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Effects of climate change on soil fertility

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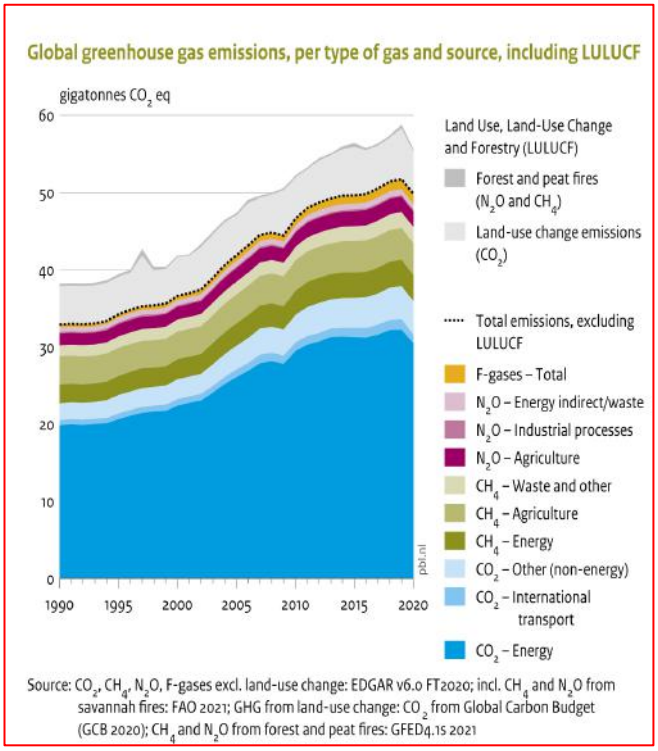
Introduction

According to the Intergovernmental Panel on Climate Change's (IPCC) most recent estimate, the average global temperature would likely increase by between 1.1 and 6.4 °C by 2090–2099 compared to temperatures between 1980–1999, with a rise between 1.8 and 4.0 °C being the most likely. The distribution and amount of precipitation that many places experience over the course of a typical year will shift as a result of climate change, which will also have an impact on global precipitation patterns. The environment, including the soil, will be impacted by this climatic change.

Factors causing climate change

1. Human factors: By emitting carbon dioxide and other greenhouse gases into the atmosphere, humans contribute to climate change. Today, there is more carbon dioxide in the atmosphere than there ever has been in at least the past 2 million years. The amount of carbon dioxide has been increased by 40% during the 20th and 21st centuries.
2. Transportation (27 percent of 2020 greenhouse gas emissions) - Fossil fuel combustion for our automobiles, trucks, ships, trains, and planes is the main source of transportation-related greenhouse gas emissions. Petroleum is the primary component of the more than 90% of fuel used for transportation, which generally consists of gasoline and diesel.
3. The combustion of fossil fuels, primarily coal and natural gas, produces about 60% of our power, accounting for 25% of 2020's greenhouse gas emissions.
4. Industry (24 percent of 2020 greenhouse gas emissions) - Industry is the main source of greenhouse gas emissions, which are mostly caused by the burning of fossil fuels for energy as well as some chemical reactions required to make things from raw materials.
5. Commercial and Residential (13 percent of 2020 greenhouse gas emissions) - Fossil fuels burnt for heating, the usage of specific products that contain greenhouse gases, and waste management are the main causes of greenhouse gas emissions from commercial and residential buildings.
6. Agriculture (11% of 2020 greenhouse gas emissions) - Rice production, agricultural soils, and livestock like cows all contribute to agriculture's greenhouse gas emissions.
7. Land Use and Forestry (13% of 2020 greenhouse gas emissions) - Land areas can operate as a sink (absorbing CO2 from the atmosphere) or a source of greenhouse gas emissions.



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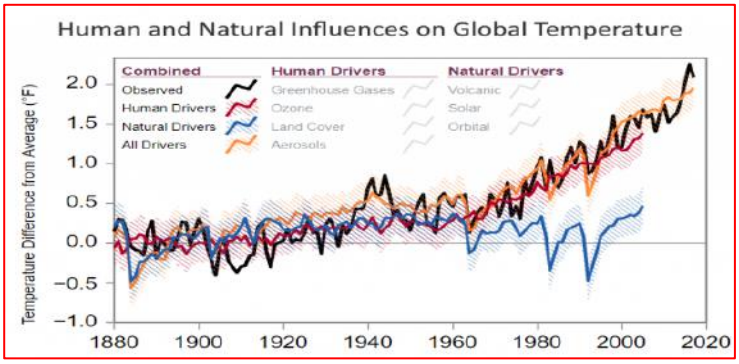
Natural causes

1. Changes in the Earth's Orbit and revolution
2. Variations in Solar Activity
3. Changes in the Earth's Reflectivity
4. Volcanic Activity
5. Changes in Naturally Occurring Carbon Dioxide Concentrations



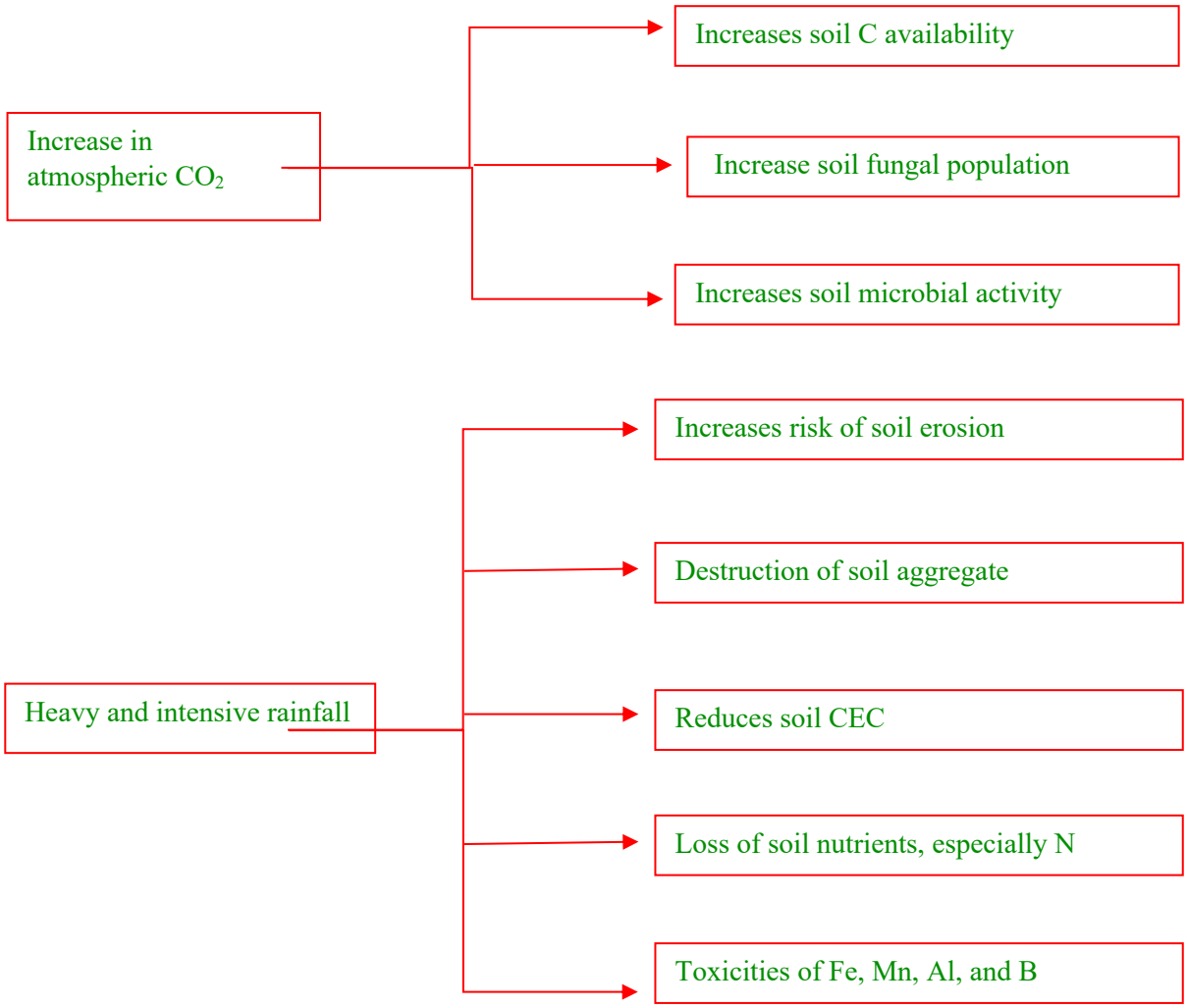
Effect of climate change on soil properties

Rise in temperature

- Deterioration of soil structure
- Increases risk of soil erosion
- Reduction of water retention capacity
- Increases rhizospheric temperature
- Salinization of soil

Decreased rainfall

- Increases salt content
- Soil moisture deficit
- Possibility of occurring drought
- Loss of nutrient from rooting zone
- Reduces N-fixation in legumes



Physical properties

1. **Soil texture**: Despite being a relatively stable soil attribute, soil texture is the main determinant of how well soil will adapt to local climate change. The regional climate fluctuations and the resulting changes in the capillary water transport from groundwater to the root zone have a significant impact on the seasonal soil moisture regime. Independent of plant cover, groundwater influence, and regional temperature change, silt soils are said to be the most susceptible to climate change, whilst clay soils are said to be the least sensitive.
2. **Soil structure**: Thunderstorms, severe rainfall, surface runoff, and water filtration all have an immediate effect on soil structure. Due to the vulnerability of soil macro fauna and microorganisms to climate change, soil biological function may also be indirectly impacted by climate change, which in turn may have an impact on soil structure.
3. **Soil porosity and bulk density**: The main factors affecting the soil's moisture and aeration condition are its structure, porosity, and pore size distribution. Therefore, any changes in porosity have a direct impact on the soil's ability to store water (via infiltration and water retention) and the amount of CO2 and CH4 that the soil may emit under aerobic and anaerobic circumstances, respectively. Scenarios for future climate change, including temperature increases, CO2 levels, and

variable and extreme rainfall events may affect soil porosity and pore-size distribution and consequently soil functions.

4. **Soil water retention capacity**: Climate change, particularly unpredictable and intense rain or drought, has a significant impact on the availability and distribution of soil water.

Chemicals Properties

1. **Soil pH**: Due to the direct effects of climate change, the pH value of the majority of soil is not anticipated to alter quickly. Additionally, as a result of climate change, changes in rainfall patterns brought on by tidal and seasonal variations may have an impact on soil pH.
2. **Cation exchange capacity (CEC)**: CEC is a critical factor in determining soil fertility, particularly in terms of the retention of the main cationic nutrients Ca, Mg, and K, as well as the immobilisation of potentially poisonous cations Al and Mn. Since CEC is related with the organic matter content in soil, a higher decomposition rate and decline in SOM due to rise in temperature results in a reduction of CEC of coarse-textured soils and low-activity clay soils.
3. **Soil salinization**: As temperature rise, evapo-transpiration rises as well, and as rain falls less frequently, so does the amount of salt that can be leached from the soil. The melting of glaciers on earth may cause sea levels to rise by 3 mm annually as a result of thermal expansion, which may hasten the salinization of agricultural fields and groundwater without any control.
4. **Nutrient cycle**: An essential factor in soil fertility is the nutrient cycle, particularly nitrogen, which is intimately related to the carbon and water cycles. Therefore, variables impacting the carbon cycle and water will eventually affect the amount of nutrients in the soil. The C and N cycle in soils may be altered by climate change, which causes soil acidification and, in turn, modifies the community structures of plants, animals, and microbes in many regions of the world. Ammonia volatilization, which happens as soil pH rises, lowers the amount of manure slurries and may cause eutrophication and soil acidification issues. An increase in global temperature may have a negative impact on how much carbon is allocated to the soil, which will increase the amount of CO2 that soils release into the atmosphere and reduce the amount of organic carbon in the soil, creating a positive feedback loop in the global carbon cycle.
5. **Soil fertility and nutrient uptake**: Variations in precipitation and air temperature have a significant impact on the temperature and moisture regime in the root zone, which primarily determines the availability of nutrients to plants, the growth and development of roots, the distribution of carbon to roots, and the regulation of nutrient uptake. The tendency of plants to more easily absorb water-soluble nutrients increases as the temperature rises, which raises transpiration rates. However, sufficient soil moisture is necessary for nutrient uptake. Higher temperatures reduce nutrient uptake induced by mass flow in the dry conditions.

Biological properties

1. **Organic matter**: In general, a rise in temperature speeds up the decomposition of organic matter in soil. As opposed to temperature increases, changes in soil moisture content brought on by climate change may have a greater impact on SOM decomposition in many ecosystems. When the soil moisture content is between 50 and 60 percent, the highest levels of microbial activity and SOM decomposition are

observed. The storage of soil organic carbon (SOC), which was found to decline with an increase in mean annual temperature, is also significantly impacted by global warming (MAT).

2. **Nutrient transformation in soil:** The biological transition of nutrients between organic and inorganic pools in soil may be significantly impacted by changes in moisture and temperature brought on by global climate change. The release of N and P from organic matter in bio-available forms may rise as a result of increased soil microbial activity brought on by increased temperature.
3. **Soil microbial biomass**: SMB is the living component of organic matter and the soil's most labile source of carbon. It is a good indicator of the size of the microbial community and the fertility of the soil. If water and nutrition availability are not restricting the development, warming or elevated temperature may stimulate microbial metabolism, their abundance, and nutrient cycling, particularly in temperate habitats. Temperature rise might also speed up soil respiration. Elevated carbon dioxide levels over a longer period may have a little direct effect on MBC.

Climate change adaptation and mitigation

Adaptation: Strategies that help people become more resilient to unpredictable and unfavourable changes in the climate. This can be accomplished by implementing conservation agriculture practises to maintain: Sufficient moisture, organic matter, nutrients in the soil by using zero tillage, mulching, crop rotation, avoiding monoculture, modifying the timing of agricultural operations, and applying the right amounts of inputs, such as irrigation, fertilisers, pesticides, etc., at the right time.

Mitigation: Attenuating the consequences of climate change through mitigation techniques entails lowering the atmospheric concentration of greenhouse gases: through establishing C sinks through soil C sequestration and preservation, through implementing better soil management techniques in agriculture, ensuring that fertiliser is applied at the proper rate and timing to minimise leaching and volatilization losses.

Conclusion

It is anticipated that the effects of global climate change would alter soil physical properties that affect soil fertility. These modifications may result in soil salinization, decreased nutrient and water availability, altered C and N dynamics and decreased soil biodiversity. The chemical characteristics of soil are mostly impacted by climate change's negative effects. Physical, chemical, and biological characteristics of the soil are closely tied to its biological characteristics, which in turn balance the soil's carbon and nutrient cycles and, ultimately, its fertility. Since the majority of soil functions, including pH, cation exchange capacity, water and nutrient retention, as well as soil structure, depend on soil organic matter, the fluctuation in its rate of decomposition as a result of global warming has a negative impact on the soil fertility. Thus, by implementing some of the adaptation and mitigation strategies such integrated nutrient management, residue management, conservation agriculture, etc., the negative effects of climate change on soil fertility can be reduced.

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