Technical note 8.

What is Soil Productivity?

In agronomics, soil productivity is the expression of total crop yield from the soil-plant-atmosphere continuum. Mineral fertility plays a key role in soil productivity. But a soil rich in mineral fertility is not necessarily a productive soil! Drainage, weeds, insects, disease, drought, exposure, genetics, and other factors may adversely affect total yield even though the soil's mineral fertility is charged to optimum levels. To convert a fertile soil to a productive soil we must *understand* the forces that stimulate productivity and, *how* to manage them to ensure the soil remains productive.

Which soil do you prefer?

Consider this: If we plant a seed in the ground and it fails to germinate or, the emerged seedling looks unhealthy or dies soon after, the reasons behind these events often seem capricious or baffling. How do we explain them? 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 growth-promoting and growth-limiting forces within the soil-plant-atmosphere continuum. Soil is a three-phase system composed of solids, gases, and liquids. The solid phase includes sand, silt, clay and, a small fraction 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 consists of water plus dissolved nutrients, called the *soil solution*.

Now, we must provide that the different phases in the soil are balanced to sustain productivity. Too many solid particles packed in a 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. Similarly, living plants and microorganisms must be continuously supplied with oxygen otherwise they will suffocate and eventually die off. On the other hand, adding too much air to the soil comes at the expense of water. Loose, sandy soil drains excessively because there are many large pores to conduct water away via gravity. The supply of plant-available water in terrestrial agro-ecosystems is the dominant factor affecting soil productivity, worldwide. Furthermore, oxygen in the atmosphere serves as the fuel for microorganisms decomposing organic matter. Too much air in the soil makes a difficult (if not impossible) job of increasing organic matter levels. A poorly conditioned soil-plant-atmosphere explains, more often than not, the myriad of agronomic symptoms surrounding low or marginal productivity.

Sunlight, and air and soil temperature are external agents that also affect plant growth. The non-mineral nutrients carbon (C), hydrogen (H), and oxygen (O) make up the physical structure of the plant. They comprise roughly 95 percent of terrestrial plants, accounting for most of the bulk dry weight or "biomass" produced. The essential nutrients C, H, O are taken directly from the air and water by plants. As such, the supply of gases like carbon dioxide in the atmosphere also affect productivity.

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, from the right source, at the right time and place to satisfy plant demand (the "4Rs").
- Soil moisture can be controlled through irrigation and drainage or management practices that improve water capture, infiltration, and plant nutrient utilization.
- Physical conditions in the soil can be manipulated by timely cultivation with the *right* tillage tools to provide the optimal rooting environment.
- Good agronomic practices foster efficient space utilization, while effective weed control ensures 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 and water holding capacity in the soil can be enhanced by recycling crop residues, planting cover crops, and the application of animal manure or compost to improve organic matter content.

That leaves sunlight and temperature as 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 light and thermal conductance. Conversely, a north-facing slope would be a natural choice to mitigate the effects of excessive exposure. Trenches can protect frost-sensitive plants, allowing citrus plantations to flourish even in **freezing temperatures**.

There are, in fact, infinite ways to harness soil productivity by combining human innovation 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.

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 improves water use efficiency.

Desert soil in Arizona above, may look unpromising as a growth medium. But many arid and semi-arid lands under good management are, in fact, capable of supporting high levels of plant production.

Chinampas, or floating gardens pictured 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 nighttime 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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