Developing a Research Agenda for the Caribbean Food System to respond to Global Climate Changes

Briefing Paper on Soil and Water
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Definitions

Soils normally consist of a solid phase, a gaseous phase and a liquid phase. The solid phase is the mineral soil particles and organic matter; the gaseous phase consists of soil air the composition of which varies from that of the atmosphere depending on the activity in the soil and the depth in the soil profile. The liquid phase is the soil water phase which is essential for many of the chemical and biological activities in the soil.

Water is defined here as all the water in excess of wilting point of plants i.e. water in excess of the wilting point of plants i.e. water in the soil for plant growth and water to satisfy the evaporation demand of the atmosphere whether the water is within the soil or outside the soil.

SOIL

Within a soil physical, chemical and biological activities occur.

Physical Activities

Mineral soil particles are relatively stable to climatic changes. It takes hundreds of years for mineral rocks to weather to form soil and it requires a temperature of greater than 600^0C for kaolinite to break down the sesquioxides of iron and aluminum.

Soil Organic Matter (SOM) the other solid phase constituent is readily changed by chemical and biological activity. SOM is important in soil fertility and aggregate stability or structure maintenance and is the single most important factor in soil rejuvenation. Temperature rise increases the rate of SOM decomposition and this would have a negative impact on soil fertility status.

Chemical Activities

The soil is a medium in which a wide range of chemical activities take place. Chemicals are ionized, adsorbed and desorbed from soil colloids, transformed, and react with other chemicals. These reactions much take place in the presence of water and the rate of reaction is temperature dependent. Generally, the rate of a chemical reaction doubles for every 10^0C rise in temperature.

The rate of plant growth and development is determined by a series of reactions in a chain and the rate is ultimately determined by the rate limiting step e.g. water availability and nutrient uptake. Therefore, as temperature increases the other reactions in the chain must also increase if plant growth is to benefit. If the other reactions in the chain do not increase an increase in temperature can adversely and significantly retard plant growth and development.

Biological Activities

A range of soil flora and fauna occupy the soil. The activities of these organisms are strongly influenced by temperature. A rise in temperature would increase the biological activities of these organisms resulting in:

- increased decomposition of SOM;
- increased Nitrogen, Nitrous oxide and carbon dioxide production; and
- decreased oxygen content of the soil (due to increased utilization by soil organisms).

Increased decomposition of SOM means greater release of N for plant growth but a faster degradation of soil aggregation and soil structure. Increased release of N_2O and CO_2 into the atmosphere adds to the greenhouse gases. Since oxygen in soil declines with depth and the soil eventually becomes anaerobic at some depth in the profile increased utilization of soil oxygen decreases the depth to anaerobic soil conditions and hence rooting depth.

WATER

The amount of water used by a crop comprises three components:

a) water for chemical and biological activities in the soil;

b) water for biological activities in the plant e.g. photosynthesis, production of assimilates, and translocation of nutrients and assimilates; and

c) water to satisfy the atmosphere or evaporation demand.

The third component is by far the greatest demand. It is so large that in computing water requirements for crop growth (or irrigation requirement) the other components are neglected.

The evaporation demand is determined by temperature, humidity and wind speed. As temperature increases, evaporation demand increases and more water has to be supplied to satisfy the demand. If adequate water were provided, plant growth would increase with increase in temperature up to the optimum temperature for the crop.

Water deficit is the difference between evaporation demand and the water available for plant growth. Crops have different sensitivities or tolerances to water deficits. In addition the tolerance varies with the stage of the crop. For example, sugar cane is more tolerant than banana to water stress. In fact, water deficit or water stress is actually needed at sugar cane ripening but not at the boom period of growth. In banana, 120-180 days after planting when the fruit is being formed and emerges from the leaf sheath is the most sensitive to water deficit. Because these requirements cannot be achieved under rainfed agriculture, irrigation is critical.

Crop water requirements (essentially the evaporation demand) are large. A hectare of a crop requires 30-50 cubic metres of water daily to satisfy the demand. The value increases with temperature and wind speed and decreases with humidity. Although we can compute "ball park" figures, we have not been able to determine the figures accurately for the Caribbean because some of the parameters for the various crops are not known.

While precipitation has increased in the high latitudes of the Northern Hemisphere, it has declined after the 1960's over the subtropics and tropics (Climate Change 1995). This decline should not be critical for us in the humid or wet and dry topics because the total annual precipitation is more than adequate to meet the demand if we can harness and store sufficient quantities of water. However, it becomes important in a rainfed system of agriculture.

There have been some predictions of possible yield decline of crops caused by increase in temperature and the consequent increase in water deficits. Jones and Wigley (1990) have reported that global mean temperature has risen by about 0.5^0C over the last 100 years, while Singh (1997) has reported that the mean temperature rise I the Caribbean seems somewhat higher approaching 1^0C. He used models which estimated losses in sugar cane yields from 42 t ha^{-1} to $54ha^{-1}$ through moisture stress (Singh and El Maayar 1998). These estimates seem very high for a 1^0C change in temperature but the important point here is that the losses can be significantly reduced or eliminated if irrigation is provided.

References

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