What is Soil Productivity?

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 other factors may cut production even when mineral fertility is high. To convert a fertile soil to a productive soil we must understand the factors that stimulate productivity and, how we can manage these factors to ensure that the soil remains productive.

If we plant a seed in the soil and it fails to germinate or dies soon after germinating, we are often at a loss to explain why this happens. There are many possible biotic (living) and abiotic (non-living) culprits to examine. The basis of soil productivity can only be understood in terms of a dynamic balance of growth-promoting and growth-limiting factors co-existing in the soil-plant-water-microbe realm. 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 (O₂), carbon dioxide (CO₂), and nitrogen (N₂) 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 has to be struck among the solid, liquid, and gas if soil is to support a high level of productivity. Too many solid particles in a given volume of soil (as happens when we compact soil) comes at the expense of air. Similarly, when water enters the soil, it does so at the expense of air. Soils must inhale and exhale, just like humans. Without oxygen in the soil, the function of roots is severely limited. In plants, lack of soil air induces an effect similar to suffocation. On the other hand, adding too much air to the soil (as happens when we do a lot of tillage) comes at the expense of water. Loose soil drains quickly because there are many large pores through which water may percolate. It can be pulled deep down in the soil profile by gravity or, under saturated conditions, evaporated to the atmosphere. In loose sandy soil, water is often the most limiting factor to plant growth. Further, the oxygen in air serves as the fuel which microorganisms use to decompose organic matter. Too much air at the expense of solids and liquids makes it difficult to increase organic matter levels in the soil. All of these extremes have a negative effect on soil productivity.

Sunlight and optimum air-soil temperature are external factors necessary for 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 are obtained by plants from air and water. Insufficient carbon dioxide, water, or light will reduce plant growth.

This picture may look complicated, but in reality there is much that we have control over. 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 conditions in the soil can be managed 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. We can’t control them, but it’s possible to exploit topography by growing warmth-loving plants on a southern exposure to maximize temperature and sunlight. Plants that do well in cooler soil would be a natural choice for a north-facing slope.

Thus, we have many options to exploit when it comes to harnessing the soil’s productivity potential. In fact, the list of possibilities is limited only by human ingenuity. With science-informed, sound agronomic practices, we can make the soil both fertile and productive. 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.

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.

Desert soil may look unpromising as a growth medium but in reality many arid lands support high levels of plant productivity.