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Examining The Role of Soil in Promoting Sustainable Development and Achieving the UN Sustainable Development Goals (SDGs)

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Abstract

Soil is a critical component of terrestrial ecosystems, playing an invaluable role in supporting plant growth, regulating water and nutrient cycles, filtering pollutants, and providing habitat for soil organisms. However, increasing pressures from human activities, including intensive agriculture, deforestation, urbanization, and climate change are degrading soils across the world. Therefore, sustainable management of soil resources is imperative to ensure continued provisioning of ecosystem services, promote sustainable development outcomes, and help us to achieve the UN Sustainable Development Goals (SDGs). This paper reviews literature across multiple disciplines to examine the vital links between soil and realization of the SDGs. Soil properties influence productivity and food security, water availability and quality, climate regulation through carbon storage, biodiversity conservation, and human health. Degraded soils undermine these ecosystem services, exacerbating poverty, hunger, and inequality. Research shows ecosystem-based approaches that prioritize soil health, including conservation agriculture, agroecology, and regenerative systems, can sustainably intensify agriculture while restoring multi-functionality. Additionally, nature-based solutions utilizing plant-soil interactions for restoration have demonstrated cost-effectiveness. Achieving land degradation neutrality is now an explicit target under the United Nations Convention to Combat Desertification (UNCCD), emphasizing the need to scale soil-focused initiatives within the SDG framework. Therefore, protecting and restoring global soil assets can serve as a nexus in policy frameworks to simultaneously advance progress across multiple SDGs.

Keywords: Sustainable Development Goals (SDGs), United Nations Convention to Combat Desertification (UNCCD), Soil, Environment

1. Introduction

The complex, dynamic soil ecosystem is at the interface of the lithosphere, biosphere, atmosphere, and hydrosphere. Soils regulate elemental cycles of carbon, nitrogen, and phosphorus and water flows, as well as enable the establishment of agricultural crops, woods, and grasslands that sustain life [1–3]. Soils filter contaminants and waste from percolating water, store water and nutrients for plants, and house complex soil biota that recycle organic materials. Soil quality and health determine how well soil provides ecological services. Globally, land use changes and unsustainable land management are diminishing soils' ability to supply these services [4–6].

Meeting food, fiber, and fuel demands will strain soil resources as the global population reaches 9.7 billion by 2050 [7, 8]. Maintaining the multi-functionality of global soil assets will help achieve key international policy goals like reducing and adapting to climate change, protecting biodiversity, increasing food security, and other Sustainable Development Goals [9,10]. There are growing requests to clearly recognize the links between soil health and sustainable development [11]. With 2015-2024 declared the International Decade of Soils by the UN, sustainable soil management policies and programs are being implemented worldwide [12].

This research synthesizes major literature from several fields to analyze how soils affect multiple UN SDG-related sustainable development outcomes. Section 2 addresses soil conditions' effects on ecosystem service provisioning, focusing on SDGs 2 (zero hunger), 6 (clean water and sanitation), 13 (climate action), 14 (life below water), and 15 (life on land). Section 3 reviews conservation agriculture, agroecology, and regenerative systems literature on sustainable soil management. Section 4 examines UNCCD, EU Green accord, and Farm to Fork strategy policy frameworks and land degradation neutrality progress. Section 5 ends by recommending key areas for scaling soil-focused activities

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to accelerate SDG fulfillment in integrative policy frameworks.

2. Sustainable Development Goals and Soil Ecosystem Services

Soils provide provisioning, regulating, sustaining, and cultural ecological functions that directly and indirectly benefit humans [13]. Soils provide food and nutrition security by growing 95% of global food output, animal fodder, timber, and bioenergy crops [8]. Well-structured, nutrient-balanced, water-retentive soils boost agricultural productivity and climate resilience [14,15]. Pesticides and industrial chemicals in root zone water are filtered and decomposed by soils, regulating contamination of ground and surface water [16]. Soil organic matter (SOM) from decomposing plant and animal leftovers can store enormous amounts of atmospheric CO2 when stabilized by soil particles and aggregates [17]. Soils contain twice as much carbon as the atmosphere, and restoring degraded lands allows for ‘negative emission technologies’ [18]. Soil biota, microorganisms, and animals drive biogeochemical processes that cycle nutrients, create SOM, and build soil structure for self-sustaining soil fertility [19]. Maintaining or improving global soil assets' multi-functionality through sustainable management can assist achieve various SDGs, as stated below.

2.1. Zero Hunger SDG

Soil quality and fertility determine biomass productivity in croplands, pastures, and forests, which support agriculture and food production. Multiple studies show that soil organic matter, nutrient availability, water retention capacity, and crop yields are positively correlated [14, 20]. Over time, bedrock weathering supported ecosystem productivity during dry years, demonstrating that deeper soil layers affect resilience [1]. Erosion, salinization, and nitrogen depletion can harm crop growth and yields [21]. World Bank estimates land degradation affects world crop earnings by 7 billion USD, hurting 1.3 billion people, primarily small-holder farmers [22].

Thus, SDG 2's goal of ending hunger and malnutrition requires healthy soils. To fulfill rising food demands without expansion or land use change, sustainably improving farmland productivity closes yield gaps [7]. Sustainable agricultural intensification (SAI) emphasizes soil health management for climate-smart, resilient agriculture [23, 24]. SAI conservation methods including cover cropping, crop rotations to replenish SOM, and integrated soil fertility management increase yields on small farms and big businesses [25]. Thus, data strongly suggests sustainable soil management can boost local and global food security.

2.2 Clean Water and Sanitation SDG 6

Soils greatly influence terrestrial ecosystem water resource quality and availability by regulating water infiltration, storage, drainage, and purification. Poorly structured soils impede infiltration, increasing surface runoff and erosion concerns, especially after heavy rains. Increased sediment and nutrient loads into water bodies require larger water treatment investments for home, municipal, and industrial usage [26]. Soil health and vegetative cover restoration are cost-effective watershed management and source water protection measures [27].

Through irrigation and drainage infrastructure and modifying tillage practices, soil management influences ground and surface hydrological flows in agricultural environments [28]. Even after repair, soil degradation reduced water retention after 7 years of warming tests [29]. Conservation agriculture, residue retention, and erosion control can boost precipitation absorption in water-scarce regions like the Mediterranean [30]. Soil-focused initiatives support SDG 6's water resource conservation, security, and quality goals.

2.3. Climate Action SDG 13.

Soil organic matter, the greatest terrestrial carbon sink, regulates global carbon cycles and temperature. While lithology and climate are important regulators, vegetation and land use changes greatly affect SOM formation and turnover, affecting soil carbon storage [31]. SOM stabilization and mineralization are balanced by plant and microbial inputs after carbon saturation. Unsustainable land management accelerates SOM decomposition, decreasing cropland and grassland soil carbon stores worldwide [32].

Clearing native vegetation for agriculture, overgrazing pastures, excessive tillage, mono-cropping, and insufficient residue return damage soil structure and release 133 gigatons of carbon from SOC reservoirs [33]. Soil degradation causes 12-14% of

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global greenhouse gas (GHG) emissions, hindering SDG 13 climate change mitigation [34]. This has increased attention on sustainable soil management to reduce agricultural emissions and absorb atmospheric carbon. Adopting excellent management practices might sequester over 4 per 1000 or 0.4% of global carbon stocks annually [35]. Soil-centric Negative Emission Technologies that increase SOC can reduce global warming by 10% with supportive policies [36].

2.4 SDG 14—Life Below Water

Although soil management and SDG 14 marine conservation targets are less direct, terrestrial processes strongly impact coastal and ocean ecosystem health [37]. Unsustainable farming methods cause soil erosion, nutrient runoff, hypoxic zones, algal blooms, and eutrophication in estuarine and marine ecosystems [38]. Sediment loads harm reef ecosystems. Conservative estimates put over 20% of coral reefs at high or very high risk from soil erosion and land runoff [39].

Improving soil health and vegetation cover reduces agricultural nitrogen and sediment loads, improving downstream water quality [40]. Catchment actions like erosion management and revegetation reduce river sediment fluxes even during tropical cyclones [41]. Regenerative techniques can reduce soil-nutrient-water flows to fragile aquatic systems by reducing external inputs and improving recycling. Sustainable soil management supports SDG 14 marine biodiversity and habitat protection targets with many co-benefits.

2.5. SDG 15:

Life on Land Soils maintain complex food webs for almost 25% of global biodiversity, including bacteria, fungi, arthropods, earthworms, and other animals [42]. Soil organisms drive biogeochemical processes that mobilize and cycle nutrients, turnover SOM, build soil structure, and maintain fertility [43]. Intensively managed agricultural soils are losing below-ground biodiversity due to habitat fragmentation and pesticide use. [44]. Functional diversity loss and soil food web structure changes reduce long-term ecological services [45].

Soil quality and land management indirectly affect above-ground ecosystems and biodiversity. Alpine meadow plant and microbial diversity was positively and negatively affected by 7 years of diurnal asymmetric warming trials [46]. Grazing

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intensity and timing control can change plant functional group competition and soil biota habitat compatibility [47, 48]. Human activities like nitrogen fertilizer and industrial pollutants modify soil pH, threatening grassland biodiversity [49].

Soil biodiversity must be protected and managed sustainably to conserve and restore terrestrial ecosystems, an SDG 15 goal [50]. Landscape heterogeneity and habitat connectedness promote gene flows, building evolutionary robustness and supporting endemic species [51]. Functional biodiversity-based agroecology and organic methods have improved soil health and above-ground productivity [52]. The research strongly recommends integrating soil biological processes into conservation planning and biodiversity policy frameworks.

3. Sustainable Soil Management Systems

Solving global soil resource concerns requires holistic approaches due to soils' cross-cutting links to ecosystem services and sustainable development. Integrating ecology, sustainable land management, climate change adaptation, and circular economies might assist regenerate soil functions that support human well-being [53]. Key literature on techniques and management systems that improved soil health and restored multi-functionality in agricultural landscapes globally is discussed here.

3.1 Eco-agriculture

Conservation Agriculture (CA) uses minimal soil disturbance, permanent soil cover with crop residues, and crop rotations and associations to achieve sustainable and profitable agriculture and improve farmer livelihoods [54]. CA techniques increase soil organic matter, water penetration, and retention, making them more drought-resistant than conventional farming [55]. Meta-analyses demonstrate CA boosts global topsoil carbon [56]. Long-term conservation tillage increased soil microbial diversity, including bacteria, fungi, and protozoa [57].

CA systems improve crop yield variability under rainfall fluctuation by lowering erosion hazards and enhancing rainwater utilization efficiency [58]. In most cases, avoiding plowing and saving fuel offset higher labor and pesticide expenses [59]. Despite the benefits, residue retention,

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weed management, and small-scale farmer equipment issues continue to slow uptake. Optimizing synergistic CA-compliant techniques for wider adoption across varied agroecosystems requires more research.

3.2 Agri Ecology

Ecological principles are used to create sustainable food systems that balance environmental, economic, and social sustainability [60]. Agroecology recycles nutrients, energy, and wastes like natural processes to increase biodiversity [61]. Crop rotations, crop-livestock integration, intercropping, agroforestry, and organic methods reduce synthetic inputs by creating healthy soils. Many agroecology approaches complement conservation and regenerative agriculture.

Studies show multi-functional biodiverse systems boost plant-microbe interactions for nutrient mobilization and pest management [62, 63]. Diversified systems can match conventional agriculture outputs while increasing soil carbon storage for climate adaptation and mitigation [64]. Agroecology transitions increase women's participation, which could change rural gender relations [65]. However, insufficient policy support for ecological techniques limits agroecology scaling. Traditional knowledge and smallholder farmer participatory innovation processes must be integrated to overcome socio-economic constraints [66].

3.3, Regenerative Agriculture

Regenerative Agriculture “farming and grazing practices that, among other benefits, reverse climate change by rebuilding soil organic matter and restoring biodiversity” [67]. Comprehensive land management methods include conservation agriculture, integrated crop livestock systems, silvopastoral systems, agroforestry, and others improve farm ecosystem health. Minimizing physical disturbance, rotating and intercropping plants, avoiding synthetic pesticides, and actively establishing soil biotic ecosystems are key [68].

Integrating adaptive multi-paddock grazing with seasonal high-density herd movements replicates migratory patterns for appropriate recuperation [69]. Nutrient density and availability increase over time by increasing root exudates feeding soil microorganisms, lowering inorganic fertilizer use [70]. Mixes of cover crop and cash crop rotations rebuild SOM, retain

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water, and support pollinators to promote production [71]. Regenerative methods can cost-effectively sequester nearly 1 tons of CO2 per acre annually, reversing soil carbon losses [72]. However, absence of consistent verification techniques hinders uptake and policy support. Mainstreaming involves supply chain partnerships and farmer incentives to go beyond yield-focused systems [73].

4. Policy Frameworks Supporting Sustainable Soil Management

Given the strong links between soil health and ecological services, land degradation neutrality is a global policy goal. Land degradation neutrality combats predicted losses from land use and climate change to maintain or improve ecosystem services [74].

4.1 The UN Convention to Combat Desertification

To support livelihoods and human wellbeing, the UNCCD, the main international framework for land degradation, prioritizes soil health restoration. The SDGs' Land deterioration Neutrality (LDN) aim requires preventing additional deterioration and repairing degraded soils. Over 20% of global vegetated areas have declined over the past 20 years [75]. Urgent action is needed to address species extinction, poverty, and carbon emissions from ecosystem productivity loss. The UNCCD Global Land Outlook study adds that local context and participatory monitoring are crucial to restoration success [76].

Analysis suggests cost-effective strategies such agroforestry, conservation agriculture, and native species pasture regeneration are not widely used [77]. Poor institutional coordination between agriculture, soil, water, forestry, and climate change agencies hinders LDN activities [78]. LDN can be accelerated by eco-schemes that reward farmers for soil-based carbon sequestration. The need to substantially scale land restoration activities and empower marginal and small holder farmers through well-aligned incentives and capacity training is widely agreed upon [79].

4.2 EU Farm-to-Fork and Biodiversity Strategies

The recently agreed Farm to Fork (F2F) and Biodiversity policies set high goals for regional food systems and land

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management as part of the EU's Green Deal [80]. The F2F technique promotes organic farming and reduces chemical inputs and soil hazards [81]. To harmonize monitoring and evaluation frameworks for comparing regional progress on erosion, organic matter decline, compaction, salinization, and soil sealing trends, EU-wide soil health definitions and indicators are proposed by 2021 [82].

Through buffer strips, rotational fallow, hedges, and other high-diversity landscape features, the Biodiversity Strategy intends to restore 10% of agricultural land by 2030. Conservation management will encompass 30% of croplands and grasslands [83]. Recently developed earth observation, remote sensing, and digital soil mapping technologies will be used to monitor biodiversity reductions and identify priority intervention zones [84].

Regenerative agriculture based on soil health is also discussed. The F2F and Biodiversity plans set production and consumer sustainability goals, although discussions remain over CAP reforms in the region. Harmonizing suggested eco-schemes under the new CAP to give enough incentives for farmers across member states to embrace soil conservation measures including no-till systems, erosion control, integrated nutrient management, etc. [85-87]. The proposed CAP amendments also aim to give at least 35% of budgets to climate, environment, and animal welfare eco-schemes.

Targets, indicators, and monitoring frameworks offer hope for a reinvigorated policy environment to fund soil sustainability projects [88]. Flexible procedures for participatory planning and decentralized decision making can help nutrition-sensitive, regenerative agriculture succeed [89, 90]. To guarantee universal acceptability and compliance, trade-offs between socio-economic viability and ambitious environmental requirements must be considered.

5. Case Study

The study investigated surface soil samples from varied farmed areas in India to build regional databases and examine soil nutrient constraints. K, S, and Zn/Fe deficiencies were most severe in 30-62% of samples. In contrast, most samples had adequate P, Mn, and Cu. Significant

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positive connections of OC with P, K, S, and Fe show its major role in soil quality. PCA explains >73% of pH, EC, OC, P, K, and S variability. Outputs assist detect regional soil fertility limits. To maximize crop yields, provide insufficient nutrient supplements locally. The findings can be used to create soil test-based fertilizer use efficiency recommendations for Indian agriculture. Future studies should evaluate crop responses, production gaps, and needs-based balanced nutrition decision support tools.

Collins and Page (2019) suggest that fertility rates are heritable, making world population stabilization difficult and rising food and resource demand [91]. Bongaarts (2019) outlines the global biodiversity and ecological services assessment, revealing unparalleled biodiversity reduction [92].

Several studies propose sustainable intensification of agriculture to boost food production while reducing environmental effect. Xie et al. (2019) evaluates sustainable intensification research prospects, while Cassman and Grassini (2020) present a worldwide perspective [93-94]. Bangash et al. (2013) examine how climate change affects Mediterranean river water delivery and erosion control [95].

Nielsen et al. (2011) emphasize soil biodiversity for carbon cycling. Biological diversity loss affects ecological activities including carbon cycling [96]. Agrobiodiversity use and conservation in agricultural environments are discussed by Jackson et al. (2007) [97]. In their 2020 assessment, Newton and Schreefel define and explain regenerative agriculture, which restores soil health [98-99].

Davis (2008) concludes with an assessment of sub-Saharan African agricultural extension strategies and prospects, which is essential for spreading sustainable farming [100].

6 Conclusions

This research systematically analyzed relevant studies linking soil health to ecosystem services like climate regulation, water security, food production, biodiversity protection, and human livelihoods and well-being. Soils underpin most SDG targets, yet present degradation trends severely harm terrestrial ecosystems. The evidence suggests that degraded soils reduce production, intensify climate

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change, and increase poverty and malnutrition in emerging regions. Soil erosion, salinization, and fertility reductions indirectly harm coastal conservation and water supplies.

Sustainable soil management methods including conservation agriculture, agroecology, and regenerative farming systems provide many benefits over input-intensive methods, according to research. Sustainable organic matter, biological nutrient cycling, and soil biodiversity enable resilient, climate-smart agriculture for local and global communities.

References

1. Tilman, D.; Cassman, K.G.; Matson, P.A.; Naylor, R.; Polasky, S. Agricultural Sustainability and Intensive Production Practices. Nature 2002, 418, 671–677.
2. Telo da Gama, J.; Loures, L.; Lopez-Piñeiro, A.; Quintino, D.; Ferreira, P.; Nunes, J.R. Assessing the Long-Term Impact of Traditional Agriculture and the Mid-Term Impact of Intensification in Face of Local Climatic Changes. Agriculture 2021, 11, 814.
3. Francaviglia, R.; Almagro, M.; Vicente-Vicente, J.L. Conservation Agriculture and Soil Organic Carbon: Principles, Processes, Practices and Policy Options. Soil. Syst. 2023, 7, 17.
4. Cherlet, M.; Hutchinson, C.; Reynolds, J.; Hill, J.; Sommer, S.; von Maltitz, G. World Atlas of Desertification Rethinking Land Degradation and Sustainable Land Management; Publications Office of the European Union: Luxembourg, 2018; ISBN 978-9-27975-350-3.
5. Tomlinson, I. Doubling Food Production to Feed the 9 Billion: A Critical Perspective on a Key Discourse of Food Security in the UK. J. Rural Stud. 2013, 29, 81–90.
6. Dong, X.; Martin, J.B.; Cohen, M.J.; Tu, T. Bedrock Mediates Responses of Ecosystem Productivity to Climate Variability. Commun. Earth Environ. 2023, 4, 114.
7. Zheng, W.; Rao, C.; Wu, Q.; Wang, E.; Jiang, X.; Xu, Y.; Hu, L.; Chen, Y.; Liang, X.; Yan, W. Changes in the Soil Labile Organic Carbon Fractions Following Bedrock Exposure Rate in a Karst Context. Forests 2022, 13, 516.

@2024 International Council for Education Research and Training
ISSN: 2959-1376
2024, Vol. 03, Issue 03, 265-285
DOI: https://doi.org/10.59231/SARI7734

8. Wang, X. Managing Land Carrying Capacity: Key to Achieving Sustainable Production Systems for Food Security. Land 2022, 11, 484.

9. Wijerathna-Yapa, A.; Pathirana, R. Sustainable Agro-Food Systems for Addressing Climate Change and Food Security. Agriculture 2022, 12, 1554.

10. Weil, R.R.; Brady, N.C. The Nature and Properties of Soils, 15th ed.; Pearson Prentice Hall: Harlow, UK; London, UK; New York, NY, USA, 2017; ISBN 978-1-29216-223-2.

11. Rahman, S.; Ali, A.; Raihan, A. Soil Carbon Sequestration in Agroforestry Systems as a Mitigation Strategy of Climate Change: A Case Study from Dinajpur, Bangladesh. Adv. Environ. Eng. Res. 2022, 3, 1–13.

12. Li, H.; Wu, Y.; Liu, S.; Xiao, J.; Zhao, W.; Chen, J.; Alexandrov, G.; Cao, Y. Decipher Soil Organic Carbon Dynamics and Driving Forces across China Using Machine Learning. Glob. Chang. Biol. 2022, 28, 3394–3410.

13. Mansoor, S.; Farooq, I.; Kachroo, M.M.; Mahmoud, A.E.D.; Fawzy, M.; Popescu, S.M.; Alyemeni, M.N.; Sonne, C.; Rinklebe, J.; Ahmad, P. Elevation in Wildfire Frequencies with Respect to the Climate Change. J. Environ. Manag. 2022, 301, 113769.

14. Ahmad Rather, R.; Bano, H.; Ahmad Padder, S.; Perveen, K.; Al Masoudi, L.M.; Saud Alam, S.; Ho Hong, S. Anthropogenic Impacts on Phytosociological Features and Soil Microbial Health of Colchicum luteum L. an Endangered Medicinal Plant of North Western Himalaya. Saudi J. Biol. Sci. 2022, 29, 2856–2866.

15. De Girolamo, A.M.; Barca, E.; Leone, M.; Lo Porto, A. Impact of Long-Term Climate Change on Flow Regime in a Mediterranean Basin. J. Hydrol. Reg. Stud. 2022, 41, 101061.

16. Yang, G.; Ryo, M.; Roy, J.; Lammel, D.R.; Ballhausen, M.-B.; Jing, X.; Zhu, X.; Rillig, M.C. Multiple Anthropogenic Pressures Eliminate the Effects of Soil Microbial Diversity on Ecosystem Functions in Experimental Microcosms. Nat. Commun. 2022, 13, 4260.

17. Shen, L.; Cheng, G.; Du, X.; Meng, C.; Ren, Y.; Wang, J. Can Urban Agglomeration Bring “1 + 1 > 2Effect”? A Perspective of Land Resource Carrying

@2024 International Council for Education Research and Training
ISSN: 2959-1376

2024, Vol. 03, Issue 03, 265-285
DOI: https://doi.org/10.59231/SARI7734

Capacity. Land. Use Policy 2022, 117, 106094.

18. Devkota, K.P.; Devkota, M.; Rezaei, M.; Oosterbaan, R. Managing Salinity for Sustainable Agricultural Production in Salt-Affected Soils of Irrigated Drylands. Agric. Syst. 2022, 198, 103390.

19. Guterres, A. The Sustainable Development Goals Report 2020; United Nations, Department of Economic and Social Affairs: New York, NY, USA, 2020; pp. 1–64.

20. Lal, R.; Bouma, J.; Brevik, E.; Dawson, L.; Field, D.J.; Glaser, B.; Hatano, R.; Hartemink, A.E.; Kosaki, T.; Lascelles, B.; et al. Soils and Sustainable Development Goals of the United Nations: An International Union of Soil Sciences Perspective. Geoderma Reg. 2021, 25, e00398.

21. Shukla, P.R.; Skea, J.; Calvo Buendia, E.; Masson-Delmotte, V.; Pörtner, H.O.; Roberts, D.C.; Zhai, P.; Slade, R.; Connors, S.; Van Diemen, R. IPCC, 2019: Climate Change and Land: An IPCC Special Report on Climate Change, Desertification, Land Degradation, Sustainable Land Management, Food Security, and Greenhouse Gas Fluxes in Terrestrial Ecosystems; IPCC: Geneva, Switzerland, 2019.

22. Darouich, H.; Ramos, T.B.; Pereira, L.S.; Rabino, D.; Bagagiolo, G.; Capello, G.; Simionesei, L.; Cavallo, E.; Biddoccu, M. Water Use and Soil Water Balance of Mediterranean Vineyards under Rainfed and Drip Irrigation Management: Evapotranspiration Partition and Soil Management Modelling for Resource Conservation. Water 2022, 14, 554.

23. Zhu, J.; Wang, Q.; Qi, W.; Zhao, X.; Xu, Y.; Sun, Y.; Zhang, D.; Zhou, X.; Mak-Mensah, E. Exploring the Potential of Biochar and Mulched Drip Irrigation with Plastic Film on Crop Yields in Water-Stressed Regions: A Global Meta-Analysis. J. Soil. Sci. Plant Nutr. 2023.

24. Ramírez, M.; López-Piñeiro, A.; Peña, D.; Rato Nunes, J.; Albarrán, Á.; Muñoz, A.; Gama, J.; Loures, L. Seasonal and Interannual Fluctuation of the Microbial Soil Community in a Maize Field under Long-Term Conservation Agriculture Management. Sustainability 2017, 9, 778.

25. Mace, G.M.; Norris, K.; Fitter, A.H. Biodiversity and Ecosystem Services: A

@2024 International Council for Education Research and Training
ISSN: 2959-1376
2024, Vol. 03, Issue 03, 265-285
DOI: https://doi.org/10.59231/SARI7734

Multilayered Relationship. Trends Ecol. Evol. 2012, 27, 19–26.

26. Kaletová, T.; Loures, L.; Castanho, R.A.; Aydin, E.; da Gama, J.T.; Loures, A.; Truchy, A. Relevance of Intermittent Rivers and Streams in Agricultural Landscape and Their Impact on Provided Ecosystem Services—A Mediterranean Case Study. Int. J. Environ. Res. Public Health 2019, 16, 2693.

27. Telo da Gama, J.; Rato Nunes, J.; Loures, L.; Lopez Piñeiro, A.; Vivas, P. Assessing Spatial and Temporal Variability for Some Edaphic Characteristics of Mediterranean Rainfed and Irrigated Soils. Agronomy 2019, 9, 132.

28. MEA. Ecosystems and Human Well-Being: Wetlands and Water; World Resources Institute: Washington, DC, USA, 2005; ISBN 1-56-973597-2.

29. World Bank. World Development Report 2008: Agriculture for Development; The World Bank: Washington, DC, USA, 2007; ISBN 978-0-82136-807-7.

30. Kumar, A.; Burdak, B.; Thakur, H.; Harshavardhan, S.; Nalamala, S. A Review on Role of Micro Irrigation for Modern Agriculture. Pharma Innov. J. 2023, 12, 2585–2589.

31. FAO. Status of the World's Soil Resources: Main Report; FAO: Rome, Italy, 2015; p. 648.

32. Loures, L.; Gama, J.; Nunes, J.; Lopez-Piñeiro, A. Assessing the Sodium Exchange Capacity in Rainfed and Irrigated Soils in the Mediterranean Basin Using GIS. Sustainability 2017, 9, 405.

33. Dominati, E.; Patterson, M.; Mackay, A. A Framework for Classifying and Quantifying the Natural Capital and Ecosystem Services of Soils. Ecol. Econ. 2010, 69, 1858–1868.

34. Lal, R. Soil Carbon Sequestration Impacts on Global Climate Change and Food Security. Science 2004, 304, 1623–1627.

35. World Bank World Development Report 2020: Trading for Development in the Age of Global Value Chains; The World Bank: Washington, DC, USA, 2019; ISBN 1-46-481457-0.

36. Runge, T.; Latacz-Lohmann, U.; Schaller, L.; Todorova, K.; Daugbjerg, C.; Termansen, M.; Liira, J.; Le Gloux, F.; Dupraz, P.; Leppanen, J.; et al. Implementation of Eco-schemes in Fifteen European Union Member States. EuroChoices 2022, 21, 19–27.

@2024 International Council for Education Research and Training
ISSN: 2959-1376
2024, Vol. 03, Issue 03, 265-285
DOI: https://doi.org/10.59231/SARI7734

37. Latacz-Lohmann, U.; Termansen, M.; Nguyen, C. The New Eco-Schemes: Navigating a Narrow Fairway. EuroChoices 2022, 21, 4–10.

38. Morgera, E. SDG 15: Protect, Restore and Promote Sustainable Use of Terrestrial Ecosystems, Sustainably Manage Forests, Combat Desertification, Halt and Reverse Land Degradation, and Halt Biodiversity Loss. In The Cambridge Handbook of Sustainable Development Goals and International Law; Cambridge University Press: Cambridge, UK, 2022; pp. 376–398.

39. Ueckerdt, F.; Bauer, C.; Dirnaichner, A.; Everall, J.; Sacchi, R.; Luderer, G. Potential and Risks of Hydrogen-Based e-Fuels in Climate Change Mitigation. Nat. Clim. Chang. 2021, 11, 384–393.

40. Redvers, N.; Celidwen, Y.; Schultz, C.; Horn, O.; Githaiga, C.; Vera, M.; Perdrisat, M.; Plume, L.M.; Kobei, D.; Kain, M.C. The Determinants of Planetary Health: An Indigenous Consensus Perspective. Lancet Planet. Health 2022, 6, e156–e163.

41. WHO. Sustainable Healthy Diets: Guiding Principles; Food & Agriculture Org.: Rome, Italy, 2019; ISBN 9-25-131875-1.

42. Hermoso, V.; Carvalho, S.B.; Giakoumi, S.; Goldsborough, D.; Katsanevakis, S.; Leontiou, S.; Markantonatou, V.; Rumes, B.; Vogiatzakis, I.N.; Yates, K.L. The EU Biodiversity Strategy for 2030: Opportunities and Challenges on the Path towards Biodiversity Recovery. Environ. Sci. Policy 2022, 127, 263–271.

43. Miu, I.V.; Rozylowicz, L.; Popescu, V.D.; Anastasiu, P. Identification of Areas of Very High Biodiversity Value to Achieve the EU Biodiversity Strategy for 2030 Key Commitments. PeerJ 2020, 8, e10067.

44. Mammola, S.; Riccardi, N.; Prié, V.; Correia, R.; Cardoso, P.; Lopes-Lima, M.; Sousa, R. Towards a Taxonomically Unbiased European Union Biodiversity Strategy for 2030. Proc. R. Soc. B 2020, 287, 20202166.

45. Lee, B.X.; Kjaerulf, F.; Turner, S.; Cohen, L.; Donnelly, P.D.; Muggah, R.; Davis, R.; Realini, A.; Kieselbach, B.; MacGregor, L.S. Transforming Our World: Implementing the 2030 Agenda through

@2024 International Council for Education Research and Training
ISSN: 2959-1376
2024, Vol. 03, Issue 03, 265-285
DOI: https://doi.org/10.59231/SARI7734

Sustainable Development Goal Indicators. J. Public Health Policy 2016, 37, 13–31.

46. EEA. The European Environment—State and Outlook 2020: Knowledge for Transition to a Sustainable Europe; EEA: Luxembourg, 2019.

47. FAO. Pulses: Symbiosis for Life; Food and Agriculture Organization: Rome, Italy, 2016.

48. Dorling, D. World Population Prospects at the UN: Our Numbers Are Not Our Problem? In The Struggle for Social Sustainability; Policy Press: Bristol, UK, 2021; pp. 129–154. ISBN 1-44-735612-8.

49. Collins, J.; Page, L. The Heritability of Fertility Makes World Population Stabilization Unlikely in the Foreseeable Future. Evol. Human. Behav. 2019, 40, 105–111.

50. Bongaarts, J. IPBES, 2019: Summary for Policymakers of the Global Assessment Report on Biodiversity and Ecosystem Services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services; Wiley Online Library: Hoboken, NJ, USA, 2019; ISBN 0098-7921.

51. Cassman, K.G.; Grassini, P. A Global Perspective on Sustainable Intensification Research. Nat. Sustain. 2020, 3, 262–268.

52. Xie, H.; Huang, Y.; Chen, Q.; Zhang, Y.; Wu, Q. Prospects for Agricultural Sustainable Intensification: A Review of Research. Land 2019, 8, 157.

53. Bangash, R.F.; Passuello, A.; Sanchez-Canales, M.; Terrado, M.; López, A.; Elorza, F.J.; Ziv, G.; Acuña, V.; Schuhmacher, M. Ecosystem Services in Mediterranean River Basin: Climate Change Impact on Water Provisioning and Erosion Control. Sci. Total Environ. 2013, 458–460, 246–255.

54. Nielsen, U.N.; Ayres, E.; Wall, D.H.; Bardgett, R.D. Soil Biodiversity and Carbon Cycling: A Review and Synthesis of Studies Examining Diversity-Function Relationships. Eur. J. Soil. Sci. 2011, 62, 105–116.

55. Jackson, L.E.; Pascual, U.; Hodgkin, T. Utilizing and Conserving Agrobiodiversity in Agricultural Landscapes. Agric. Ecosyst. Environ. 2007, 121, 196–210.

56. Newton, P.; Civita, N.; Frankel-Goldwater, L.; Bartel, K.; Johns, C. What Is Regenerative Agriculture? A Review of Scholar and Practitioner Definitions Based

on Processes and Outcomes. Front. Sustain. Food Syst. 2020, 4, 194.

57. Schreefel, L.; Schulte, R.P.O.; De Boer, I.J.M.; Schrijver, A.P.; Van Zanten, H.H.E. Regenerative Agriculture–the Soil Is the Base. Glob. Food Secur. 2020, 26, 100404.

58. Davis, K.E. Extension in Sub-Saharan Africa: Overview and Assessment of Past and Current Models, and Future Prospects. J. Int. Agric. Ext. Educ. 2008, 15.

59. Jarmul, S.; Dangour, A.D.; Green, R.; Liew, Z.; Haines, A.; Scheelbeek, P.F. Climate Change Mitigation through Dietary Change: A Systematic Review of Empirical and Modelling Studies on the Environmental Footprints and Health Effects of 'Sustainable Diets'. Environ. Res. Lett. 2020, 15, 123014.

60. Fanzo, J. Healthy and Sustainable Diets and Food Systems: The Key to Achieving Sustainable Development Goal 2? Food Ethics 2019, 4, 159–174.

61. Eme, P.; Douwes, J.; Kim, N.; Foliaki, S.; Burlingame, B. Review of Methodologies for Assessing Sustainable Diets and Potential for Development of Harmonised Indicators. Int. J. Environ. Res. Public Health 2019, 16, 1184.

62. Marín-Sanleandro, P.; Gómez-García, A.M.; Blanco-Bernardeau, A.; Gil-Vázquez, J.M.; Alías-Linares, M.A. Influence of the Type and Use of Soil on the Distribution of Organic Carbon and Other Soil Properties in a Sustainable and Resilient Agropolitan System. Forests 2023, 14, 1085.

63. Jones, A.; Panagos, P.; Barcelo, S.; Bouraoui, F.; Bosco, C.; Dewitte, O.; Gardi, C.; Erhard, M.; Hervás, J.; Hiederer, R. The State of Soil in Europe. JRC Ref. Rep. 2012, 78.

64. Telo da Gama, J.; Loures, L.; López-Piñeiro, A.; Nunes, J.R. Spatial Distribution of Available Trace Metals in Four Typical Mediterranean Soils: The Caia Irrigation Perimeter Case Study. Agronomy 2021, 11, 2024.

65. Panagos, P.; Borrelli, P.; Poesen, J.; Meusburger, K.; Ballabio, C.; Lugato, E.; Montanarella, L.; Alewell, C. Reply to the Comment on "The New Assessment of Soil Loss by Water Erosion in Europe" by Fiener & Auerswald. Environ. Sci. Policy 2016, 57, 143–150.

@2024 International Council for Education Research and Training
ISSN: 2959-1376
2024, Vol. 03, Issue 03, 265-285
DOI: https://doi.org/10.59231/SARI7734

66. Miháliková, M.; Dengiz, O. Towards More Effective Irrigation Water Usage by Employing Land Suitability Assessment for Various Irrigation Techniques. Irrig. Drain. 2019, 68, 617–628.

67. Prokop, G.; Jobstmann, H.; Schönbauer, A.; European Commission; Directorate-General for the Environment. Overview of Best Practices for Limiting Soil Sealing or Mitigating Its Effects in EU-27: Final Report; European Commission: Luxembourg, 2011; ISBN 978-9-27920-669-6.

68. Lacerda, N.B.D.; Lustosa Filho, J.F.; Blum, S.C.; Escobar, M.E.O.; Oliveira, T.S.D. Organic Matter Pools in a Fluvisol after 29 Years under Different Land Uses in an Irrigation Region in Northeast Brazil. J. Arid Environ. 2023, 208, 104861.

69. Bennett, E.M.; Peterson, G.D.; Gordon, L.J. Understanding Relationships among Multiple Ecosystem Services. Ecol. Lett. 2009, 12, 1394–1404.

70. Daniel, T.C.; Muhar, A.; Arnberger, A.; Aznar, O.; Boyd, J.W.; Chan, K.M.; Costanza, R.; Elmqvist, T.; Flint, C.G.; Gobster, P.H. Contributions of Cultural Services to the Ecosystem Services Agenda. Proc. Natl. Acad. Sci. USA 2012, 109, 8812–8819.

71. Montanarella, L.; Pennock, D.J.; McKenzie, N.; Badraoui, M.; Chude, V.; Baptista, I.; Mamo, T.; Yemefack, M.; Singh Aulakh, M.; Yagi, K. World’s Soils Are under Threat. Soil 2016, 2, 79–82.

72. Yu, C.; Han, F.; Fu, G. Effects of 7 Years Experimental Warming on Soil Bacterial and Fungal Community Structure in the Northern Tibet Alpine Meadow at Three Elevations. Sci. Total Environ. 2019, 655, 814–822.

73. Zhong, Z.; Fu, G. Response of Soil Fungal Species, Phylogenetic and Functional Diversity to Diurnal Asymmetric Warming in an Alpine Agricultural Ecosystem. Agric. Ecosyst. Environ. 2022, 335, 107993.

74. Lal, R. Sequestering Carbon and Increasing Productivity by Conservation Agriculture. J. Soil Water Conserv. 2015, 70, 55A–62A.

75. Minasny, B.; Malone, B.P.; McBratney, A.B.; Angers, D.A.; Arrouays, D.; Chambers, A.; Chaplot, V.; Chen, Z.-S.; Cheng, K.; Das, B.S. Soil Carbon 4 per Mille. Geoderma 2017, 292, 59–86.

@2024 International Council for Education Research and Training 2024, Vol. 03, Issue 03, 265-285
ISSN: 2959-1376 DOI: https://doi.org/10.59231/SARI7734

76. Emde, D.; Hannam, K.D.; Most, I.; Nelson, L.M.; Jones, M.D. Soil Organic Carbon in Irrigated Agricultural Systems: A Meta-analysis. Glob. Change Biol. 2021, 27, 3898–3910.

77. Kane, D.; Solutions, LLC. Carbon Sequestration Potential on Agricultural Lands: A Review of Current Science and Available Practices; National Sustainable Agriculture Coalition Breakthrough Strategies and Solutions, LLC.: Washington, DC, USA, 2015; pp. 1–35.

78. Masson-Delmotte, V.; Zhai, P.; Pirani, A.; Connors, S.L.; Péan, C.; Berger, S.; Caud, N.; Chen, Y.; Goldfarb, L.; Gomis, M.I. Climate Change 2021: The Physical Science Basis; Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change; IPCC: Geneva, Switzerland, 2021; p. 2.

79. Singh, B.P.; Cowie, A.L.; Chan, K.Y. Soil Health and Climate Change; Springer: Berlin/Heidelberg, Germany, 2011.

80. Bakó, G.; Molnár, Z.; Bakk, L.; Horváth, F.; Fehér, L.; Ábrám, Ö.; Morvai, E.; Biro, C.; Pápay, G.; Fűrész, A.; et al. Toward a High Spatial Resolution Aerial Monitoring Network for Nature Conservation—How Can Remote Sensing Help Protect Natural Areas? Sustainability 2021, 13, 8807.

81. van Oijen, M.; Bellocchi, G.; Höglind, M. Effects of Climate Change on Grassland Biodiversity and Productivity: The Need for a Diversity of Models. Agronomy 2018, 8, 14.

82. Bélanger, J.; Pilling, D. The State of the World’s Biodiversity for Food and Agriculture; Food and Agriculture Organization of the United Nations (FAO): Rome, Italy, 2019; ISBN 9-25-131270-2.

83. Goddard, L.; Gershunov, A. Impact of El Niño on Weather and Climate Extremes. In El Niño Southern Oscillation in a Changing Climate; Wiley: Hoboken, NJ, USA, 2020; pp. 361–375.

84. Abbass, K.; Qasim, M.Z.; Song, H.; Murshed, M.; Mahmood, H.; Younis, I. A Review of the Global Climate Change Impacts, Adaptation, and Sustainable Mitigation Measures. Environ. Sci. Pollut. Res. 2022, 29, 42539–42559.

85. Leisner, C.P. Climate Change Impacts on Food Security-Focus on Perennial Cropping Systems and

@2024 International Council for Education Research and Training
ISSN: 2959-1376
2024, Vol. 03, Issue 03, 265-285
DOI: https://doi.org/10.59231/SARI7734

Nutritional Value. Plant Sci. 2020, 293, 110412.

86. Gomiero, T. Soil Degradation, Land Scarcity and Food Security: Reviewing a Complex Challenge. Sustainability 2016, 8, 281.

87. Khatteli, H.; Ali, R.R.; Bergametti, G.; Bouet, C.; Hachicha, M.; Hamdi-Aissa, B.; Labiadh, M.; Montoroi, J.-P.; Podwojewski, P.; Rajot, J.-L.; et al. Soils and Desertification in the Mediterranean Region. In The Mediterranean Region under Climate Change: A Scientific Update; IRD Editions: Marseille, France, 2016; p. 14.

88. Spinoni, J.; Vogt, J.; Naumann, G.; Carrao, H.; Barbosa, P. Towards Identifying Areas at Climatological Risk of Desertification Using the Köppen–Geiger Classification and FAO Aridity Index. Int. J. Climatol. 2015, 35, 2210–2222.

89. Montanarella, L.; Scholes, R.; Brainich, A. The IPBES Assessment Report on Land Degradation and Restoration; Secretariat of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services: Bonn, Germany, 2018.

90. van der Esch, S. Exploring Future Changes in Land Use and Land Condition and the Impacts on Food, Water, Climate Change and Biodiversity: Scenarios for the UNCCD Global Land Outlook; PBL Publishers: The Hague, The Netherlands, 2017.

91. Sun, W.; Li, S.; Zhang, G.; Fu, G.; Qi, H.; Li, T. Effects of Climate Change and Anthropogenic Activities on Soil PH in Grassland Regions on the Tibetan Plateau. Glob. Ecol. Conserv. 2023, 45, e02532.

92. Zha, X.; Tian, Y.; Ouzhu; Fu, G. Response of Forage Nutrient Storages to Grazing in Alpine Grasslands. Front. Plant Sci. 2022, 13, 991287.

93. Zhang, H.; Fu, G. Responses of Plant, Soil Bacterial and Fungal Communities to Grazing Vary with Pasture Seasons and Grassland Types, Northern Tibet. Land Degrad. Dev. 2021, 32, 1821–1832.

94. Domenech, T.; Bahn-Walkowiak, B. Transition towards a Resource Efficient Circular Economy in Europe: Policy Lessons from the EU and the Member States. Ecol. Econ. 2019, 155, 7–19.

95. Amelung, W.; Bossio, D.; de Vries, W.; Kögel-Knabner, I.; Lehmann, J.;

Amundson, R.; Bol, R.; Collins, C.; Lal, R.; Leifeld, J. Towards a Global-Scale Soil Climate Mitigation Strategy. Nat. Commun. 2020, 11, 5427.

96. Eckert, E.; Kovalevska, O. Sustainability in the European Union: Analyzing the Discourse of the European Green Deal. J. Risk Financ. Manag. 2021, 14, 80.

97. Fetting, C. The European Green Deal; ESDN Report; ESDN: Vienna, Austria, 2020; p. 53.

98. Montanarella, L.; Panagos, P. The Relevance of Sustainable Soil Management within the European Green Deal. Land Use Policy 2021, 100, 104950.

99. Schebesta, H.; Candel, J.J. Game-Changing Potential of the EU's Farm to Fork Strategy. Nat. Food 2020, 1, 586–588.

100. Nicastro, R.; Carillo, P. Food Loss and Waste Prevention Strategies from Farm to Fork. Sustainability 2021, 13, 5443.

101. Husain, N. (2024). The essentiality of implementing curriculum and activities for gender education in present education system. *Shodh Sari*, *03*(01), 234–242. https://doi.org/10.59231/sari7668

102. Oredein, A. O. (2024). Differential Educational Attainment among Learners: Implications for Achieving Sustainable Development Goal Four. *Shodh Sari*, *03*(01), 31–46. https://doi.org/10.59231/sari7652

103. Hamza, S. (2023). Exploring transversal green skills required of technology graduates for environmental sustainability. *Shodh Sari*, *02*(04), 392–418. https://doi.org/10.59231/sari7647

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