Technical note 8.

What is Soil Productivity?

In agronomics, soil productivity is the expression of crop yield from the soil-plant-atmosphere domain. Mineral fertility plays a key role in soil productivity. But a fertile soil is not necessarily a productive soil! Drainage, weeds, insects, disease, drought, exposure, and related stress may down rate productivity even though mineral fertility is optimal. To convert a fertile soil to a productive soil we must *understand* the forces that stimulate productivity and, *how* to manage them to ensure that the soil remains productive.

Which soil do you prefer?

If we plant a seed in the ground and it fails to germinate or, the new seedling looks unthrifty or even dies after germinating, we are often at a loss to explain why this happens. There are many potential biotic (living) and abiotic (non-living) culprits to interrogate. The basis of soil productivity can only be understood in terms of a dynamic balance of co-incident growth-promoting and growth-limiting forces within the soil-plant-atmosphere domain. Soil is a three-phase system composed of solids, gases, and liquids. The solid phase includes sand, silt, clay and, usually a small percentage of organic matter in the form of humus and microbes. Oxygen (O_2), carbon dioxide (CO_2), and nitrogen (N_2) make up most of the gas phase. The liquid phase is water plus dissolved nutrients, which we call the *soil solution*. Now, we must *understand* that a balance should be struck among the solid, liquid, and gas components for the soil to sustain high productivity. Too many solid particles in each volume of soil, for example when soil is compacted, comes at the expense of air. Similarly, when water enters the soil, it does so at the expense of air. Living soil must inhale and exhale, just like humans. Without oxygen, normal, healthy, metabolism cannot proceed in the plant's rooting system. For plants, not having enough air in the soil induces an effect akin to suffocation. On the other hand, adding too much air to the soil, for example when soil is over-cultivated, comes at the expense of water. Loose soil drains quickly because there are many large pores through which water may percolate. Water is pulled deep down in the soil profile by gravity or, under saturated conditions, may evaporate away from the surface to the atmosphere. In loose, sandy, non-irrigated soil, the lack of plant available water is the principal factor limiting plant growth. Further, oxygen in the atmosphere serves as the fuel for micro-organisms decomposing organic matter. Too much air in the soil volume makes a difficult job of increasing organic matter levels. Poor soil conditions, like those above, often are the heart of agronomic problems directly related to productivity.

Sunlight and optimum air-soil temperature are external forces that sustain plant growth. The non-mineral nutrients carbon (C), hydrogen (H), and oxygen (O) are the backbone of the plant. They comprise 95 percent of the basic structure of all plants and account for most of their bulk dry weight or "biomass". The nutrients C, N, O needed by plants are obtained from air and water. As such, low supply of carbon dioxide, water, or light will reduce plant growth.

This picture may look complicated, but we have control over many things, for example:

- Supply of mineral nutrients can be controlled to ensure they are available in the right quantity, at the right time and place to satisfy plant demand.
- Soil moisture can be controlled through irrigation and drainage or management practices that improve water capture, infiltration and plant use efficiency.
- Physical condition of the soil can be manipulated by timely cultivation with the *right* tillage tools to provide the best possible rooting environment.
- Good agronomic practice fosters efficient space utilization, while effective weed control insures that the crop growing "table" does not become overcrowded with unwanted guests.

- Insects and disease can be controlled through rotation, time of planting, selection of resistant crop cultivars, and failing these, pesticides.

- Nutrient holding capacity of infertile soils can be enhanced by return of crop residues, cover crops, and applications of manure to boost organic matter content.

This leaves sunlight and temperature as the only wildcard variables. Although we have no control over weather, it's possible to exploit topography by growing warmth-loving plants facing a southern exposure to maximize temperature and sunlight. Plants thriving in cool soil and air temperature would be a natural choice facing North.

There are, in fact, unlimited ways to harness the soil's productivity potential by tapping human ingenuity that is coupled with science-informed, sound agronomic practices. The technical details may seem complicated at times, but the action we take when we *understand* is straight-forward and purposeful.

Innovative water management practices like drip irrigation ensures precision placement of water via in-line emitters (inset above). Since water is applied in precise quantities directly to the soil, drip irrigation reduces evaporation and boosts water use efficiency.

Desert soil, above, may look unpromising as a growth medium. Many arid lands, under good management are, in fact, able to support high levels of plant production.

Chinampas, or floating gardens (above), were constructed by building up fields in the shallow basin of Mexican lakebeds by the Aztecs ca, AD 1150-1350. This type of innovative construction helped overcome the major limits to agriculture production in this environment: variable rainfall, frosts, and soil fertility. The proximity of the field surface to the water table provides adequate soil moisture for crops, today known as "subirrigation". The water also buffers night time temperatures, reducing the chance of frosts. In the past, soil fertility was maintained by adding vegetation, household refuse, and nutrient-rich silt dredged up from the canals to the field surface.

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