, the Lombard women, defining themselves as “Italian citizens,” submitted to the Parliament a petition in which they claimed the right to vote, as they had before Unification, and asked for it to be extended to the whole country. However, only at the end of the Second World War was this right finally recognized.

The Italian Constitution consists of 139 articles and the gender issue is affirmed in three of them. Article 3 states: “*all citizens shall have equal social dignity and shall be equal before the law, without distinction of gender, race, language, religion, political opinion, personal and social conditions.*” Article 37 intervenes directly on women’s work, stating that “*Women workers shall be entitled to equal rights and to equal pay as men for equal work. Working conditions shall allow women to fulfil their essential role in the family and ensure appropriate protection for the mother and child.*” In Art. 51 one reads: “*Any citizen of either sex is eligible for public and elected offices on equal terms, according to the requirements established by law. To this end, the Republic shall adopt specific measures to promote equal opportunities between women and men.*”

It took many years before laws were enacted accepting the provisions of the Constitution; it was indeed necessary to reform the previous family law and draft new legislation on the matter to eliminate, at the juridical level, the patriarchal conception of the family in favour of shared parent responsibility. Until the 1970s, legislation tended to “protect” women rather than sanction their equal opportunities; the interventions were aimed at safeguarding the rights of women whose condition continued to be in many respects lower than that of men.

With the right to vote for women in 1945, Italy anticipated the international legislation on this matter, which saw the affirmation of the principle of equal opportunities introduced in 1948, when the United Nations adopted the Universal Declaration of Human Rights. In Europe the problem relating to equal opportunities

between men and women has been tackled since the 1960s with the drafting, decade after decade, of five action programmes. Among the European Union treaties relating to equal opportunities, it is appropriate to mention: the Maastricht Treaty (1993), (Art. 119) which established equal salaries between men and women for the same job, and the Treaty of Amsterdam (1997) which promoted “gender equality,” combated gender discrimination, included women’s rights among fundamental social rights and promoted the adoption of measures aimed at facilitating professional activities undertaken by women. Due to gender diversity, either for biological, social and cultural reasons, the term “equal dignity with respect to gender differences” is often preferred to “gender equality,” with the goal of promoting equity, diversity, complementarity and inclusion as a necessary key for an effective fair socio-cultural and economic evolution of society.

Societal cultural evolution and the measures implemented by national and international laws have led to an increased presence of women also in the scientific community. Yet despite some encouraging signals, women are still underrepresented especially in leadership positions and in award rates in STEM disciplines (Sharma and Yarlagadda, 2022). According to UIS (UNESCO Institute of Statistics) data, female researchers worldwide constitute less than 30% of the total in 2016 (UIS, 2019). Appreciable differences exist between Western (39.3%) and Central-Eastern Europe (32.7%) with respect to the percentage calculated on total persons employed in R&D (research and development) in 2017 or the latest year available (UIS, 2019). At the European level, overall, 48.1% female doctorates (EU-27) were recorded in 2018, with an increase of about 1% over 2010 (EC DG RTD, 2021). Substantial differences persist among fields of studies, with a majority of women in Education, Arts and Humanities (66%), Social Sciences (56%), Agriculture (57%), Health and Welfare (60%), and a minority in the other fields, where the differences among genders are particularly high, i.e., in ICT (26%) and Engineering (29%) (EC DG RTD, 2021). The differences increase when permanent academic positions are considered, where women represent about 42% of the total academic staff, and where only 26% of them are employed at top positions (EC DG RTD, 2021).

Compared to Europe, in Italy, women represent about 40% of the total academic staff but only about 24% are at the highest positions (EC DG RTD, 2021). According to the Gender Balance reports periodically published by most of universities, the figures are different, according to local conditions, but recurrent: on average, PhD students, doctorates and post doc are more or less equally distributed by sex (Liccardo et al., 2019). The differences increase with permanent positions, where men are always more represented than women (EC DG RTD, 2021). Similar overall trends are reported for public research organisations, like the National Research Council (CNR) and the Italian National Agency for New Technologies, Energy and Sustainable Economic Development (ENEA), with top positions largely occupied by male scientists (CUG ENEA, 2020; Avveduto et al., 2021).

Many reasons can be invoked to explain the Italian situation that, as detailed above, shows a slightly higher under-

representation of women in both total academic staff and in leading positions. For example, French women researchers in a 2002 survey were found to take advantage of a good child-care system (Hermann and Cyrot-Lackmann, 2002). Italy is characterised by a lower level of family- and child-related policies than other EU countries (Bozzon et al., 2017), despite what stated in Article 37 of the Constitution, and care-giving is often perceived by women as a limitation in academic career (e.g., Preston, 2004).

Some recent papers address the specific gender conditions in soil science globally (Dawson et al., 2021), in the United States (Vaughan et al., 2019) and in land use sciences (Kamau et al., 2021). Updated analyses are also contained in de Vries (2017). The general conclusion agree on an under-representation of women in soil-related careers, especially in leadership positions. No published data are available about soil science in Italy, although the situation may be slightly different from that of other countries.

Soil Science in Italy is typically taught in agriculture-related university studies, i.e., in a field where women are well represented at the EU level, as reported above. Research in soil science however follows the methods of hard sciences, which are disciplines showing a systematically lower proportion of female students (e.g., Tandrayen-Ragoobur and Gokulsing, 2022).

For moving towards equality, diversity and inclusion in soil science, we need to know the gender balance at country level. So far, only a few studies exist. Beside the already mentioned in depth study for the United States (Vaughan et al., 2019), a recent paper deals with gender equality in soil science in Indonesia (Fiantis et al., 2022) connecting the women presence in soil science to soil security. No published data are available about soil science in Italy, although the situation may be slightly different from that of other countries.

This paper intends to provide a picture of the gender balance in Italian soil science and general recent trends, based on data retrieved from different sources: women soil scientists working in public research institutions and universities; women soil scientists affiliated to scientific societies; women publishing in soil related fields. An analysis of the impact of Italian women-authored papers is also provided to understand the contribution of Italian women to soil science in the last 20 years.

MATERIALS AND METHODS

A specific curriculum in Soil Science is not present in the Italian university system. Soil Science, and its sub-disciplines, are taught in faculties of Agricultural and Forest Sciences (mainly), Natural Sciences, Geology, Environmental Sciences, Environmental Engineering. Specific doctorate courses in Soil Science are given in some universities, but still some soil scientists hold a doctorate in Agricultural, Geological or Biological and Environmental Sciences. Defining a soil scientist is therefore an issue. Moreover, if researchers or professors working at university “state” their affiliation to a specific discipline, this does not apply to other

research institutions. Therefore, we used different sources and methods as described in the following subsections.

Women in the Past of Italian Soil Science

The information about early Italian women soil scientists were retrieved from the Italian Society of Soil Science archives integrated with what is available on the web and with direct accounts from people who knew them, including the Authors of this paper.

University

Research staff in Italian universities are grouped into sectors that do not always correspond to ERC (European Research Council) sectors, as they are often more specific. Despite this specificity, Soil Science is embedded in two sectors: Pedology (AGR/14), and Agricultural Chemistry (AGR/13). As soil biologists are a minority and are included in different sectors such as Microbiology, Ecology and Entomology, they were not considered in this work. Some additional soil scientists are present in faculties of Earth Sciences and belong to other sectors. Also, in this case they are a minority within a much larger number of geomorphologists and quaternary geologists. While the Pedology sector (AGR/14) only includes soil scientists, that of Agricultural Chemistry (AGR/13) is bigger and also includes plant biochemists.

The data for the analysis were downloaded from the Ministry of University and Research (MUR) website (<https://www.mur.gov.it/it>), selecting the permanent staff belonging to sectors AGR/14 and AGR/13 in 2001, 2011 and 2021. No attempt was made to split the Agricultural Chemistry sector into soil scientists and plant biochemists, but this was taken into consideration when discussing the results. No suitable official data are instead available for PhD students or post-doc working at Italian universities.

Public Research Institutes

Soil research is also addressed in several Italian research institutions: National Research Council, CNR (www.cnr.it), Council for Agricultural Research and Agricultural Economy Analysis, CREA (<https://www.crea.gov.it/>), Italian Institute for Environmental Protection and Research, ISPRA (<https://www.isprambiente.gov.it/>), Italian National Agency for New Technologies, Energy and Sustainable Economic Development, ENEA (<https://www.enea.it/>) amongst others. However, traditionally, soil research has been mainly carried out in some research centres of CREA and CNR.

CREA, with over 1000 researchers, is the largest Italian research body dealing exclusively with agri-food topics; it is supervised by the Ministry of Agricultural, Food and Forestry Policies. CREA was established in 2015, from the merging of CRA (Council for Agricultural Research) and INEA (National Institute of Agricultural Economics) and is under the direct supervision of the Ministry for Agriculture (Gaudio, 2020). CREA is organised in 12 research centres (6 related to specific supply chains and 6 dedicated to horizontal topics) throughout the country. One of these centres is dedicated to Agriculture and Environment and Soil Science (CREA-AA). In this work, the analysis was based on

data as reported in the Plan of Positive Actions (PAP) of CREA (CREA, 2021).

The CNR is the largest Italian public multidisciplinary research institution, with more than 8000 employees, more than half of whom work as researchers. The CNR is organised in seven broad disciplinary departments, and in about one hundred institutes. Soil-related disciplines are mostly addressed in the departments of Biology, Agriculture and Food Sciences (DiSBA), and of Earth System Sciences and Environmental Technologies (DTA), in different institutes and laboratories spread all over Italy. In the 1970s a large research project on soil conservation was launched by the CNR, involving many soil scientists from Academia and Research Institutions and paving the way for soil science growth in Italy (Calzolari, 2013).

In order to capture the presence of women soil scientists at CNR, a search was performed on the CNR intranet site, where publications are stored by researchers (restricted access source). As the repository has however been actively maintained by researchers themselves only in the last 10 years on a voluntary basis, the database might not be complete. The search was launched, using the word “soil” as a keyword within the title field. Only papers published in journals between 1980 and 2021 were considered. The resulting titles were manually checked for detecting the gender of the contributing authors and their h-index, considering only the names of people affiliated to the CNR. The specific competence of the contributing authors was not checked, in order to avoid biases. Therefore, false positive cases may have been included in the search; on the other hand, false negative cases were also possible. However, a homogeneous distribution of the errors was assumed between genders.

For permanent and still active researchers, the present career position was checked (I, II, or III, comparable to the university positions of full professor, associate professor and assistant professor, respectively), on the CNR site (<http://www.dcp.cnr.it/DPUASI/>) together with the institute and department of affiliation.

Scientific Societies

There are three scientific societies covering aspects of soil science in Italy: the Italian Society of Soil Science (SISS) and two academic societies, the Italian Society of Pedology (SIPe) and the Italian Society of Agricultural Chemistry (SICA).

The SISS was established 70 years ago, and its purpose is to promote the progress, coordination and dissemination of Soil Science and its applications, and to foster relationships and collaboration between its practitioners. For this reason, it has always included specialists and researchers of various backgrounds belonging to different academic societies and research institutes. Moreover, the SISS, as a full member of the International Union of Soil Sciences (IUSS) and the European Confederation of Soil Science Societies (ECSSS), collaborates with international soil science institutions with similar purposes or common programmatic aspects. The mission of the SISS is inspired by the statute of the IUSS (formerly International Soil Science Society) founded in Rome in 1924. Data on members

were collected from the archives of the Society where the minutes of the general assembly and the composition of the executive board are stored considering the members affiliated in 2001, 2011, and 2021.

The SIPe is smaller and broadly corresponds to the Pedology sector at universities and research centres. Its purpose is to promote, support and coordinate studies and research in the field of Pedology and its applications. The SIPe was founded recently, in 1998, and the membership data were made available on electronic media. The search focused on active members in 2001, 2011, and 2021 and the percentages of women soil scientists, as well as time trends were calculated.

The SICA was founded in 1981 with the aim of constituting a point of reference for those researchers and scholars who operated in the vast context of chemical and biochemical disciplines applied to agriculture. The SICA embraces members whose interest is soil chemistry, plant biochemistry and physiology, food chemistry, waste recycling, and environmental chemistry. It broadly corresponds to the Agricultural Chemistry sector in academia and research centres. For this analysis, the membership data were made available on the society website (<https://www.chimicagraria.it/index.php>). Also in this case, our search focused on active members in 2001, 2011, and 2021.

Scopus Literature Search

A specific literature search was performed on Scopus for the years 2001, 2011, and 2021, separately. In order to capture all possible soil science sub-disciplines, and in analogy with the approach followed for the CNR, a simple search was launched, using the word “soil” within the article title field, limiting the search to “Italy” in the affiliation country field. Only Scopus articles were then considered, omitting conference papers, reviews, editorials, data papers and/or book chapters. For some more detailed analyses, only Q1 journals (i.e., top 25% of journals within a subject category) in the soil science category were considered, following the impact factor reported in Thomson Reuter’s Journal Citation Reports (JCR). Each resulting title was checked to detect the Italian contributing authors, i.e., affiliated to Italian institutions, omitting Italian scientists working abroad, and foreign authors occasionally affiliated to Italian institutions. Italian authors were checked and manually separated by gender. The first author’s gender was also checked. Only a limited refinement was performed on the retrieved articles, just in case clear evidence of “no soil science” content was found by checking the article contents. As noted for CNR, using the term “soil” for the search may return false positive and false negative cases. However, a homogeneous distribution of the errors was assumed between genders.

RESULTS AND DISCUSSION

Women in the Past of Italian Soil Science

The SISS was founded in 1952, but the first woman scientist was only elected to the SISS board in 1976. Despite the tiny minority, early women soil scientists played a major role in paving the way

for young women to be introduced to Soil Science. We wish to remember three of them, involved in different roles and sub-disciplines, all of them pioneers in their activities: Enza Arduino, Linda Federico Goldberg, Antonia Huyzendveld Arnoldus.

Enza Arduino (1927–2005) was a soil scientist at the University of Torino from 1959 to 1997, when she retired. She was head of the soil chemistry area from 1974, although she became full professor and the director of the Institute of Soil Chemistry only in 1986, at the age of 59. She held an MSc degree in Chemistry and was so interested in soil mineralogy that she was appointed as the chair of the Soil Mineralogy Commission of the Italian Soil Science Society, and sat for years on the board of the Italian Group of AIPEA (Association Internationale pour l'Etude des Argiles). Her first works were about the heavy metal contents in soils, mainly from the quantitative point of view, but metals were soon linked to uptake by plants and to their transfer into surface waters. At the beginning of the 1980s, she was the promoter of a new field of studies at her university. Acknowledging that metal transfer into the biosphere or hydrosphere depended on soil properties, including mineralogy, meant that soil forming factors should play a determinant role when upscaling the results of lab experiment into the landscape. That was the beginning of a new way of thinking that may be obvious to many readers now, but was not so evident to several soil chemists in Italy at that time. She tutored many students and had many co-workers, men and women. Among those who she tutored, one woman has to be cited: Elisabetta Barberis, a soil scientist who was the dean of the Agricultural Faculty and later the vice rector of the University of Torino. Enza Arduino died in 2005, but maybe thanks also to her open mind, the majority of those working at the Soil and biogeochemistry unit of the University of Torino are women, in all positions, from full professors (2 women vs. 1 man) to PhD students.

Linda Federico Goldberg was the first woman president of the Italian Society of Soil Science (SISS) in the period 1984–1990 32 years after its foundation. Another 27 years were to pass before the next woman was elected SISS president (<https://scienzadelsuolo.org/storia.php>). In 1985 Linda Federico Goldberg, in collaboration with Enza Arduino, coordinated the production of the volume “Methods of soil chemical analysis” published by Edagricole. The text followed that coordinated by Tommaso Eschena in 1976 (the Normalized Methods of Soil Analysis published in the SISS Bulletin no. 10) and remained a reference until 1997 when a new edition “Series of analytical methods for agriculture” directed by Paolo Sequi was published. Linda Federico Goldberg in 1987 was admitted at the Georgofili Academy and until 2002 she was one of the few women in the Academy (no more than 5–6%). In the first 20 years of the 2000s, the trend at the Georgofili Academy changed with a growing number of women academics, but to date no woman has ever been elected President.

Antonia Huyzendveld Arnoldus (1942–2018) was born in The Netherlands, but she lived in Italy for most of her life. She graduated in pedology with Alfred Zink in 1973 with a thesis on soil surveys in southern Lazio. She continued to work in Lazio during her long career, producing the first detailed soil maps in

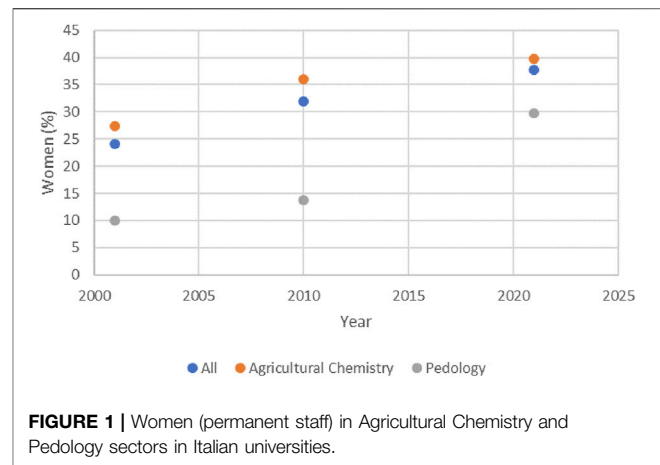


FIGURE 1 | Women (permanent staff) in Agricultural Chemistry and Pedology sectors in Italian universities.

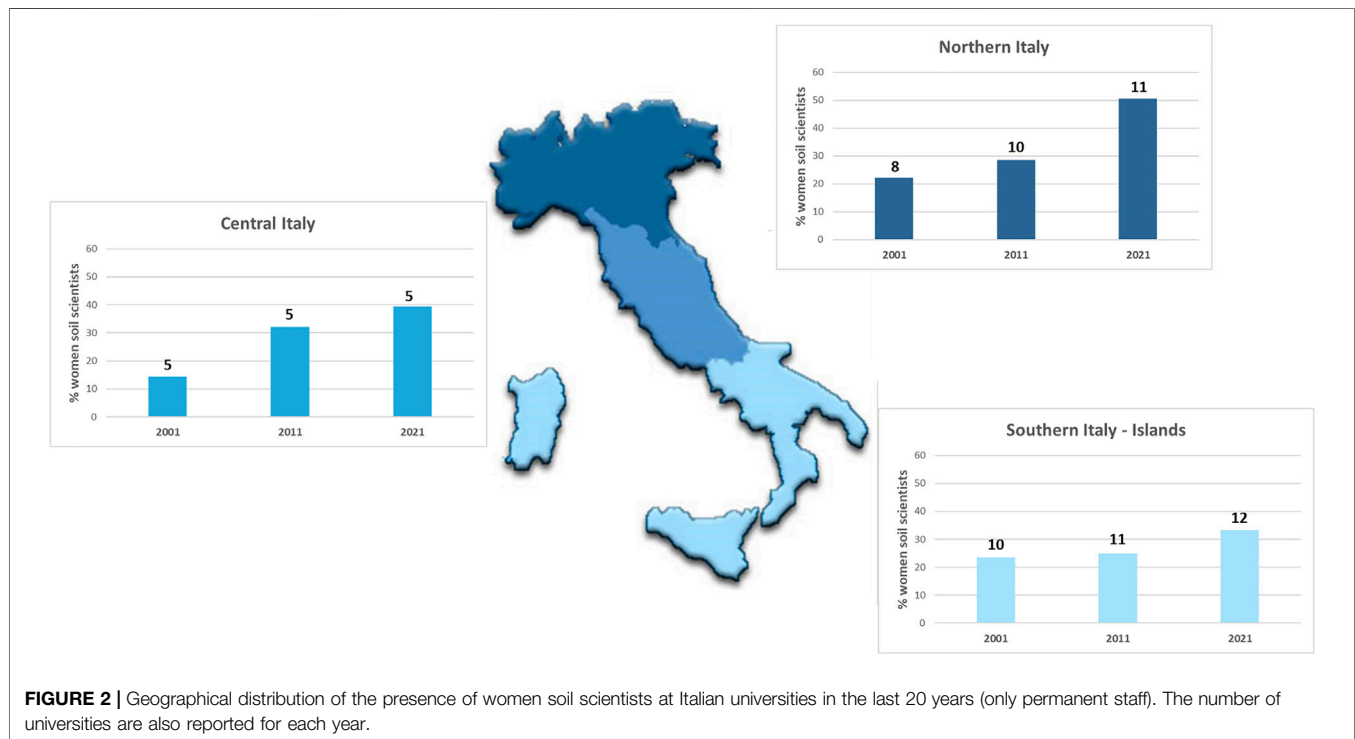
that region which remained the only ones until the late 1990s. She was the first female pedologist of the Italian Society of Soil Science in the early 1980s, a founder of the Italian Association of Pedologists in 1992 and vice-president until 2000. She mostly operated as a professional pedologist, but she had several teaching contracts with the universities of Siena and Rome, and an intense research activity. Her major scientific interest was on pedo-archaeology, a discipline in which she was a real pioneer for Italy. She participated in dozens of archaeological surveys and published a long list of articles and reports. She had a profound knowledge of alluvial plains and their palaeo-geography in Lazio and Tuscany. She was an example for many young women pedologists, being capable of taking care of her children while continuing her field activities. She was an open-minded scientist, deeply aware of the importance of soil as the archive of earth and human history, well before the present general acknowledgment. We remember one of her statements: *Soil is the “living skin” of the earth. Apart from its basic social and environmental functions to produce and protect, it contains information, since part of Earth’s and Man’s history are recorded in the soil profile.*

University

In the last 20 years, the percentage of women scientists in the Pedology and Agricultural Chemistry sectors taken together has increased, from 25% in 2001 to 40%, in 2021 (**Figure 1**). The percentages are lower when only the Pedology sector is considered: women accounted for only 10% of scientists in 2001 and increased to 32% in 2021 (**Figure 1**). The increasing trend is encouraging, but when the career level is considered, the situation is very far from one of equality. As shown in **Table 1**, in 2021, only 26% of the full professors were women globally, but the percentage decreased to less than 15% in the Pedology sector. The well-known trend of a lower number of women at top positions was well visible, in all datasets and all years, confirming the vertical segregation mechanism highlighted in the Gender Balance reports published periodically by most universities and consisting of a persistent under-representation of women in senior management and governance bodies. The first female full professor in the Pedology sector appeared only in the most recent dataset, while women assistant professors were

TABLE 1 | Roles of women soil scientists at Italian universities in the last 20 years (N, number of scientist; only permanent staff).

University soil scientists	2001				2010				2021			
	Women		Men		Women		Men		Women		Men	
	N	%	N	%	N	%	N	%	N	%	N	%
Whole dataset												
Full Professors	7	14	44	87	8	20	33	80	9	26	26	74
Associate Professors	9	21	34	79	15	35	28	65	31	42	43	58
Assistant Professors	24	38	40	63	31	41	44	59	22	46	26	54
Total	40	25	118	75	54	34	105	66	62	40	95	61
Agricultural Chemistry												
Full Professors	7	17	35	83	8	24	25	76	8	29	20	71
Associate Professors	9	26	25	74	14	39	22	61	25	43	33	57
Assistant Professors	21	39	33	61	27	45	33	55	19	48	21	53
Total	37	29	93	72	49	38	80	62	52	41	74	59
Pedology												
Full Professors	0	0	9	100	0	0	8	100	1	14	6	86
Associate Professors	0	0	9	100	1	14	6	86	6	38	10	63
Assistant Professors	3	30	7	70	4	27	11	73	3	38	5	63
Total	3	11	25	89.3	5	17	25	83	10	32	21	68



present already in 2001. The proportion of full professor women in Italy is 24% (in 2018, EC DG RTD, 2021), below the European average of 26%. This proportion decreases for Agricultural Sciences to 19% (28.50 for EU 27; EC DG RTD, 2021). If in Agricultural Chemistry the proportion (29%) is higher than the average of the Agricultural Sciences sector, the proportion for Pedology is much lower.

Women were (and are) equally poorly present at universities of all cities, with no specific geographic trend (Figure 2). Interestingly, in 2001 and 2011, when the groups were smaller,

fewer women were present; where groups were formed by only 1–3 people women made up 5 and 9%, in 2001 and 2011, respectively (data not shown). The situation improved in 2021.

Public Research Institutions

Council for Research and Agricultural Economics

Our analysis highlighted a very important trend towards gender equality: out of the 1894 CREA employees 934 are currently males and 960 females. There is a slight prevalence of women in the profile of Researcher/Technologist (levels I-III, 407 women vs.

TABLE 2 | Roles of women in the CREA Research Centre of Agriculture and Environment (CREA-AA; N, number of scientists).

	Women N	Women %	Men N	Men %
CREA-AA researchers				
I level (full professor)	31	54	26	46
II level (associate professor)	3	60	2	40
III level (assistant professor)	3	43	4	57
All	37	54	32	46
CREA-AA techologists				
I level (full professor)	0	0	4	100
II level (associate professor)	1	33	2	67
III level (assistant professor)	7	54	6	46
All	8	40	12	60

Level I assimilated to Full Professor, Level II assimilated to Associate Professor, Level III assimilated to Assistant Professor.

360 men). The male presence is predominant in the technical profiles (levels IV-VIII men 446 vs. 271 women). Women remain predominant in the managerial level of the Central Administration, although top positions are still mainly covered by men.

The specific data for the Research Centre of Agriculture and Environment (AA) in 2021 are reported in **Table 2**. As for CREA-AA, we do not have data for a temporal trend assessment. However, the present gender balance situation is much more balanced as compared to other research institutions and universities.

National Research Council

The search for publications on soil authored by CNR scientists was based on data available in the CNR intranet (restricted access). A total number of 1109 articles dealing with soil were published by CNR researchers between 1981 and 2021. In 633 of them at least one woman author was present (i.e., in 57% of cases). In the same period, CNR men were present in about 82% of cases. Women as lead authors represent 34% of cases (**Table 3**), and this percentage increases to 41% if single authors are counted only once. Considering the years 2001, 2011, and 2021, women were present in 46, 58, and 66% of the published articles, respectively, with an increase of 42% between 2001 and 2021. This trend is reflected by the women lead authorship which increased between 2001 and 2021 of 52% considering authors only once (13% as total).

Considering the whole time period, between 1981 and 2001, 461 male researchers published articles on soil, and 314 women researchers, i.e., 41% of the total (**Table 3**). Considering the years

TABLE 4 | Gender distribution of CNR soil scientists among the different career levels: Level I assimilated to Full Professor, Level II and Level III, assimilated to Associate Professor and Assistant Professor, respectively (N, number of scientists).

CNR all	Women N	Women %	Men N	Men %
I level (full professor)	11	33	22	67
II level (associate professor)	15	40	23	60
III level (assistant professor)	60	47	69	53
All	86	43	114	57

2001, 2011, and 2021, the % of women scientists were 24, 43, and 47%, respectively, with an increase of 96% between 2001 and 2021 (**Table 3**).

Different professional figures contribute to CNR research activities, including technicians, PhD students, post doc researchers and temporary staff who are usually fully acknowledged among the authors. Limiting the analysis to working permanent research staff (excluding technicians, temporary staff and retired scientists), 219 soil scientists are currently working at the CNR (**Table 4**), of whom 86 are women (43%) and 114 men (57%). At level I (equivalent to full professor), which is the highest degree, women account for 33% of positions, while at level II (associate professor) and III (assistant professor) they represent 39.5 and 46.5%, respectively, highlighting again a discriminating difference in top positions.

Considering the h-indexes attributed to the research staff, we observed the trend reported in **Figure 3**. The average h-indexes recorded in Scopus did not differ between women and men in any of the professional levels, and accordingly with their role, the h-index increased from the level III to the level I (**Figure 3**). From these results, it clearly appears that, in contrast with a still unbalanced opportunity for career promotion, research quality is equally achieved by both genders at all levels.

Researchers publishing on soil topics were spread across all CNR departments, although they were more represented at the Department of Biology, Agriculture and Food Sciences (DISBA) and at the Department of Earth System Sciences and Environmental Technologies (DTA), which have soil and soil conservation topics within their missions. However, DISBA is more focused on Agricultural Sciences and DTA more on Earth and Environmental Sciences. Considering only researchers affiliated to these departments, we observed the trend reported in **Table 5**.

While in DTA the general distribution of genders at the different levels was comparable to (or higher than) the overall CNR staff (Avveduto et al., 2021), in DISBA the percentage of

TABLE 3 | Gender distribution of soil scientists affiliated to CNR in 2001, 2011 and 2021, as derived by soil science articles.

YEAR	N of papers	N of papers with Women	N of papers with Man	% Papers with Women	Women N	Men N	% Women	% Women as lead authors
2001	13	6	12	46	5	16	24	23
2011	45	26	34	58	33	43	43	47
2021	61	40	50	66	55	62	47	26
1981–2021	1109	633	905	57	314	461	41	34

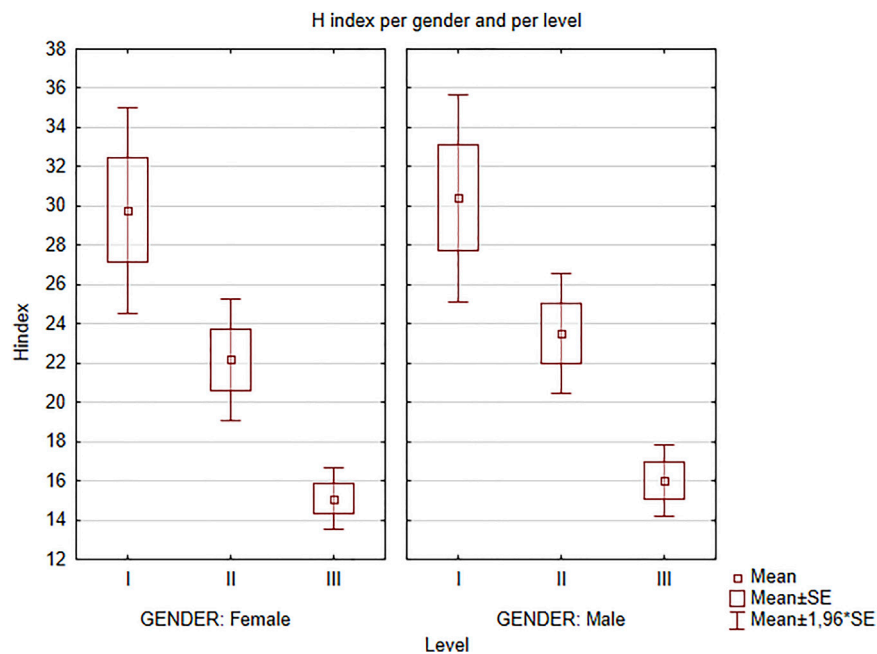


FIGURE 3 | Mean, standard error and confidence interval of scientists' H Indexes, for gender and career levels in the CNR. Level I = Full Professor, Level II = Associate Professor, Level III = Assistant Professor.

TABLE 5 | Gender distribution of CNR soil scientists among the different career levels in DISBA (Department of Biology, Agriculture and Food Sciences) and in DTA (Department of Earth System Sciences and Environmental Technologies).

	Women N	Women %	Men N	Men %
DISBA				
I level (full professor)	1	11	8	89
II level (associate professor)	9	47	10	53
III level (assistant professor)	20	44	26	56
All	30	41	44	59
DTA				
I level (full professor)	6	35	11	65
II level (associate professor)	5	36	9	64
III level (assistant professor)	26	48	28	52
All	37	44	48	56

women at the I level was considerably lower than the CNR average (Level I: 27 and 73% for women and men, respectively; Level II: 39 and 61%; Level III: 50.5 and 49.5%). Nevertheless, the average h-index, again, did not show any difference between genders at levels II and III (**Figure 4**).

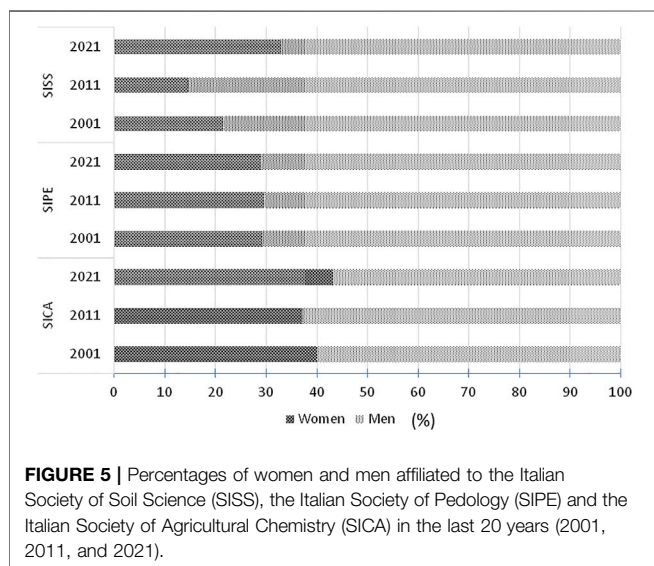
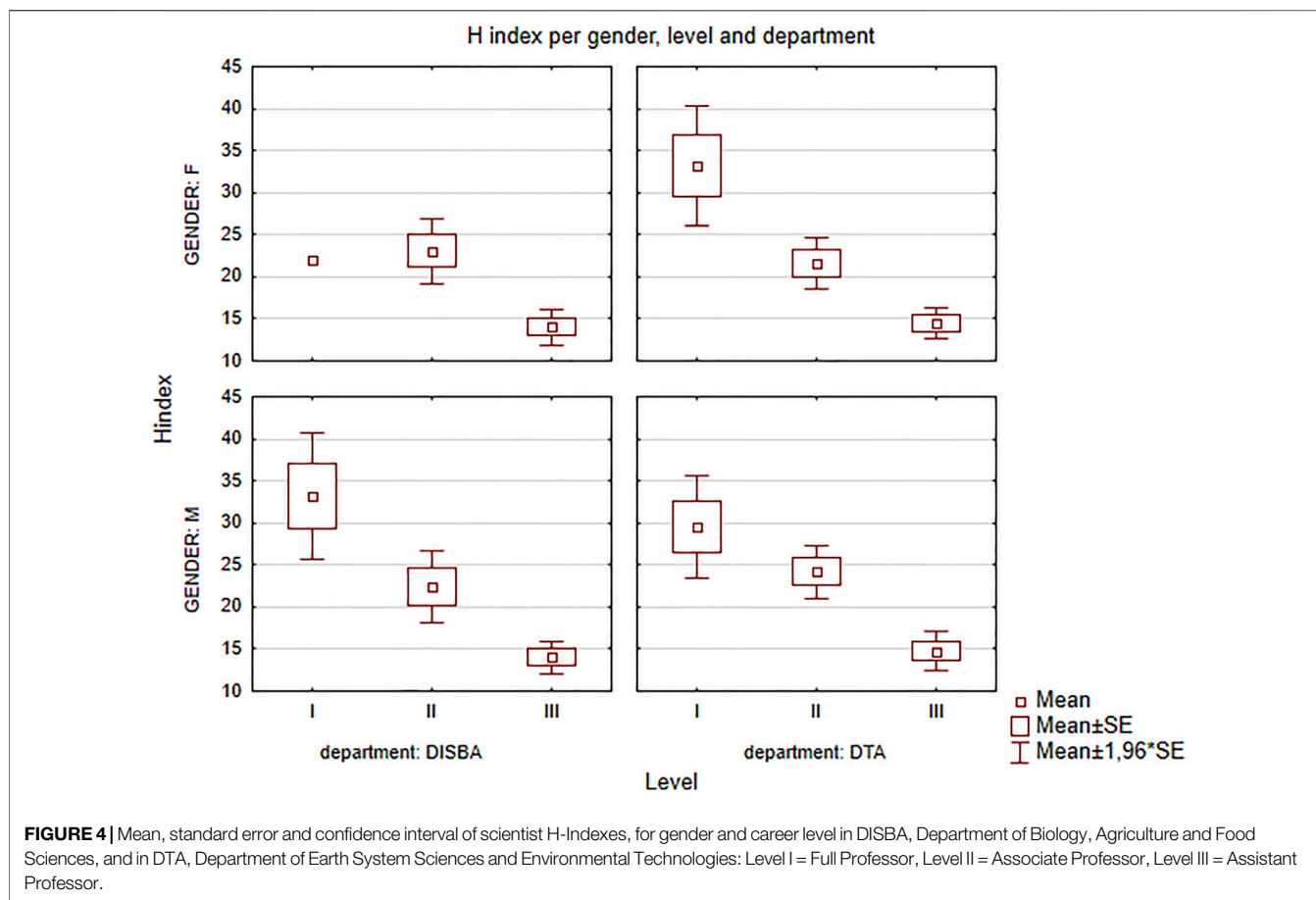
Scientific Societies

The proportion of women affiliated to the Italian Society of Soil Science (SISS) increased from 21 to 33% from 2001 to 2021, with a slight decrease in 2011 (**Figure 5**). In 1952 the 14 founding members were exclusively male and only after 27 years did a woman join the society's executive board as the president of the commission III. However, it took as long as 32 years for a woman, Linda Goldberg, to become President of the SISS. Since then, the SISS registered a new trend with an ever-increasing presence of

women on the board, due to both a general increase in total members and a more inclusive policy of the society. Female presence on the executive board was higher than the percentage of women in the membership, reaching an average of 30–35% in the 2020s, and, since 2017, and until present, SISS presidents have all been women! In this period, women also actively participated in innovation and evolution of SISS goals, expressing their great interest in the new SISS-connected institutions and organisations created to face the different soil issues arising over time.

The proportion of women affiliated to the Italian Society of Pedology (SIPE) showed steady data in the 3 years considered (**Figure 5**). Despite the presence in this dataset of PhD students and post-docs, women formed about 30% of the whole population. The SIPE board had long reflected the dominance of male soil scientists; the first woman on the board dates from 2004, reflecting the scarce abundance at both universities and research centres; the second joined in 2013 when women represented 20% of the board. This year (2022) however, the proportion of women is 50% and both the president and the vice-president are women soil scientists!

The proportion of women affiliated to the Italian Society of Agricultural Chemistry (SICA) was around 40% of the whole population in the 3 years considered (**Figure 5**). Since 1981, the year of SICA foundation, women have been a constant presence on the SICA board representing about 20%, mostly with the role of secretary-treasurer (5 out of 16) and board members (18 out of 64). This percentage has increased to 28% in the last 10 years. Nevertheless, the first woman president dates back to 2008, and the current vice-president, a woman, will become president in 2024!



The percentages for the Italian soil societies are near to the global average of 32% of women soil scientists calculated over 44 soil science societies in 2020 (Dawson et al., 2021). Considering the European societies, whose average proportion of women is 38%, Italian societies are less gender balanced as

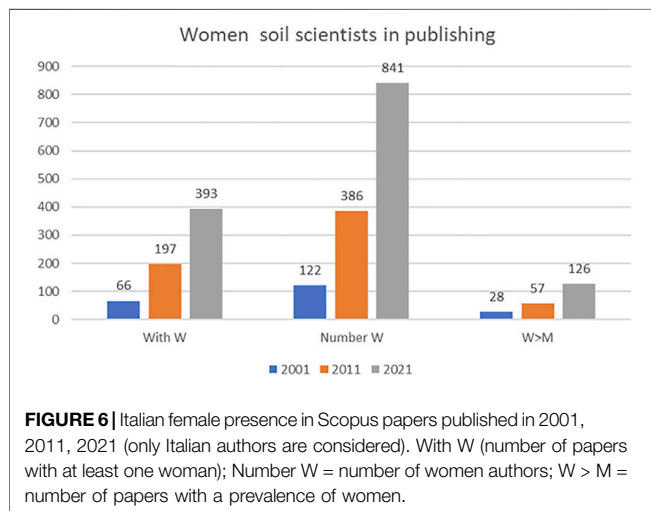
compared to Baltic and eastern countries, which range from 36% to 69%, and interestingly also compared to Spain and Portugal (42% each).

Comparing these results, we could in general observe a still lower presence of women in universities, research institutions and soil scientific societies. Nevertheless, the recorded gender imbalance is not as high as the differences described in the ISTAT report (ISTAT, 2021), which shows a greater preference of men for hard science disciplines, such as Science, Technology, Engineering and Mathematics (STEM), with respect to women (37 % men vs. 17% women). This may however be related to the strong relationship between Agricultural studies and soil science in Italy, as stated above. Agriculture was indeed surprisingly among the sectors with the highest percentages of women in Europe (EC DG RTD, 2021). As a positive remark, we highlight an enhanced inclusion and pro-active participation of women in the three societies, progressively increasing with time, although only in the last 20 years has the number of women in leading positions been really significant. In general, the national research institutions have reached a greater gender equality compared to universities. With regard to scientific societies, even if the trend was generally positive, inclusion of women in the SISS was always lower as compared to SIPE and SICA. One reason could be that the SISS is the oldest Italian scientific soil society, while SICA and SIPE were founded in more favourable

TABLE 6 | Articles dealing with soil in Scopus in 2001, 2011 and 2021.

year	N articles	With W N	With W %	W/total %	W > M %	100% W N (%)	Women as first author %
2001	137	66	48	27	20	12 (9%)	34
2011	291	197	68	33	20	22 (8%)	42
2021	592	393	66	34	21	58 (10%)	43
All Groups	1020	656	64	33	21	92	41

N of articles, total number of papers considered for year; with W (N) and with W (%), number and percentage of papers with at least a woman; W/total %, percentage of women over the total of Italian authors; W > M %, percentage of papers with a majority of Italian women compared to Italian male scientists; 100% W (N) and (% in brackets), papers authored by only Italian women.



periods for female inclusion with a faster trend towards gender equity. On the other hand, the SICA has shown the highest presence of women, probably due to a larger focus on soil chemistry and biology, that means more lab than field activities, with respect to, for example, pedology and soil hydrology.

Bibliographic Search

In all, 1020 articles were retrieved from Scopus dealing with soil to a certain extent and authored by Italian researchers (**Table 6**): 137, 291 and 592 articles published in 2001, 2011, and 2021, respectively. While in 2001 at least 48% of papers featured a female author, in 2021 this figure rose to about 66% of the total, with an increase of 38% in 20 years (but with a constant value since 2011). The percentage of women among the authors slightly increased with time, rising from 27% (122 Italian female authors) in 2001 to 34% in 2021 (841 Italian female authors; **Table 6** and **Figure 6**). However, the number of papers with a prevalence of women was more or less constant (21% on average, that is 28, 57, and 126 papers in the 3 years considered; **Figure 6**), as well as the percentage of papers authored by female scientists alone (9%, 8%, and 10%, in 2001, 2011, and 2021, respectively; **Table 6**). An increasing trend in the proportion of women as lead authors was also observed (**Table 6**): in 2001 the papers with an Italian woman as lead author were 38 (34 authors) versus 74 (64 authors) with an Italian man, with a proportion of 34%; in 2011 the proportion was 42% (92 and 128 papers, respectively lead by Italian women and

men; 44% considering authors of multiple papers only once); in 2021 the papers with an Italian woman as lead author were 143 (125 authors) versus 186 papers lead by Italian men (168 individual authors) with a proportion of 43%.

Considering all the papers, the average citations per year and the Impact Factors (IF) of the journals considered in relation to the presence of female authors (**Figure 7**) were checked. A similar trend was observed between publications with at least one female scientist (series 1 on y axis of **Figure 7A**) and those without (series 0 on y axis of **Figure 7B**), although the number of citations of articles authored by at least one woman was slightly higher compared to the articles of only men (on average 3.9 and 3 citations per year, respectively). The articles where women authors prevailed over men (series 1 on abscissa of **Figure 7B**) showed higher average citations per year compared to articles with prevalence of men over women (series 0 on abscissa of **Figure 7B**): 5.4 and 3.0 citations per year, respectively. In both types of articles, those including at least one woman (**Figure 7A**) and those with a prevalence of one gender or another (**Figure 7B**), the average IF of the considered Journals did not differ. Moreover, different ranges of female author presence (0%, 25%, 50%, 75%, and 100%) were also considered to evaluate average citations and IF (**Figure 7C**). The average number of citations per year increased with increasing women presence (from 0 to 75%), reaching a maximum in correspondence of articles with 75% of women. However, differences among groups were not statistically significant.

For further analyses, only Q1 Journals with at least 10 records and with a publishing history covering at least 10 years were considered (**Table 7**): Applied Soil Ecology (ASE), Biology and Fertility of Soils (BFS), Catena, Chemosphere (CHEM), Environmental Science and Pollution Research (ESPR), European Journal of Soil Science (EJSS), Geoderma (GEODER), Journal of Hydrology (JoH), Science of the Total Environment (STOTEN), Soil Biology and Biochemistry (SBB).

In all, 167 articles were considered (**Table 7**). Articles authored by at least one female scientist were on average (calculated among all Journals) 71% of the total, with high standard deviation (46 on average), while the average percentage of women on the total Italian authors was 36%. On average, in 25% of cases women authors prevailed on men, and the calculated number of female authors per paper was 1.56.

Different trends may be observed among the journals (**Table 7**): Applied Soil Ecology showed the highest rate of articles with at least one female author (92%), the highest average number of women among the authors (average of

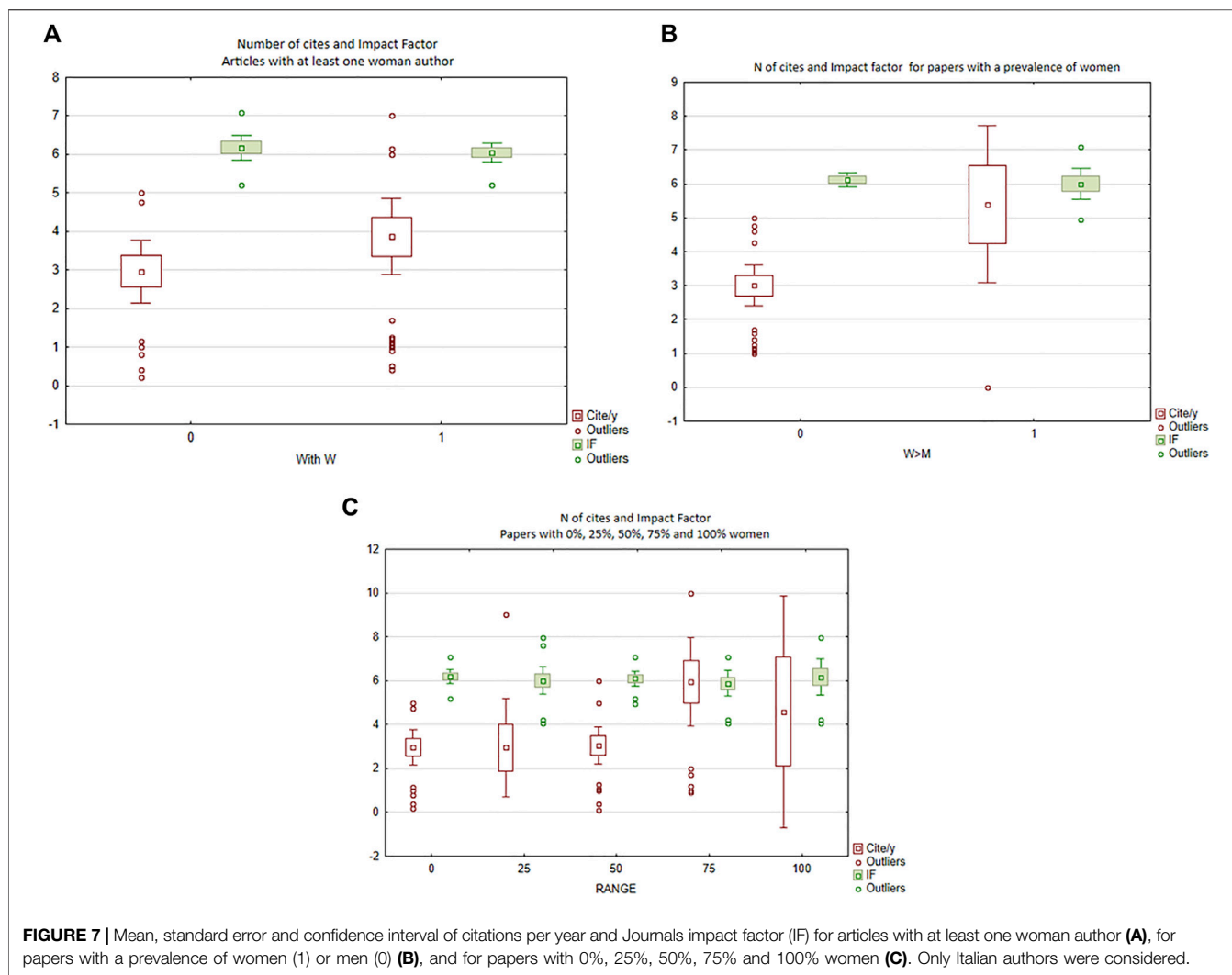


FIGURE 7 | Mean, standard error and confidence interval of citations per year and Journals impact factor (IF) for articles with at least one woman author **(A)**, for papers with a prevalence of women (1) or men (0) **(B)**, and for papers with 0%, 25%, 50%, 75% and 100% women **(C)**. Only Italian authors were considered.

TABLE 7 | Women authors in articles published in selected journals (Q1 and >10 articles).

Source	Total N	With W % (Means)	With W (Std.Dev.)	Ratio % (Means)	Ratio % (Std.Dev.)	W > M (Means)	W > M (Std.Dev.)	Number W (Means)	Number W (Std.Dev.)	IF
ASE	12	92	0.29	50.2	27.09	0.5	0.52	3.33	2.46	4.046
BFS	13	77	0.44	41.48	28.54	0.31	0.48	2.15	1.57	6.432
Catena	24	71	0.46	30.08	25.38	0.13	0.34	1.38	1.61	5.198
CHEM	14	86	0.36	45.6	31.9	0.36	0.5	1.86	1.41	7.086
ESPR	14	86	0.36	52.92	34.96	0.43	0.51	1.86	1.96	4.949
EJSS	10	60	0.52	25.5	32.51	0.2	0.42	0.8	0.92	4.223
GEODER	31	55	0.51	27.81	30.11	0.19	0.4	1.13	1.26	6.114
JoH	11	55	0.52	16.39	16.46	0	0	0.73	0.79	5.722
STOTEN	27	70	0.47	37.33	33.92	0.3	0.47	1.59	1.67	7.609
SBB	11	73	0.47	36.86	35.39	0.18	0.4	1.18	0.87	7.963
All Grps	167	71	0.46	35.65	31.05	0.25	0.44	1.56	1.63	6.083

Total N, number of papers per journal; With W % (mean, StdDev), mean N of papers with at least a woman (and standard deviation); ratio %, percentage of women scientists over the total Italian authors; W > M, ratio of papers with a majority of Italian female scientists as compared to Italian male scientists; Number W (means, StdDev), average number of women per paper (and standard deviation); IF, journal Impact Factor. Only Italian authors are considered. ASE, Applied Soil Ecology; BFS, Biology and Fertility of Soils; Catena; CHEM, Chemosphere; ESPR, Environmental Science and Pollution Research; EJSS, European Journal of Soil Science; GEODER, Geoderma; JoH, Journal of Hydrology; STOTEN, Science of the Total Environment; SBB, Soil Biology and Biochemistry.

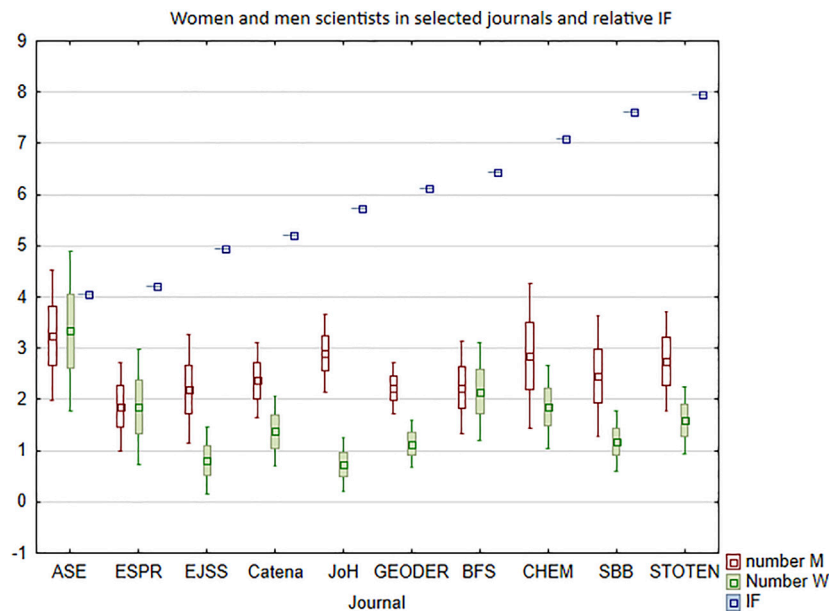


FIGURE 8 | Mean, standard error and confidence interval of number of women scientists (W), male scientists (M) in selected Journals (Q1 and >10 articles). The Impact factor (IF) of these journals is also reported. Applied Soil Ecology (ASE), Biology and Fertility of Soils (BFS), Catena, Chemosphere (CHEM), Environmental Science and Pollution Research (ESPR), European Journal of Soil Science (EJSS), Geoderma (GEODER), Journal of Hydrology (JoH), Science of the Total Environment (STOTEN), Soil Biology and Biochemistry (SBB).

3.3 women)—which was significantly higher than that found for the European Journal of Soil Science, Geoderma, Journal of Hydrology and Soil Biology and Biochemistry—and a higher rate of articles with a prevalence of female authors (50%). On the other hand, European Journal of Soil Science, Geoderma and Journal of Hydrology show the lowest rates for all the figures, below the mean values for all the chosen indicators.

The total number of women authors compared to men per journal is shown in **Figure 8**. Applied Soil Ecology, Biology and Fertility of Soils and Environmental Science and Pollution Research showed comparable numbers; a prevalence of men is recorded for all the other journals, and the differences were statistically significant for Geoderma and the Journal of Hydrology.

Chemosphere and Environmental Science and Pollution Research showed high scores for articles with at least one female author (86% each) and for the average percentages of women (46% and 53%, respectively). The other journals showed intermediate scores. It is worth noting that traditional soil science journals, such as the European Journal of Soil Science and Geoderma, still show a clear prevalence of male scientists. Catena, albeit with a more interdisciplinary and geomorphological approach, is also a reference journal for “pure” soil scientists. Also in this case, all indicators showed values below or near the overall average (**Table 7**). Women are better represented in journals with a focus on soil chemistry, and/or soil biology: Chemosphere, Environmental Science and Pollution Research, Applied Soil Ecology, Biology and Fertility of Soils and, to a certain extent Soil Biology and Biochemistry (**Figure 8**).

The Journal of Hydrology is aimed at hydrological sciences, with a prevalent engineering approach, a field where women are traditionally less represented (EC DG RTD, 2021). Science of Total Environment is a typical multi-disciplinary journal, with a great attention to innovative approaches. In this case, the presence of women is generally higher than the average (**Table 7**). With the exception of Geoderma (IF = 6.114), the journals with Impact Factor higher than average, Biology and Fertility of Soils (IF = 6.432), Chemosphere (IF = 7.086), Science of Total Environment (IF = 7.609) and Soil Biology and Biochemistry (IF = 7.963) recorded a good proportion of women among authors (**Figure 8** and **Table 7**).

CONCLUDING REMARKS

This work allowed to quantify for the first time in Italy and to show gender distribution differences in the national soil science community. Comparing the results obtained for the last 20 years, we highlighted an enhanced inclusion and pro-active participation of women, progressively increasing with time. In general, national research institutions have reached a more equal gender equality compared to universities. With regard to scientific societies, even if the trend has been generally positive, female inclusion in the SISS was always lower compared to the SIPE and SICA, probably because the SISS was founded before the other two societies. The highest presence of women in the SICA shows that some soil science sub-disciplines are more open to women (soil chemistry ~ biology > pedology ~ hydrology). That said, the presence of

four women (out of six) as Presidents or Vice-Presidents of Italian soil science societies points strongly to the present and future active role of women. Indeed, when we move to evaluate scientific production, no statistical differences appeared between women and men at all career levels, confirming the key contribution of women to soil science, despite having often to tackle major professional difficulties and disparities.

In spite of the progressive gender equality in quantitative terms, only in the last 20 years has the number of women in leading positions been significant. Yet it is still far from constituting an effective equality: the increase in the number of active women in soil science is not yet reflected in career opportunities, as witnessed in both the CNR and universities. This leads to the loss of highly qualified female expertise from the training phase to career start, as well as the persistent under-representation of women in top roles and research centre leaderships, a well-known effect commonly referred to as the “leaky pipeline.” (Blickenstaff, 2005). At universities, this phenomenon has become even more acutely expressed in recent years, probably because of the introduction of temporary research positions. This may have further amplified the dropping out of highly skilled women. The persisting imbalance in career advancement might also be related to an internationally documented difficulty for women to receive funds which adequately support their own scientific activity (Sato et al., 2021). The average research funding success rate at EU level, calculated as the number of beneficiaries of a research grant over the number of applicants, is on average higher for men (EC DG RTD, 2021). As for Agricultural Sciences, the research funding success rate differences between women and men in Italy is -9.03 as compared to an European average of 0.8 (EC DG RTD, 2021). However, we did not investigate in this article the Italian gender distribution in competitive projects due to the lack of consistent national databases. In addition, the Italian social system is still far from being an adequate and advanced structure, in which both women’s private lives and careers may be equally favoured, removing obstacles which prevent full personal and professional equity, especially in the first steps of their scientific careers. In this context, university, as a training and research institution, should play a key role in targeting actions for overcoming the gender gap, by offering research-tailored solutions, as recently reported in a document published by the Ministry of Research and University (Addis et al., 2018). Any step towards greater inclusion, strengthening the differences as an added value and fully exploiting individual attitudes, skills and abilities, will lead to a more sustainable, fair and resilient society.

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Thus, in answer to the opening question: “Gender equality in soil science in Italy: wishful thinking or reality?,” although progress has undoubtedly been made in the number of women entering and working in soil science and in their role, a full equality remains an elusive goal and requires further investment in resources and research towards structural and systemic interventions that may successfully lead to a more gender-balanced society. Several authors suggest positive actions to be undertaken in order to actively promote gender equality (Brevik et al., 2021; Dawson et al., 2021; Fiantis et al., 2022), moving towards gender equity, intended as the recognition that different groups of people have different needs and need different resources and efforts to succeed. This includes identifying the obstacles specific to the career success of women and operating to remove them (Vaughan et al., 2019). With this paper a first contribution for the comprehension of the Italian situation in soil science was provided.

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article; further inquiries can be directed to the corresponding author.

AUTHOR CONTRIBUTIONS

All authors listed have made a substantial, direct, and intellectual contribution to the work and approved it for publication.

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CONFLICT OF INTEREST

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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