SOIL TESTING FOR CLIMATE CHANGE ADAPTATION

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Climate change is a long-term change in the average values of the meteorological elements such as precipitation and temperature. These long-term changes may be due to natural phenomena like volcanic eruptions, fluctuations in solar radiation, tectonic shifts, and even small changes in Earth's orbit, or anthropogenic activities based greenhouse gas (GHG) emissions. Main driver behind the increased emissions of GHGs is Industrial Revolution. IPCC (2023) reported that CO_2 emissions from fossil fuel combustion and industrial processes accounts for 64% of the global net anthropogenic GHG emissions and that from land use, land-use change, and forestry is 11%. Methane (CH_4) emission due to anthropogenic reasons is 18% and that of nitrous oxide (N_2O) is 4% while share of fluorinated gases is 2%. Considering various sectors in 2019, 34% (20 $GtCO_2$-eq) of the total net anthropogenic GHG emissions came from energy sector, 24% (14 $GtCO_2$-eq) from industry, 22% (13 $GtCO_2$-eq) from agriculture, forestry and other land use, 15% (8.7 $GtCO_2$-eq) from transport and 6% (3.3 $GtCO_2$-eq) from buildings.

China, the United States, India, the EU27, Russia, and Brazil were tagged as the six largest GHG emitters responsible for 61.6% of the global GHG emissions in 2022 (Crippa et al., 2023). Between 2010 and 2019, agricultural emission of CH_4 and N_2O are estimated respectively as 4.2 ± 1.3 and 1.8 ± 1.1 $GtCO_2$-eq yr^{-1}. Major sources of agriculture-based N_2O emissions are manure application, nitrogen deposition, and nitrogen fertilizer use; whereas agriculture-based CH_4 emissions are from enteric fermentation in ruminants, manure management and rice cultivation (Nabuurs et al., 2022).

IMPACT OF CLIMATE CHANGE EFFECTS ON AGRICULTURE

Climate change comes with direct and indirect impacts on agriculture activities and crop productivity. Increase in temperature, altered rainfall patterns, extreme weather events (such as floods, droughts, heat waves, cold waves, cyclones and storms), shortage of irrigation water, deteriorating soil and water quality, changing patterns of pest and disease infestations, and soil flora and fauna dynamics, intrusion of seawater onto land, and other climate change related biotic and abiotic stresses are the negative effects of climate change on agriculture though change in temperature and moisture regimes have few positive impacts on crop productivity.

Projections based on an ensemble of 21 climate model simulations, under a scenario of extreme warming, showed that world crop yields might be reduced by 3-12% by the middle of the century and by 11-25% by the end of the century, particularly for soybeans, maize, and winter wheat (Wing et al., 2021). According to the Ministry of Agriculture & Farmers Welfare (2023), projections shows that if Indian agriculture fail to adopt adaptation measures, climate change reduce rainfed rice yields by 20% in 2050 and 47% in 2080 scenarios, irrigated rice yields by 3.5% in 2050 and 5% in 2080 scenarios, wheat yield by 19.3% in 2050 and 40% in 2080 scenarios, and *kharif* maize yields by 18% in 2050 and 23% in 2080 scenarios. Climate change is also expected to lower the nutritional quality of produce.

Climate change has implications on soil fertility through its effect on soil structure, stability, soil compaction, loss of CO_2 from soil, etc. It also might lead to reduced feed availability and quality, heat stress, diseases brought on by outbreaks and weakened animal immune systems, and animal mortality from extreme weather events like storms, floods, heat waves, and cold snaps resulting in reduced animal production, welfare, and life expectancy (Godde et al., 2021).

ROLE OF SOIL TESTING IN MITIGATING CLIMATE CHANGE

Soil testing plays an important role in climate change adaptation as it helps stakeholders make informed decisions about efficient soil management practices. In India, soil testing was initiated during 1955-56 with the setting-up of 16 Soil Testing Laboratories under the Indo-US Operational Agreement. Subsequently, several new Soil Testing Laboratories were established to cater to the needs of the farmers. Currently, the country has 1284 static and 184 mobile soil testing laboratories, totaling1468 laboratories with an analyzing capacity of 11.786 million samples per year (FAI, 2022).

Soil testing helps farmers to assess the fertility status of their soils and the nutrient requirement to grow different crops in those soils, identification of problem soils, and select right recommendations for crop management. This allows quantification of crop nutrient requirements as per the nutrient-supplying capacity of soil, avoidance of excessive nutrient application beyond crop needs, and reduces the offsite transport of nutrient elements and the resulting environmental degradation. Soil testing is an important climate change adaptation strategy in agriculture due to the following reasons:

Assessing Soil Health: Soil testing provides insights into soil health indicators such as soil organic matter content, nutrient levels, pH, microbial activity and soil physical characteristics. To motivate Indian farmers in adopting soil test-based fertilizer recommendations, the Government of India has initiated Soil Health Card (SHC) scheme in the year 2015. The scheme helped in creating awareness about soil testing, soil health, and its importance in crop management among farmers. SHC has an added advantage over routine soil testing in terms of presenting information on soil health status as impacted by management practices, amelioration recommendations, and crop-specific fertilizer and manure recommendations (Purakayastha et al., 2019).

Optimum Nutrient Application: Fertilizer use in agriculture contributes to GHG emissions and global climate change mainly due to the emission of CO_2, N_2O, and CH_4 during their manufacturing phase and through various reactions after soil application. Soil test based nutrient use enhances crop productivity per unit land area, reduce overuse of fertilizers that in turn reduce GHG emissions associated with fertilizer use, and also prevent nutrient runoff and pollution of water bodies. Higher soil fertility helps developing climate resilience in crops. Evidences from China suggest that adoption of soil testing and formulated fertilization improved climate resilience of rice producers in central China (Liu et al., 2023).

Carbon Sequestration: Soil is the largest terrestrial carbon reservoir, containing more carbon than the atmosphere and vegetation combined. Soil testing supports carbon sequestration efforts by providing valuable information that could help to formulate strategies to enhance soil carbon storage. Soil carbon sequestration involves increasing soil organic carbon through practices such as cover cropping, reduced tillage, crop rotation and agroforestry. These practices improve water retention and nutrient cycling in soil, reduce soil erosion, enhance soil health & fertility and increase climate resiliency (Avasiloaiei et al., 2023).

CONCLUSION

Agriculture can act as a source and sink of GHG, and thus have strong implications on the global climate change scenario. Soil testing can aid in the judicious use of expensive chemical fertilizers, optimizing nutrient management, and carbon sequestration under field conditions, and thus form an indispensable tool for climate-resilient agriculture. However, soil testing has a greater impact when used in combination with other mitigation and adaptation strategies.

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