

# INCREASING ENVIRONMENTAL SCIENCES STUDENTS' AWARENESS OF THE LINK BETWEEN SOIL AND SUSTAINABLE DEVELOPMENT GOALS

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## Abstract

Education must prepare students to find solutions for the global and local challenges of today and the future, by conferring students the knowledge, skills and attitudes to address them, including environmental degradation. Soils perform a number of key environmental, social and economic functions (e.g. production of food and biomass, nutrient cycling, water filter, climate control). Various Sustainable Development Goals (SDGs) are connected with soil. Sustainable soil use is crucial for many SDGs. Target 2.4 of SDG 2 (Zero Hunger) mentions the implementation of resilient agricultural practices to improve land and soil quality. Target 3.9 of the SDG 3 (Good Health and Wellbeing) indicates that the number of deaths and illnesses from soil pollution and contamination must be substantially reduced. Target 12.4 of SDG 12 (Responsible Consumption and Production) mentions reducing the release of chemicals to soil to minimize their adverse impacts on human health and the environment. Target 15.3 of SDG 15 (Life on Land) includes the restoration of degraded soil. Although soil is not mentioned in other SDG targets, it is related to other SDGs. We present the results of the analysis of the activity performed by the students related to soil and SDGs and the transversal competence "knowledge of contemporary problems". In the activity, the students were asked to write down with reasons the SDGs that soil is related to. Afterward, they were asked to write down soil degradation processes and their consequences for people lives and the environment. Next the students worked in groups on the link between soil functions and soil degradation processes using communication material designed by the Food and Agriculture Organization. Finally, they answered a questionnaire, and five open questions to explain the link between soil and the SDGs 2, 3, 6, 13 and 15. The students gave a value of 9.1 out of 10 to the importance of knowledge toward an integrated approach to the environment. The students rated the importance of studying Soil Science to increase their ability to perceive and realize the existence and uniqueness of soils with 8.7 out of 10. The need to raise awareness about soils among people who are not in direct contact with soils was rated with 9.2 out of 10. The students who knew that the SDGs have 169 targets were 85%. The students related the statement "Women remain a minority in soil science" to SDGs 5 (Gender Equality) and 10 (Reduced inequalities). Ninety-five percent of the students stated that "zero hunger" is not only a question of crop production, but it is also related to the quality of education, malnutrition, etc. All the students stated that there is now scientific evidence that healthy soils support nutritious and healthy food and, therefore, contribute to people's health. When students were asked about the origin of toxicity in the soil that can affect human health, 50% named heavy metals, 35% radioactive elements, 35% organic chemicals, and 15% diseases due to exposure to soil organisms. The students were asked if they knew that zinc deficiency is the fifth leading cause of death and disease in the developing world; only 52% said that they did. Soil science has important links to several SDGs and students must know them to advance in their achievement.

Keywords: SDG, SDG targets, Soil Science, soil nexus, Higher Education, University.

## 1 INTRODUCTION

Healthy soils are the foundation of food production and provide essential ecosystem services [1]. Soil plays an important role in food security, carbon sequestration, climate and gas regulations, water cycle, degradation of pollutants, control of pests, etc. [2]. Soil functionality depends on soil properties and their interaction, and the interaction with the biosphere, lithosphere, hydrosphere and atmosphere.

Soil threats include erosion, organic matter loss, contamination, biodiversity loss, compaction, sealing, salinization, floods and landslides, waterlogging [3], [4]. Bünemann et al. [5] established links among soil threats, soil functions and soil-based ecosystem services. In 2017, the Food and Agriculture Organization of the United Nations (FAO) published the document entitled "Voluntary Guidelines for Sustainable Soil Management" that collects technical guidelines to address soil threats. The European Union (EU) has a mission in the soil health and food area entitled "Caring for Soil is Caring for Life". Of

the objectives of this EU Mission we find: conservation of high soil organic carbon stocks, reverse the carbon concentration from losses on cultivated land (0.5% per year) to an increase by 0.1-0.4% per year, no net soil sealing, reduce soil pollution, prevent soil erosion, improve soil structure to enhance habitat quality for soil biota, etc. [6].

It is necessary to promote responsible and sustainable soil management to ensure food production and to enhance nutritional quality of food [7].

In 2015, the General Assembly of the United Nations adopted 2030 Agenda for Sustainable Development [8]. At the heart of the 2030 Agenda are 17 Sustainable Development Goals (SDGs) that cover the challenges of our time, such as poverty, hunger, health, education, climate change, land degradation, responsible production, consumption, etc. (Figure 1).



Figure 1. Sustainable Development Goals categorized into the 5 Ps.

In recent years, many articles have been published in which soils are related to SDGs. Bouma et al. [9] mention that the term “soil” is used in any SDG. However, the term soil is only mentioned in four of the 169 targets of SDGs (Table 1).

According to Tóth et al. [10], “SDGs 2, 3, 6, 11, 13, 14, and 15 refer to targets which commend direct consideration of soil resources” and “SDGs 7 and 12 will indirectly rely on the availability of healthy soil resources”.

In the article “Soils and sustainable development goals of the United Nations: An International Union of Soil Sciences perspective”, Lal et al. [11] explain explicitly the relation between soil and SDGs 1, 2, 3, 4, 5, 6, 9, 11, 12, 13, 15 and 16. They indicate that some of the aforementioned SDGs rely on plant production and others depend on soil processes. Of these soil processes, we find sorption and physical filtration, water movement, heat transfer, ion exchange, and biochemical and biophysical transformations.

Bouma et al. [12], [13] mention that the five SDGs in which soils play a key role are SDGs 2, 3, 6, 13 and 15. Rodrigo-Comino et al. [14] relate to soil SDGs 2, 3, 13 and 15, and mention the connection

between SDGs and specific Soil Science challenges as sustainable food production avoiding or reducing soil threats and environmental impacts on air and water quality, soil pollution, enhancing water storage and soils' filter capacity, soil carbon sequestration and soil nitrous oxide emissions. They also mention that these challenges are interrelated.

Table 1. Sustainable Development Goals and targets where soil is named [15].

<b>SDG 2 Zero hunger</b>
2.4 By 2030, ensure sustainable food production systems and implement resilient agricultural practices that increase productivity and production, that help maintain ecosystems, that strengthen capacity for adaptation to climate change, extreme weather, drought, flooding and other disasters and that progressively improve land and soil quality.
<b>SDG 3 Good health and well-being</b>
3.9 By 2030, substantially reduce the number of deaths and illnesses from hazardous chemicals and air, water and soil pollution and contamination.
<b>SDG 12 Responsible consumption and production</b>
12.4 By 2020, achieve the environmentally sound management of chemicals and all wastes throughout their life cycle, in accordance with agreed international frameworks, and significantly reduce their release to air, water and soil in order to minimize their adverse impacts on human health and the environment.
<b>SDG 15 Life on land</b>
15.3 By 2030, combat desertification, restore degraded land and soil, including land affected by desertification, drought and floods, and strive to achieve a land degradation-neutral world.

Keesstra et al. [16] indicate that Soil Science is a land-related discipline and because of this, it has important links with several SDGs. They showed these links by relating SDGs with soil functions and soil ecosystem services. In a later article, Keesstra et al. [17] show the links among degradation processes, ecosystem services and SDGs, and also provide the link among SDGs, concepts in soil, land and water management, biological, chemical and physical processes, and societal challenges. In the final report entitled "Providing support in relation to the implementation of soil and land related Sustainable Development Goals at EU level", Keesstra et al. [18] relate soil-related SDG targets to soil-based/soil-related SDG indicators with relevant soil functions/properties and with suggested minimum soil indicators to be monitored.

Evans et al. [19] mention that it is essential to achieve SDGs to continue to address the knowledge gaps in Soil Science.

Universities must play an important role in meeting SDGs by providing students with scientific knowledge and skills to take care of natural resources from the sustainable development perspective. This is in accordance with Target 4.7 of SDG 4, which indicates "By 2030, ensure that all learners acquire the knowledge and skills needed to promote sustainable development, including, among others, through education for sustainable development..." [8].

The University plays a key role in transmitting to its students that a transformation of the world is necessary to address the 2030 Agenda challenges and they form part of that transformation. Higher Education is addressing SDGs by including these goals in study guides, curricular and extracurricular learning activities, academic projects, etc. [20]–[28].

Each challenge addressed by SDGs requires academic knowledge from a wide variety of disciplines and different ways of analyzing and addressing them [29]. Lull et al. [30] addressed knowledge of SDGs through challenge-type activities. Those authors prepared files with the necessary elements to work on a challenge, SDGs, and transversal skills, including a description of the challenge, learning outcomes, motivating questions, the SDGs involved, message related to SDGs, the time needed to perform the challenge, assessment and the possible subjects involved in the challenge.

The objective of this work was to increase student awareness of the links between soil properties and sustainable soil management with SDGs. In this work, we describe the results of the learning activity prepared to promote knowledge of soil functions, soil threats and SDGs for Environmental Sciences students.

## 2 METHODOLOGY

The experiment was carried out with the students enrolled for the Abiotic Environment subject that belongs to the second year of the Bachelor's Degree of Environmental Sciences at the Universitat Politècnica de València (UPV) for academic year 2021-2022. Forty-seven students enrolled for this. Soil Science, Meteorology and Hydrology are taught for this subject. As part of teaching Soil Science, an activity was performed to assess one transversal skill "knowledge of contemporary issues". First, SDG logos and icons were shown on a classroom screen and the students were asked to write down which SDG may be related to soil and why. Second, the students were asked to write down what they knew about soil degradation processes and what consequences they can have for people's lives and the environment. Third, the teacher explained the functions of the soil. Next small groups were formed and each group of students was given different informative material (infographics) providing information about soil functions and degradation processes. The employed infographics can be found at <https://www.fao.org/global-soil-partnership/resources/communication-material/en/>. A student from each group presented the work done by the group and a discussion started for the whole class. Finally, the students answered a questionnaire. The questionnaire consisted of 16 questions (Table 2). Questions 1-5, 13-15 were true/false/don't know questions, questions 6-8 were rating-scale questions (0-10), and questions 9, 11-12 were multiple-choice questions and were based on information on the official United Nations' SDG website. Question 16 was a multiple-choice question. Question 10 was an open response question. After the questionnaire, the students also answered five open questions about soil with the following five SDGs: 2, 3, 6, 13 and 15. The questionnaire was answered by 20 students and the last five open questions by 17.

## 3 RESULTS

The questionnaire was answered by 42.55% of the students. The first three questions were related to soil complexity. Kopittke et al. [31] mentioned that soils are the most complex and diverse ecosystem in the world. According to Phillips [32], "Soil complexity is inextricably intertwined with soil variability, irregularity, and predictability". This author also mentions that soil complexity can be considered by taking into account holistic entities or specific soil properties or features. Forty-five per cent of the students asserted that soil behavior is easy to predict and 25% indicated having full knowledge of nutrients and rhizosphere dynamics in soil. All the students were aware of soil threats after working in groups on them. It is noteworthy that mentioned in the EU Soil Strategy 2030 adopted by the European Commission in November 2021: "Too few know that the thin layer that lies below our feet holds our future" and "Land and soil continue to be subject to severe degradation processes" [33].

Forty per cent of the students believed that there is a Framework Directive to protect soils in the EU. In the EU, there are legal provisions to protect soil, but the EU has not been able "to equip itself with an adequate legal framework granting soil the same level of protection as water, marine environment and air" [33].

The students rated a high mark (9.1 out of 10) to the importance of Soil Science knowledge to have an integrated approach to the environment, and also with a high mark (8.7 out of 10) to the degree to which their ability to perceive and realize the existence and uniqueness of soils had increased after studying a course in Soil Sciences. Knowledge about soils has significantly advanced in past years, as has the recognition of their value [33].

The students were asked to rate on a scale from 1 to 10 their agreement with a statement that mentioned the need to raise people's awareness about soils who are not in direct contact with soils, and of their productive and environmental functions. They gave an average mark of 9.16 out of 10. Dazzi and Lo Papa [34] state that in the last two decades, awareness that soils are important and multifaceted resources has increased due to initiatives like the World Soil Day, the creation of the "Global Soil Partnership" by the FAO, the declaration of the International Year of Soils in 2015 by the UN General Assembly, the declaration of an International Decade of Soils 2015-2024 by the International Union of Soil Sciences (IUSS), among others. The authors mention highlighted specific concepts, such as soil security, soil sustainability, soil ecosystem services and the launch of SDGs.

With the questions related to SDGs, a high percentage of students (85%) knew that there are 169 targets for SDGs. Soils were related to SDG 1 End poverty, insofar as there are no healthy soils, the incomes of small-scale food producers decrease, and for many people the work of soil to obtain food is a livelihood that allows them to overcome poverty. Eighty percent of the students knew that many people live on less than \$1.90 a day.

The students were asked which SDG is related to the statement “Women remain a minority in Soil Science and related fields, and their representation at conferences as guest speakers, on editorial boards, or as reviewers is even worse” [11]. They mentioned SDG 5 and SDG 10. Lal et al. [11] mention the need to rethink gender equality (SDG 5) “to create an inclusive perspective that encourages respect, collaboration and solidarity between the genders” and bring up that “equality does not mean that women and men will become the same but that women's and men's rights, responsibilities and opportunities will not depend on whether they are born male or female” [35]. In the last few decades, studies related to the role of women in Soil Science have increased [36]–[39].

About SDG 2, a high percentage of the students (70%) did not know that about 795 million people in the world were undernourished in 2014–16 [40], but 95% agreed that “Zero hunger” is not only a question of crop production, but is also related to education quality, malnutrition, etc. Nutritious foods should be more accessible and affordable to people. Target 2.4 aims to ensure sustainable food production systems and to implement resilient agricultural practices that increase productivity and production. These practices should maintain ecosystems and should improve soil quality. Von Braun et al. [41] mention that poor farming practices can degrade soils and pollute and deplete water supplies. So “researchers need to find ways to restore soil health and improve the efficiency of cropping”.

All the students stated that there is scientific evidence that healthy soils support nutritious and healthy food and, therefore contribute to people's health (SDG 3). Although the students in class received information about the health effect of zinc deficiency, only 65% stated that nutrient deficiencies and excessive heavy metals in soil and plants are directly related to human health, and zinc deficiency is the fifth leading cause of death and disease in the developing world. Natasha et al. [42] reviewed the role of zinc in soil-plant-human system, and described sources of zinc in soils, zinc phytoavailability, chemical speciation in soil, deficiency in humans and a risk assessment for human beings.

The students were presented with different pollutants and asked to indicate those found in soil that can damage health. It was a multiple-response question. Fifty per cent of the students answered heavy metals, and 35% radioactive elements and organic chemicals. However, only 15% of them named soil organisms and 10% mentioned respiratory problems caused by inhaling dust. The vast majority of soil organisms pose no threat to human health [43]. However, health problems can be caused by soil-borne human pathogens [44], [45] and particles [46]. In relation to plant growth and food production, and according to Delgado-Baquerizo et al. [47], we also have to consider the overall increase in the relative abundance of potential plant pathogens worldwide.

Only two students mentioned soil colloids and their ability to adsorb hazardous chemical elements in relation to SDG 3 and 6. This contrasts with the results obtained from the previous course in which a higher percentage of students named this soil property [48].

Table 2. Students' questions and answers.

<b>Complexity of soils and soil knowledge gaps</b>	
1. Soil is a very complex mixture with physical, chemical and biological properties, however its behavior is very easy to predict.	True (45%) False (55%) Don't know
2. Today there is a full knowledge of the dynamics of nutrients in the soil as well as their bioavailability for plants and soil organisms.	True (25%) False (60%) Don't know (15%)
3. Nowadays, it is completely known what happens in the rhizosphere from the chemical and microbiological points of view.	True (25%) False (50%) Don't know (25%)
<b>Soil threats</b>	
4. Today the world's soils are subject to increased anthropogenic pressure that leads to nutrient depletion, reduced biodiversity, organic matter loss, soil sealing, salinization and compaction that can negatively affect people's health and well-being	True (100%) False Don't know

<b>Knowledge of the existence of soil regulation at European Union level</b>	
5. Currently, there is a Framework Directive to protect soils in the EU.	True (40%) False (55%) Don't know (5%)
<b>Importance of Soil Science knowledge</b>	
6. Indicate on a scale from 1 to 10 the importance of Soil Science knowledge to have an integrated approach to the environment.	9.10 ± 0.91
7. After having studied Soil Science, indicate on a scale from 1 to 10 the degree to which your ability to perceive and realize the existence and uniqueness of soils has increased.	8.70 ± 1.26
<b>Importance of increasing soil awareness</b>	
8. Indicate on a scale from 1 to 10 your agreement with the following statement: It is necessary to raise people's awareness about soils who are not in direct contact with soils, and their productive and environmental functions.	9.16 ± 1.99
<b>Questions related to SDGs</b>	
9. How many targets are there in SDGs?	a) 25 b) 120 (5%) <b>c) 169 (85%)</b> d) 180 (5%) e) Don't know (5%)
10. Women remain a minority in Soil Science and related fields, and their representation at conferences as guest speakers, on editorial boards, or as reviewers is even worse. What SDG is this statement related to? (Lal et al. 2021) [11].	SDG 5 (named by 70%) SDG 10 (named by 20%) No answer (15 %)
<b>11. SDG 1 No poverty</b> Indicate the correct answer: Poverty, the main cause of hunger in the world, affects 10% of the world's population, who live on less than \$ ____ per day. For many people, the work of soil to obtain food is a livelihood that allows them to overcome poverty.	<b>a) 1.90 (80%)</b> b) 3.10 (10%) c) 4.50 d) 5.90 (5%) Unanswered (5%)
<b>12. SDG 2 Zero hunger</b> The number of hungry people in the world has fallen to _____ million - 216 million fewer than in 1990-1992, or about one person in nine, according to the latest edition of the UN annual report on hunger, report on the state of food insecurity in the world (FAO, 2015) [40].	a) 100 (15%) b) 485 (5%) <b>c) 795 (10%)</b> d) 1565 (0%) e) Don't know (70%)
<b>13. SDG 2</b> "Zero hunger" is not only a question of crop production, but is also related to education quality, malnutrition, etc.	True (95%) False (5%) Don't know
<b>14. SDG 3 Good health and well-being.</b> Good health and well-being are interconnected with soil because healthy soils produce healthy crops that nourish people and animals. Today there is scientific evidence that healthy soils support nutritious and healthy food and, therefore, contribute to people's health.	True (100%) False Don't know
<b>15. SDG 2 and SDG 3</b> Nutrient deficiencies and excessive heavy metals in soil and plants are directly related to human health. Zn deficiency is the fifth leading cause of death and disease in the developing world.	True (65%) False (10%) Don't know (25%)
<b>16. SDG 3</b> Soil has both negative and positive effects on human beings. Potential negative health effects from human exposure to soils due to toxicity from: Multiple responses can be chosen.	a) heavy metals. (50%) b) radioactive elements. (35%) c) organic chemicals. (35%) d) diseases from exposure to soil organisms. (15%) e) respiratory problems caused by inhalation of dust. (10%)






The students were asked to relate soil to SDGs 2, 3, 6, 13 and 15. Table 3 collects these relations extracted from the students' responses, as well as the percentage of the students who mentioned each one.

The relation established by more students was soil's function for being a natural filter for water with SDG 6 (76.5%), followed by the carbon sequestration function with SDG 13 (58.8%), healthy soils with healthy crops that nourish people with SDG 2 (52.9%), healthy soils-healthy people with SDG 3 (41.2%) and the soil function for being a natural filter for water to avoid health issues with SDG 3 (41.2%).

SDG 2 is that with which the students established more relations to soil. However, the soil function that was most related to soil was the soil's function as a natural water filter, which was also related to SDG 3 and 6.

It must be considered that the students are following an introductory course to Soil Science in which soil degradation processes are not studied in-depth. The Soil Science course is taught in the first semester. In the second semester, the same students study soil contamination and in the third year soil erosion and salinization, where there are opportunities for students to explore the relations between soil and SDGs, and their targets and indicators, in more detail.

Table 3. Relations established between soils and SDGs by students.

 <p>2 ZERO HUNGER</p>	<p>Healthy soils produce healthy crops that, in turn, nourish people. (52.9%) Soils play a critical role in food production. (23.5%) Take care of soils to obtain more food from them. (11.8%) Increase land and soil surfaces to increase food production. (5.9%) Soils produce crops (e.g. natural fibers) that can be used in, for example, food matrices. (5.9%) Soil generates economic resources; for example, a family can have a garden from which they obtain food to sell and obtain income (5.9%).</p>
 <p>3 GOOD HEALTH AND WELL-BEING</p>	<p>Healthy soils are the basis of healthy food production and, therefore, for healthy people. (41.2%) Soils filter water which avoids health issues. (41.2%). Soil microorganisms are able to degrade certain contaminants. (20.4%)</p>
 <p>6 CLEAN WATER AND SANITATION</p>	<p>Soil is a natural water filter. (76.5%) Importance of soil water storage capacity by making water available for absorption by crops (5.9%)</p>
 <p>13 CLIMATE ACTION</p>	<p>Soil C sequestration. (58.8%) Soil can affect the microclimate. (35.3%)</p>
 <p>15 LIFE ON LAND</p>	<p>Soils are a habitat for many species. (41.2%) Soils are part of terrestrial ecosystems. (20.4%)</p>

## 4 CONCLUSIONS

In this work, the inclusion of SDGs by means of an activity in a Soil Science subject taught to second-year students of the degree in Environmental Sciences is presented.

From the obtained results, the students do not establish all the possible relations between soil and SDGs, which confirms that this relation should be worked on more in class. Activities should be prepared to make students aware of the problems and challenges related to soil that SDGs underlie and involve the students to perform actions to fulfill SDGs thanks to them gaining a thorough understanding of Soil Science topics.

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