Technical note 8.

What is Soil Productivity?

In agronomics, soil productivity is the expression of crop yield from the soil-plant-atmosphere realm. 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 impact 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 emerged seedlings look unthrifty or even die soon after, 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 realm. Soil is a three-phase system composed of solids, gases, and liquids. The solid phase includes sand, silt, clay and, 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, called the *soil solution*. Now, we must *understand* that a balance should be maintained among the solid, liquid, and gas components for the soil to sustain high productivity. Too many solid particles per volume of soil, for example when soil gets 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 a constant supply of oxygen in the rooting zone, plant metabolism normally cannot go on. 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 cultivated repeatedly, 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 makes a difficult job of increasing organic matter levels. Poor root zone conditions, like those above, are the heart of myriad agronomic problems directly related to soil 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 cultural practices: rotation, time of planting,

selection of resistant crop cultivars alone, or combined with 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.

The remainders, sunlight and temperature, are the only wildcard variables. Although we have no control over the 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, infinite ways to harness the soil's productivity potential by tapping human ingenuity coupled with science-informed, sound agronomic practices. The technical details may seem complicated at times, but the actions taken when we *understand* are straight-forward and purposeful.

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

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.

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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