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Editorial

Climate, Water, Soil

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1. Prolegomena

"Climate" is a complex concept. One definition is a recorded mean statistical noise of principal planetary heat exchanges, ranging from three decades or more to thousands of years, and starting to obtain a distinguishable trend in a wide range of spatial and temporal scales in response to changes in temperature, precipitation, and solar radiation. Today, in trying to disclose the mechanisms that drive the Earth's climate and its variation, we are faced with an exceedingly complex system that includes five fundamental physical components and their interactions (i.e., atmosphere, hydrosphere, cryosphere, lithosphere, and biosphere). It is a mistake to believe that we have reached the point where we can fully understand the complex relationships between all the processes of the Earth's climate.

The climate drives the hydroclimatic characteristics of an area, affecting the availability of natural resources, biodiversity, the functioning and services of ecosystems, and human health [1–6]. Certain areas, such as the Mediterranean basin or Africa, have a greater vulnerability to climate and water scarcity phenomena and may be at higher risk [7–10]; a recent study also suggested that Africa is the most climate-vulnerable continent, characterized by low economic, governance, and social adaptation readiness [11]. Moreover, areas with growing populations and increasing water and food demands put further pressure on natural resources and face additional economic consequences from climate variabilities [10,12]. These bring forward the need for a thorough study of the evolution of the climate, the adoption of updated adaptation practices and the improved management of natural resources and agricultural and natural lands, and the use of alternative water resources, according to sustainability rules and the protection of biodiversity, animals, and humans now and in the future [13].

This Special Issue "Climate, Water, Soil" in the Water Journal aims to identify and address the above issues and challenges. Overall, this SI covers specific scientific fields, categorized as climate change concept aspects, climate, land use impacts on water availability, the impacts of agronomic practices on GHG emissions and crop production, and the evaluation of environmental parameters as predictors of fauna. In addition, a section is devoted to knowledge gaps and challenges in the climate–crop-water–soil matrix, followed by an epilogue.

2. Main Contribution of This Special Issue

The main contribution of this Special Issue (SI) can be categorized into specific domains of scientific interest as follows.

2.1. Rethinking Climate, Climate Change, and its Relationship with Water

The study of Koutsoyiannis [14] revisits the notion of climate by using the available scientific knowledge, information from historical evolution, and the origin of these concerns, focusing on water resource issues and the connection between climate and water. In the discussion, it is argued that the modern definitions of the climate are seriously affected by

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an incorrect perception, developed during the two previous centuries, suggesting that the climate should be constant unless an external agent acts upon it. The study provides real-world data to expose large climatic variability and argues that the term “climate change” can be viewed as a pleonasm in defining climate, since the climate, like the weather, has been ever-changing. Overall, it is argued that, despite the theoretical approach, the investigations included in the study as well as the information and synthesis provided are mostly new.

2.2. Climate, Land-Soil Characteristics, and Land Cover/Use as Critical Drivers of Water Balance and Availability

The study of Martínez-Retureta et al. [15] deals with the effect of use/cover change and climate change on water resource availability. In this work, changes that occurred over time within two hydrographic watersheds, in the south–central zone of Chile, were recorded and assessed to predict future cover/use changes. Moreover, a specific forest expansion scenario was used based on Chilean regulations predicting watershed occupation increases. The authors also used a local climatic model, under the RCP 8.5 scenario, for specific periods, and applied the SWAT model, focusing on the watersheds’ hydrological response. Five scenarios were used to assess land use/cover and climate change effects as well as their interaction, highlighting the sensitivity of watersheds to climate-change-based impacts.

In this Special Issue, the study of Tzanakakis et al. [16] highlights the critical role of geomorphology and the geological setting of a specific area on the island of Crete, Greece, in water availability. It is shown that, despite the high precipitation, the area is suffering from low water availability due to hydrological basin characteristics (karsts) that redirect water away, favoring precipitation loss through runoff. To overcome the problem, the authors propose specific options such as the development of an integrated water management plan, improvements in the infrastructure and the use of water, and the consideration of alternative water resources.

The accurate determination of hydrological components and water balance is necessary to establish an efficient water resource management plan. The study of Kim et al. [17] uses the Hydrological Simulation Program—FORTRAN (HSPF) model for this purpose. The model is deficient regarding the runoff and infiltration calculation arising from the inherent limitations. However, the analysis of hydrological components suggested consideration of parameters representing the soil characteristics. They also suggest additional research focusing on parameters reflecting watershed characteristics.

The study of Miszuk [18] examines the impact of the atmospheric circulation on the climate–water balance in the Sudetes Mountains. The study uses meteorological data from the period 1981–2020, applying the Lityński classification and the Penman–Monteith equation for determining evapotranspiration, and showing an insignificant effect on the climate–water balance. However, an increase in the climate–water balance was observed under the eastern circulation, whereas a negative tendency was found in specific stations, reflecting the changes in the frequency of the circulation types. These findings could be useful in planning water management in the Sudetes Mountains.

2.3. Agronomic Practices as Drivers of GHG Emissions and Plant Species Response

Hossain et al. [19] conducted on-farm trials in Bangladesh to study the effect of different irrigation methods (i.e., wetting and drying irrigation vs. continuous flooding) on yield and CH_4 and N_2O emissions in paddy cultivations. It was found that the wetting and drying irrigation method decreased the CH_4 emissions, the intensity of GHGs, and the overall global warming potential by 41% as well as water-consumption-associated costs. Moreover, wetting and drying irrigation improved water productivity by 32%.

Kocięcka et al. [20] tested the foliar application of silicon fertilizer in interaction with the level of groundwater in a sub-irrigation system to study the effect on the yield of a three-cut meadow. A reduction in dry matter during the year due to silicon application was reported. Also, the level of groundwater, silicon, and improved soil moisture increased the number of plant species and biodiversity. Overall, it was shown that changes in moisture conditions can affect the biodiversity in grasslands and the effectiveness of silicon in meadows and pastures.

Finally, Marković et al. [21] studied and highlighted the detrimental effect of salinity on the morphological and aesthetic characteristics of zinnia (*Zinnia elegans* L.) and periwinkle (*Catharanthus roseus* (L.). It was shown that an increase in salinity level reduced the linear growth of zinnia and periwinkle, as indicated by measurements in flower number, plant height, branch and leaf number, total fresh and dry biomass, and root length, with a different pattern between species.

2.4. Environmental Parameters as Predictors of Fauna

The study of Dornik et al. [22] aimed to develop a validating frame for predictors of European crayfish distribution based on multiple descriptors of soil status, such as the depth to bedrock, coarse fragments, the sand/silt/clay content, bulk density, soil erosion potential, and others. These were used to predict the populations of different indigenous species (*Austropotamobius bihariensis*, *A. torrentium*, *Astacus astacus,* and *Pontastacus leptodactylus*) inhabiting riverbanks in Romania, highlighting soil properties as important drivers of crayfish species.

3. Knowledge Gaps and Challenges in the Climate–Crop–Water–Soil System

3.1. Factors Driving the Sustainability of Natural Resources and Human Health

3.1.1. The Growing Global Population and Natural Resource Management

The world population exceeded 8.00 billion in November 2022, up from 1.00 billion in 1800. That is, it took over two-hundred-thousand years of human prehistory and history for the human population to reach 1.00 billion, and only 222 years to increase eightfold, i.e., to increase from 1.00 to 8.06 billion [23]. The UN has predicted that the population will continue to grow, and estimates put the total population at 8.60 billion by mid-2030, 9.80 billion by mid-2050, and 11.20 billion by 2100. However, some academics outside the United Nations are developing various models of world population evolution and the factors that will cause downward pressures on population growth. In such a scenario, the population will peak before 2100 [24]. By 2050, an increase in global water demand of 20–25% from that of recent years will be evident, among other things. It is also estimated that one billion additional people will be added to those living under conditions of extremely high water stress. Finally, the possibility of finding water resources on another planet and migrating there seems to be an unrealistic prospect [24].

The unsustainable use of natural resources has resulted in severe environmental impacts and socio-economic consequences for people around the world [25,26]. The socio-economic impacts caused by the unsustainable production and consumption of resources are felt unequally throughout the world, thereby worsening inequality. It is the poorest people who are most directly dependent on natural resources for their livelihoods, and therefore most exposed to risk from damage to these resources.

3.1.2. Climate

An important issue is the fluctuations in the climate and their relation to natural phenomena. The Pacific Ocean warms up (El Niño) or cools down (La Niña) even more than usual, but these events have global ramifications. A typical El Niño causes drought in Indonesia, Australia, southern Africa, and India; rainy winters in southern California and dry ones in the Pacific Northwest; quiet hurricane seasons in the Atlantic but intense ones in the Pacific; and other consequences around the world. However, these natural phenomena should not be confused with other ideas [27]. Also, we must consider that water is the main element that drives the climate and not the opposite. Highlighting the stochastic character of the climate, its huge variability, and the strong role of water in the climate can help shake the prevailing views on roles and causality in climatic processes, which may currently be the reverse of the actual processes. In addition, the increase in population mainly in urban areas leads to an increase in flood events. Finally, the climate's well-known variability is in some way confused with climate change.

3.2. Need for Insights into the Interaction between Climate, Crops, Water, and Soil

Water drives climate, which in turn affects water balance and availability by affecting important hydrological processes, such as surface runoff, groundwater recharge, and river flow, driven by precipitation and temperature patterns, relief, soil-geological and land use characteristics, and applied anthropogenic practices [28–31]. Furthermore, the climate affects crops and biodiversity directly or indirectly by impacting soil properties (e.g., soil moisture, soil erosion, soil salinity, organic carbon availability, and shifts in soil microorganisms driving carbon and nutrient cycles) [32–34], concomitantly, affecting ecosystem functionality and climate footprint (Figure 1) [31,33,35]. Shifts in land use and application of other adaption practices may lead to further changes in hydrological and soil characteristics, and water quality and availability [36,37], affecting climate footprint and feeding back for another cycle of changes and critical issues, influencing ecosystems. The most important issues and challenges caused by the "circularity" or interactions within the climate-crop-water system as well as system regulators are shown in Figure 1. These issues and challenges affect ecosystem functioning and services requiring problem or site-specific adaptations by humans, shown also in Figure 1, supported by current policies, legislative framework, and guidelines. Below are discussed some insights into the interactions among GHGs, climate parameters, soil properties, and crop performances (e.g., water use efficiency (WUE)) highlighting the critical role of plant species and soil microorganisms. It is concluded that we need much more information to shed light on the mechanisms/processes behind the interactions occurring in the climate-crop-water-soil system, and under different circumstances and climate scenarios, to achieve better and site-specific adaptation measures and practices.

An important field of research is the response of crops to climate variability, such as water consumption–evapotranspiration, and water use efficiency (WUE). So far, contradictory results have been provided. For example, early studies dealing with climate change have related the elevated CO_2 concentrations with increased leaf and canopy photosynthesis, crop yield, reduced transpiration, and improvement of WUE [38,39]. But, this positive effect on WUE and crop yield could be eliminated due to floods or to intense droughts resulting in greater leaf area [40], heat waves and increased temperatures (near the upper limit for crops) that reduce WUE and crop yields, [41,42]. Also, the climate may produce indirect effects due to greater impacts of the spread of weeds, insects, and pathogens [43,44].

Increasing the CO_2 concentration in the atmosphere and its effects on carbon sequestration are questionable; contrary to increased microbial biomass and litter inputs that increase the organic matter in the soil, increased CO_2 may induce microbial activity [45] and decrease soil organic carbon. Similarly, an increase in temperature can induce the loss of soil organic carbon and cause shifts in populations and communities of bacteria and/or archaea and fungi [46,47]. A recent study reports shifts in more labile soil organic matter under increased temperature and elevated CO_2 [48]. By contrast, drought can reduce the decomposition of organic carbon, microbial biomass, and CO_2 production [46,49]. Moreover, the increase in temperature and rainfall patterns along with the increase in CO_2, alternated with drought and heat waves may accelerate the rocks and mineral weathering releasing nutrients that can stimulate soil microorganism and plant species growth, inducing carbon sequestration. On the other hand, the increase in soil microbial activity may decrease soil organic carbon, as mentioned above. The accelerated weathering of minerals may also lead to the dissolution and release of pollutants/contaminants impacting microbial activity, plant growth, and carbon and nutrient cycles [32]. Finally, freeze–thaw events may induce the microbial degradation of soil organic matter and induce nitrification processes [46,50]. We need more information under different climatic, geospatial, land use, and management circumstances to provide robust and safe conclusions. An example of a critical domain of research is the potential changes in population communities and activities of soil microorganisms, involved in carbon and nitrogen biochemical processes due to shifts in environmental conditions driven by changes in soil moisture, temperature, and crop response and interaction with soil (via crop residuals and root effect), and their interactions with the environment and climate.

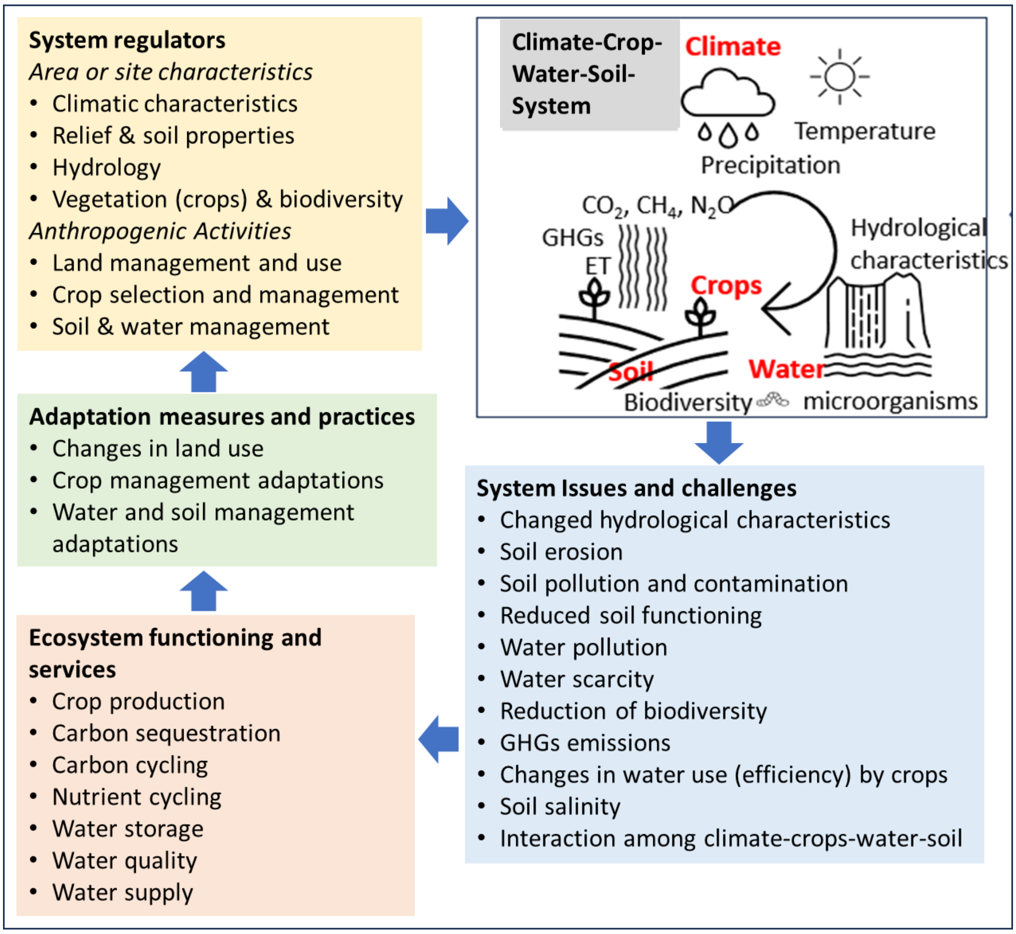

Figure 1. Conceptual illustration of the "circularity" and interactions occurring within the Climate, Crop, Water, Soil System, linked to critical issues-challenges, ecosystem functioning and services. and, subsequently, to adaptation measures and practices, as important system regulators.

The soil salinity effect, driven either by the climate (due to drought conditions) or by irrigation management, is another important issue. The salts cause toxicity phenomena, reduce water plant uptake, and impair soil microorganisms, impacting soil functioning and crop production [32,51–54]. Moreover, Na accumulation can degrade the soil structure, affecting the fate of water, nutrients, and carbon in the crop–water–soil-atmosphere matrix. Currently, these are of great concern and are targeted to connect the climate with the soil salinity status and its relationship with other stressors, soil and ecosystem functioning, and climate feedback (i.e., GHG emissions).

3.3. Resolving Prediction Deficiencies

There is considerable uncertainty regarding the prediction of the future impacts of the climate on natural resources, biodiversity, and humans, a fact that mainly arises from the deficiencies of applied methodologies [55,56]. For example, current climate/hydrological simulations at local scales may lack validity due to applied downscaling procedures and various assumptions [55,56]. The valid prediction of changes in soil erosion due to climate variability is still a challenge, an issue that is more critical in arid or semi-arid locations worldwide due to a lack of bias-corrected data for downscaling and other multivariate aspects [57]. Similarly, issues exist in modeling the plant species response and evapotranspiration due to several sources of uncertainty (e.g., lack of sufficient and valid data, errors related to the peak and low events, and low model accuracy) [58].

Biodiversity modeling faces several challenges due to the exclusion of certain biological mechanisms, such as the genetic and demographic evolution of species as well as future changes in species interactions, spreading, colonization, and other mechanisms and their interactions, all possibly driven by the climate [59]. For example, the latter means that changes in the way that humans use and affect natural resources are expected, driven by alterations in climate adaptation practices. This indirect effect may further interact with another factor, such as the growing population, suggesting impacts on natural resources and biodiversity [60,61] that should also be considered in the projections.

4. Epilogue

Climate variability leads to variables in weather patterns, including extremes. An easy way to remember the difference is that the climate is what you expect, like a hot summer, and the weather is what you actually experience, like a cool day in August. Our communities and farms are affected by shorter weather events. Their long-term sustainability is affected by the climate and climate variability is attributed to natural processes and human activities [62]. Over time, the weather forms the climate and influences the environment (soil, hydrology, plants, and animals), and the economic viability of our human systems.

The main messages of this editorial are:

(a) It is highlighted the complexity of the climate–crop–water–soil system as a critical driver of the quality of natural resources, water availability, and ecosystem functioning and services, controlled by spatial–temporal site characteristics, hydroclimatic regimes, and anthropogenic activities as critical system regulators.
(b) It is revealed the need to unfold the mechanisms/processes behind the interactions occurring across the system components under different circumstances and climate scenarios, to identify the potential consequences of this interaction on the status of natural resources and ecosystems, and shed light on the effect of anthropogenic management practices on the whole system (Figure 1).
(c) Future work should provide high-quality experimentation data, and conclusions from a wider range of climatic conditions, hydrologic regimes, agroecological zones, ecosystems, land uses, soil types, and management practices [63];
(d) Moreover, insights into the mutual relationship between the climate and the short- and long-term shifts in the hydrological cycle, such as those of Koutsoyiannis [14], vegetation attitude, biodiversity, microbiology, and (bio) chemical and physical properties of soils, as critical drivers of carbon, nutrient, and water cycles and climate footprint [63], are needed;
(e) We need, also, more stochastic and bias-corrected models for future predictions by incorporating all the known underlying processes, factors, and their interactions [30,55–57] as well as actions addressing legislation and policy issues;

These would provide the necessary information to develop improved assessment tools and build more accurate predictions, and to provide valid adaptation and mitigation decisions and practices, particularly for the climate-vulnerable areas of the planet [8].

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