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Soil Nutrients (Nitrogen, Phosphorous, and Potassium) Related to Type of Parent Material

Abstract:

Factors such as parent material, soil texture, rate of erosion, climate, biota, electrical conductivity, porosity, etc. all can determine the amount of nutrients in any given soil. While it can be difficult to tell which of these factors is the main contributor to soil nutrient fertility, my hypothesis is that the original material that makes up the soil (the parent rock and the minerals/ elements it is composed of) is the primary influencing factor when it comes to soil nutrient content and that felsic rocks would produce more nutrient-rich soil than mafic rocks. By taking soil samples from around the Colorado Rocky Mountain area, identifying their parent rocks, and testing them for nitrogen, phosphorous and potassium (NPK) levels, I tried to correlate parent rock type with the amount of nutrients in the resulting soil. However, my results were inconclusive and this leads me to believe that I underestimated the combined effects of the previously mentioned factors. Through more in-depth research of similar studies I also found that mafic rocks (due to their richness in cations, macronutrients other than NPK, and their propensity to weather at faster rates) are in fact generally more likely to produce more nutrient-rich soils. Similarly, extrusive rather than intrusive parent material is more likely to produce nutrient-rich soils because of its inherently fine-grained nature due to quick cooling (crystals don't have time to form).

Introduction:

There are many different factors affecting the amount/type of nutrients in soil. These factors include the parent material itself, which is weathered until macronutrients such as nitrogen, phosphorous, and potassium are released into solution in the soil. For instance, sedimentary material has been found to produce soil regimes with a more nutrient-rich subsoil because sedimentary material is, by definition, more weathered than igneous and metamorphic rock. This means that it has a finer, more clay-like texture and is therefore more likely to retain moisture and nutrients. Sedimentary bedrock is also more porous than igneous or metamorphic rock (since it has already been weathered and re-lithified) and is therefore more susceptible to many types of erosion, especially water-related erosion (Grider et al).

Since weathering itself is such an important factor in soil nutrient content, it follows that time, climate, and topography also have an effect on soil fertility. The older a rock is and the more exposed it is to harsh weather or the chance of falling from steep cliffs, etc. the more likely it will erode into a soil capable of retaining nutrients. These factors essentially initiate a domino effect of other factors such as rate of erosion and soil texture, which directly correlate with the stages of development a soil must go through before it reaches fertility (Bern 85).

While organic material can also contribute greatly to a soil's nutrient content (such as the presence of nitrogen-fixing organisms), there usually needs to be nutrients already present in the soil before these biotic factors can thrive (Curi 155). Therefore, if there is a higher content of other macronutrients that originate from the weathered bedrock, biotic organisms are more likely to thrive and contribute to nitrogen and/or other organically-derived nutrients within the soil.

The basis of my hypothesis is that as rock erodes into finer material, the nutrients within that rock are leeched into the resulting soil, and it follows that the type of parent rock that the soil originated from should have a significant effect on the nutrient levels in the soil. Looking at the chemical/elemental formulas of certain felsic vs. intermediate vs. mafic minerals in the Colorado Rocky Mountain area, I will determine which parent rocks endemic to these areas will yield soil more rich in nitrogen, phosphorous, and/or potassium. Furthermore, my hypothesis is that felsic parent material will produce more nutrient-rich soil than mafic parent material because the common felsic rocks in the area are mica-rich and micas are both easily weathered and their elemental formulas are rich in potassium. The presence of a macro-nutrient such as potassium may be enough to trigger other biotic and abiotic processes, which would with time, introduce other nutrients into the soil and ultimately produce a more overall fertile soil.

Materials and Methods:

Using a 6-inch long trowel, three opportunistically chosen soil samples were taken from from three different sites within Rocky Mountain National Park and Cal-Wood Education Center (camp). The type of likely parent rock (chosen because of proximity to prominent outcrops and by mineral particles within soil) associated with each soil sample was recorded. While these samples were laid out to dry, the texture of the soil was recorded and the larger rocks within the soil were more closely examined to confirm the most likely parent rock from which the soil originated. Each sample was then sifted until only silty material was left and tested with an NPK kit for low, medium, or high levels nitrogen, phosphorous, and potassium.

Results:

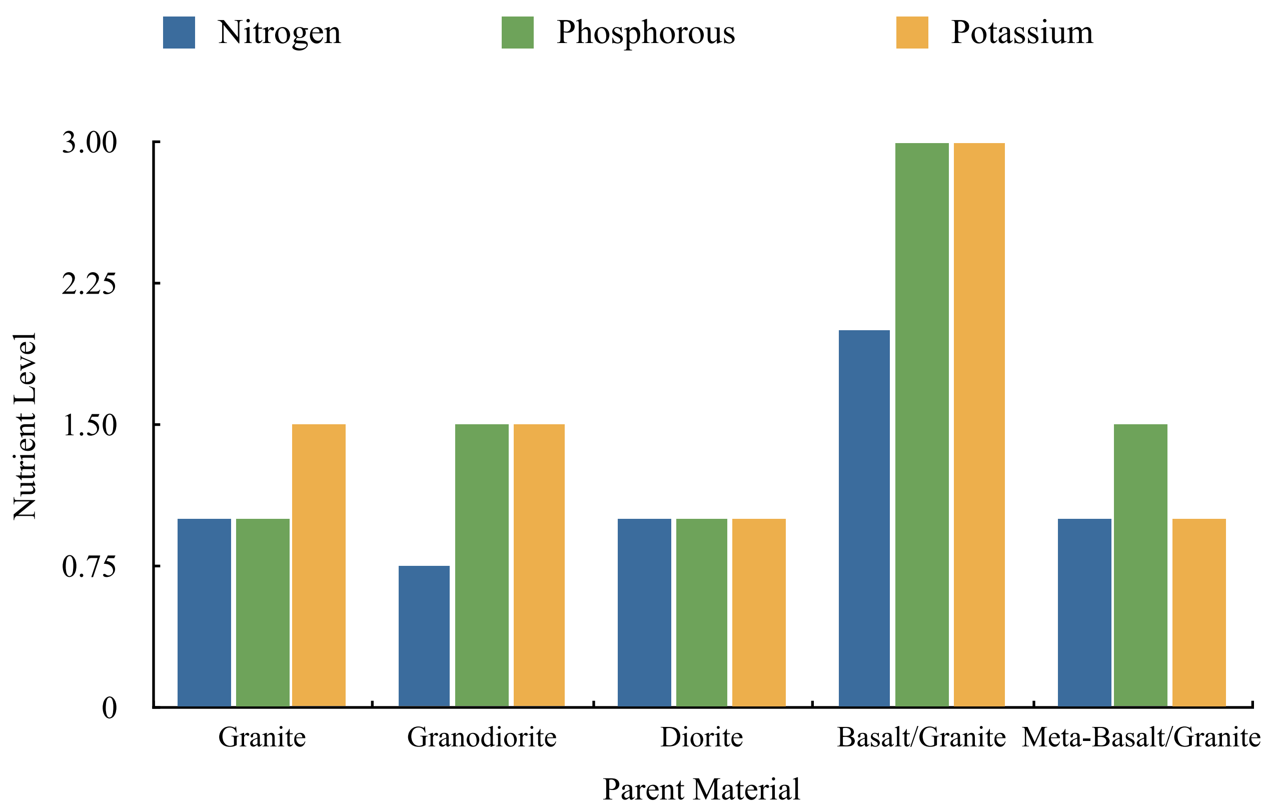

Figure 1: Bar graph of Nitrogen, Phosphorous, and Potassium levels (1=low, 2=medium, 3=high) related to type of parent rock.

There seems to be no significant trend in nutrient levels related to parent material. The soil with the least amount of nutrients was derived from a dioritic parent rock (which is intermediate on the felsic-mafic scale). The most nutrient-rich soil came from both basaltic and granitic material, while other material composed of basalt and granite yielded fairly low nutrient levels). Even looking at individual nutrients, there does not seem to be a forthcoming trend (Figure 1).

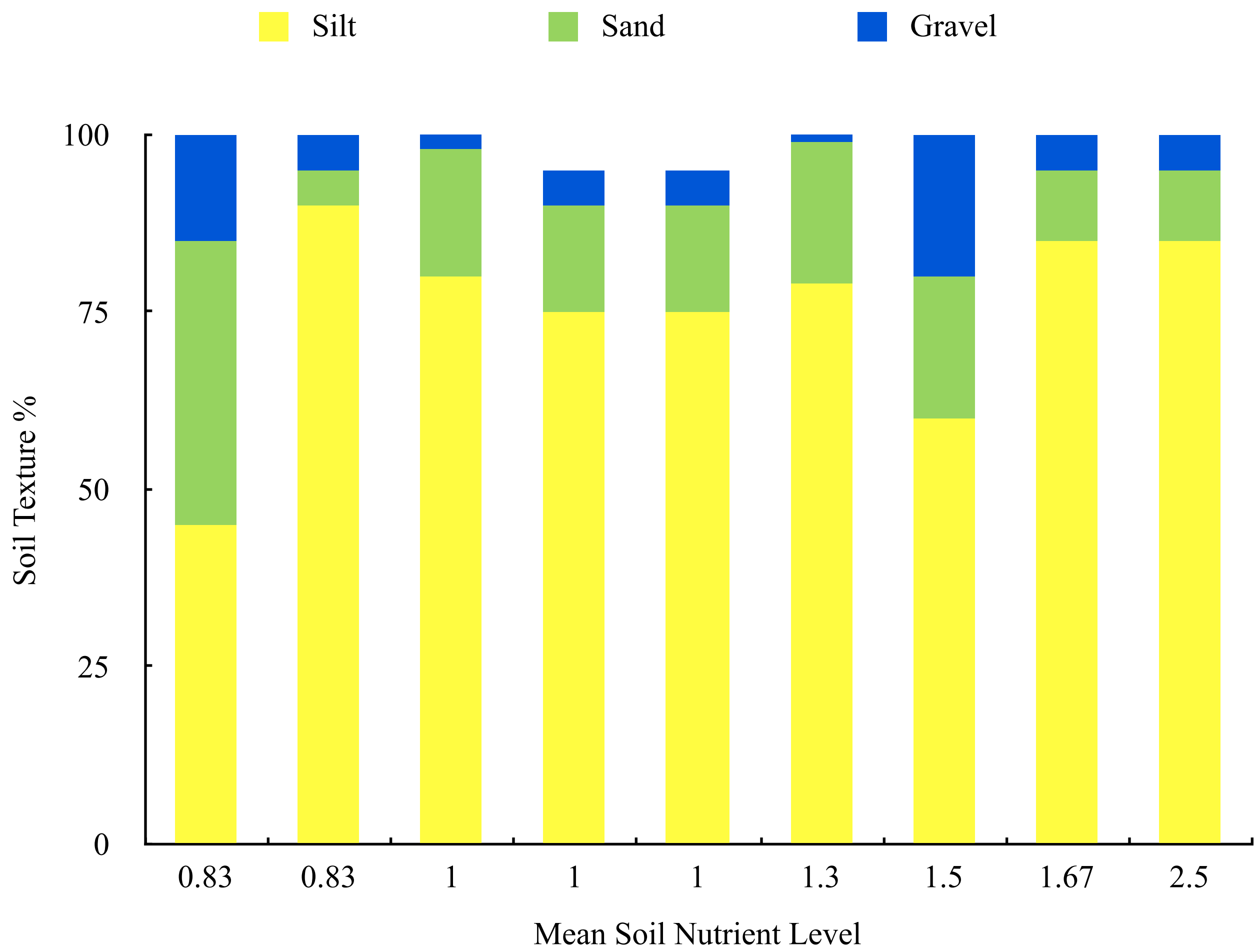

Figure 2: Stacked bar graph of soil texture content, categorized by the mean level of combined nutrients (nitrogen, phosphorous, and potassium).

Soil texture related to mean nutrient levels, while not showing a particularly strong correlation, seems to indicate that a higher content of finer soil texture correlates with higher overall soil fertility. The second and seventh bars seem to be outliers to this particular trend (Figure 2).

Discussion:

While soil fertility can be greatly influenced by the type of parent rock it was weathered from, this is usually because of the different weathering characteristics of the rocks themselves, not necessarily because of the chemical formula of the actual minerals within these rocks (although parent rock is supposed to have a significant effect on phosphorous and silica content) (Goldsmith 62). While these elements can be released from the minerals into the soil, the amount of nutrients within the soil usually has more to do with how well that soil can obtain and retain nutrients, which has more to do with soil texture. Mafic rocks tend to produce more fertile soil because they are less resistant to weathering than felsic rocks (Curi 154). This in turn produces more loamy and clay-rich (often referred to as kaolinite or smectite) soil that is better able to retain moisture and therefore better able to retain nutrient-rich solutions. Mafic rocks are also more rich in cations, such as magnesium and calcium which are other important macro-nutrients that relate to how fertile a soil will be (Systra 45).

Extrusive, rather than intrusive rocks are also more likely to produce nutrient-rich, fertile soil because magma that has cooled within the earth (intrusively) has more time to grow larger crystals that will be harder to break down (Hamdan 222). An example of this would be granite (an extrusive felsic rock) vs. basalt (an intrusive mafic rock). Granites generally contain larger, harder crystals such as quartz, plagioclase, and feldspar that are difficult to erode. Therefore, granites usually weather into more sandy soils (even in a high-energy environment such as a beach, and beach sand is notorious for being not very fertile) (Hamdan 225). Basalt, on the other hand is already fine-grained due to its extrusive nature, and because it contains mafic minerals which are higher on Bowen's Reaction Series, it is more susceptible to erosion (Figure 3). This gives it a chance to start 'collecting' nutrients sooner and allows it to become a finer-grained soil more quickly with the ability to retain more moisture and therefore, nutrients.

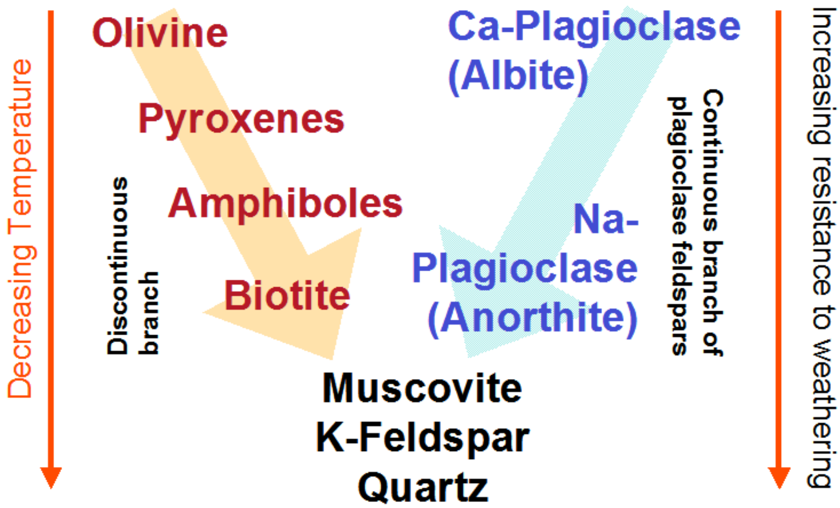

Figure 3: Bowen's Reaction Series which shows the order in which certain minerals form out of magma and the order in which they erode more easily. It also indicates silica content as well as other physical properties of how crystals form (Pal 2).

Basic sources of error in my methods could include insufficient sample size, insufficient variety of parent rocks (for instance, I had no sedimentary samples), as well as the fact that it was very difficult to conclusively associate a soil sample with a percent value of parent material that the soil was derived from. There are also a multitude of other important macro-nutrients besides nitrogen, phosphorous, and potassium that I did not get the chance to measure and that could have indicated different levels of fertility in my soils.

Another unforeseen factor that could have effected my experiment was electrical conductivity in the soil, which is know to be a prevalent factor in soil fertility (Ogundele 67). Lightning is known to be a source of nitrogen-fixing and it just so happens that the soil with the most overall nutrients (Figure 1) was located on a hill where lightning activity has been know to be concentrated (numerous trees in the area have lightning scars and there is evidence of fires originating from lightning strikes).

However, the main problem with my experiment was there are so many other factors influencing soil nutrient richness. I would have to conduct a manipulative experiment or make sure all other factors were the same before truly comparing the effect of weathering different parent rocks on the resulting soil nutrient levels.

Works Cited:

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