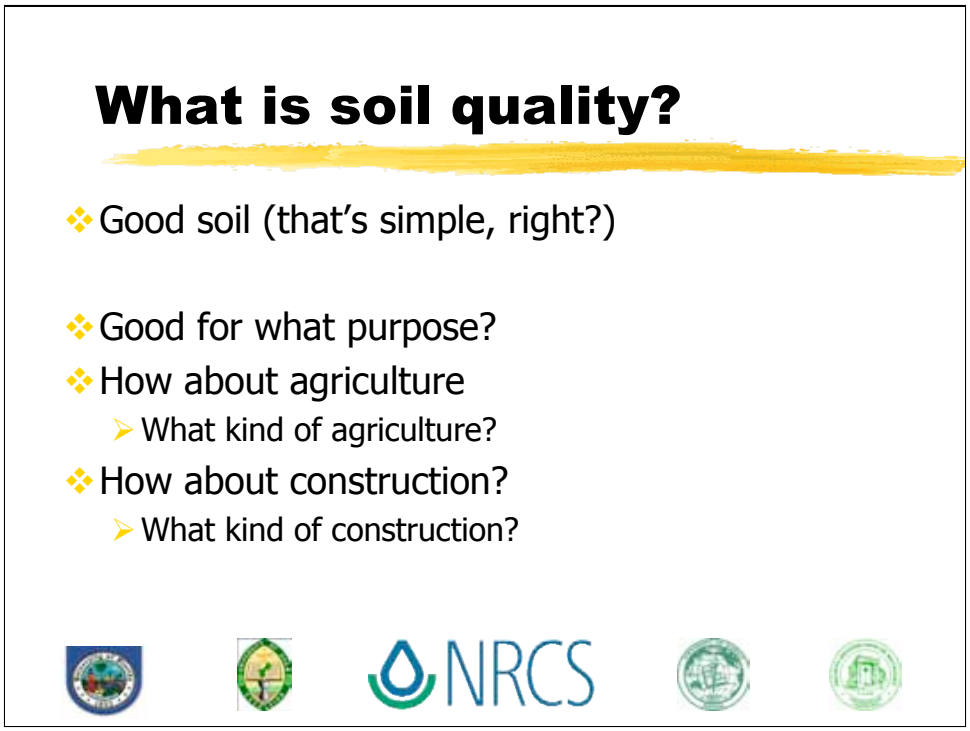
Soil Quality Considerations with Agroforestry

Michael Robotham
Tropical Technology Specialist
USDA-NRCS Pacific Islands Area
Honolulu, Hawaii USA

Overview of lecture

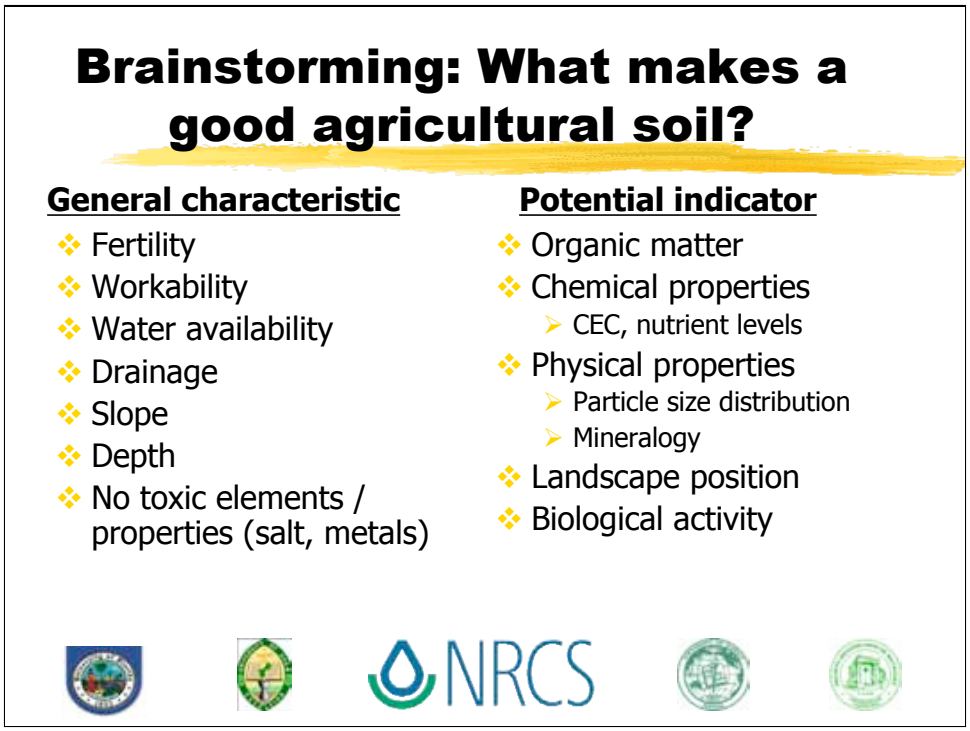
- What is soil quality?
- Why are we concerned about soil quality?
- How do different common agroforestry systems and practices affect soil quality
- Example from Palau of a successful, agroforestry-based restoration project



Most people have an intuitive sense of what makes a "good" soil. But, "good" is in the eye of the beholder and depends on the desired use.

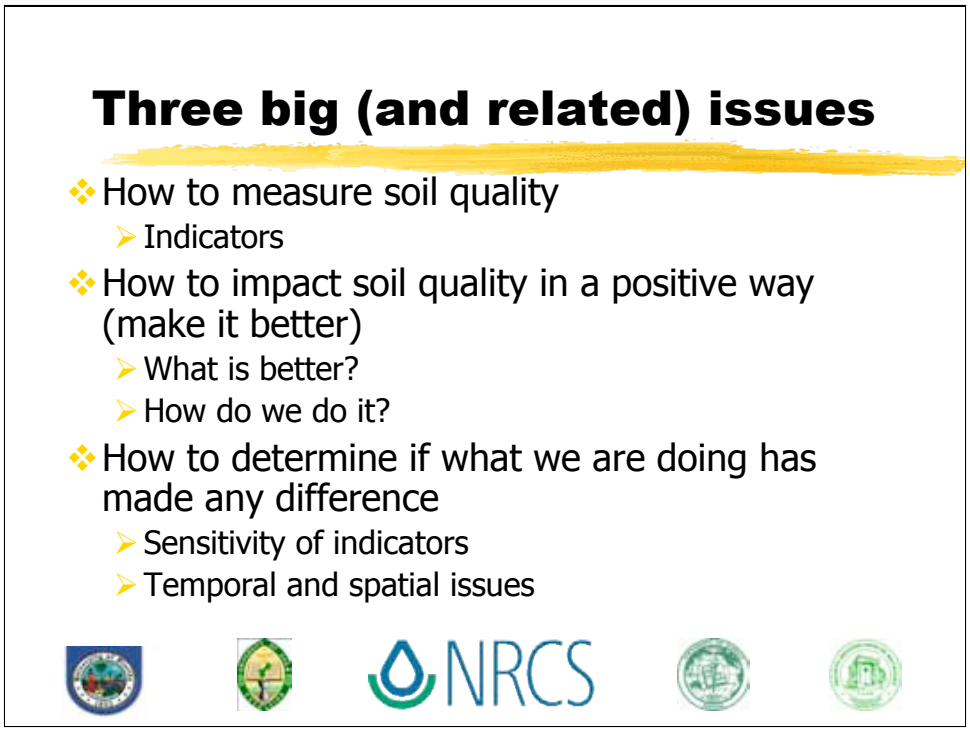
I will focus on the use of soils for agriculture and agroforestry in this talk.



Keep in mind that these general characteristics need to be further refined depending on the type of agriculture being considered. For example, a soil that is good for lowland rice or taro is likely completely unsuited for white potatoes.

The type of agriculture also makes a big difference. Some of the most desirable soils for mechanized plantation agriculture are valued for they physical properties even though they have generally low soil fertility.

One of the biggest difficulties in looking at soil quality is identifying appropriate (and measurable) indicators (some suggestions in the right hand column) that will help us get a handle on the more general and intuitive characteristics in the left hand column. Some are relatively simple (e.g. depth), others are not (what does one mean by "fertility" anyway?).



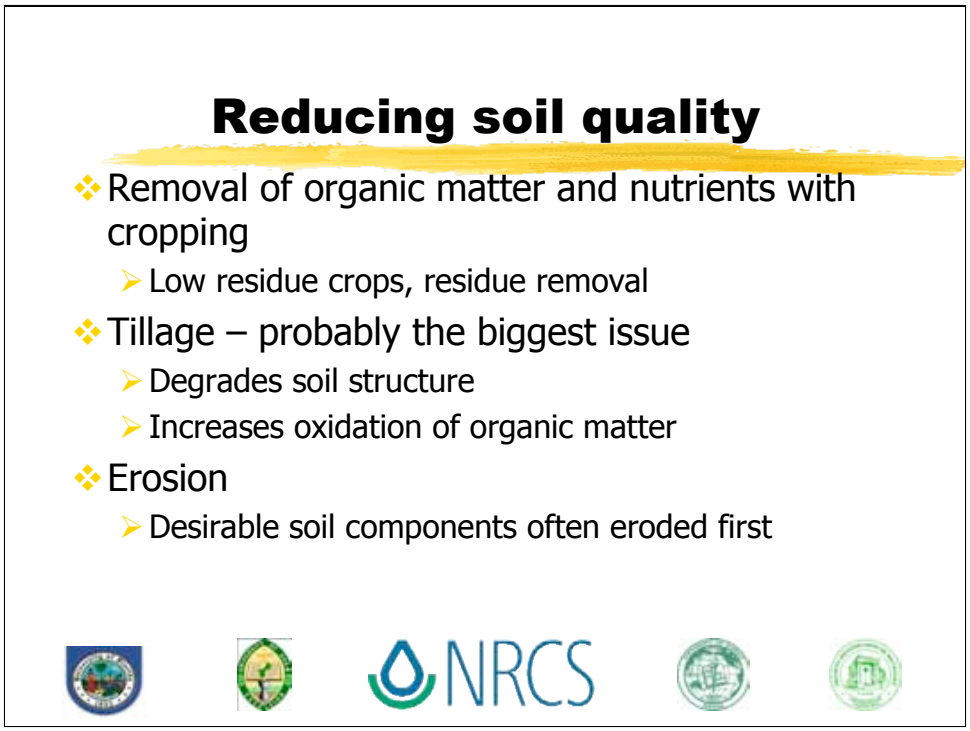
This talk is not about indicators, but it may be helpful to review the qualities of a good indicator. A good indicator should be:

1. Substantial – measures what you want to measure
2. Independent (specific) – measures only what you want, not a lot of other things
3. Factual/replicable – not subjective, result doesn't depend on the person doing the assessment
4. Plausible/reliable/sensitive – the indicator consistently changes when the property of interest changes
5. Obtainable – based on data that you can collect

Any attempt to assess soil quality, especially to document changes must also consider temporal and spatial issues. Many soil properties change slowly over time so long-term monitoring is often necessary to assess changes in soil quality. Spatial issues (scale) are also very important. Some practices may have large effects, but only in a very small area. Other practices may have small, more widely distributed effects.

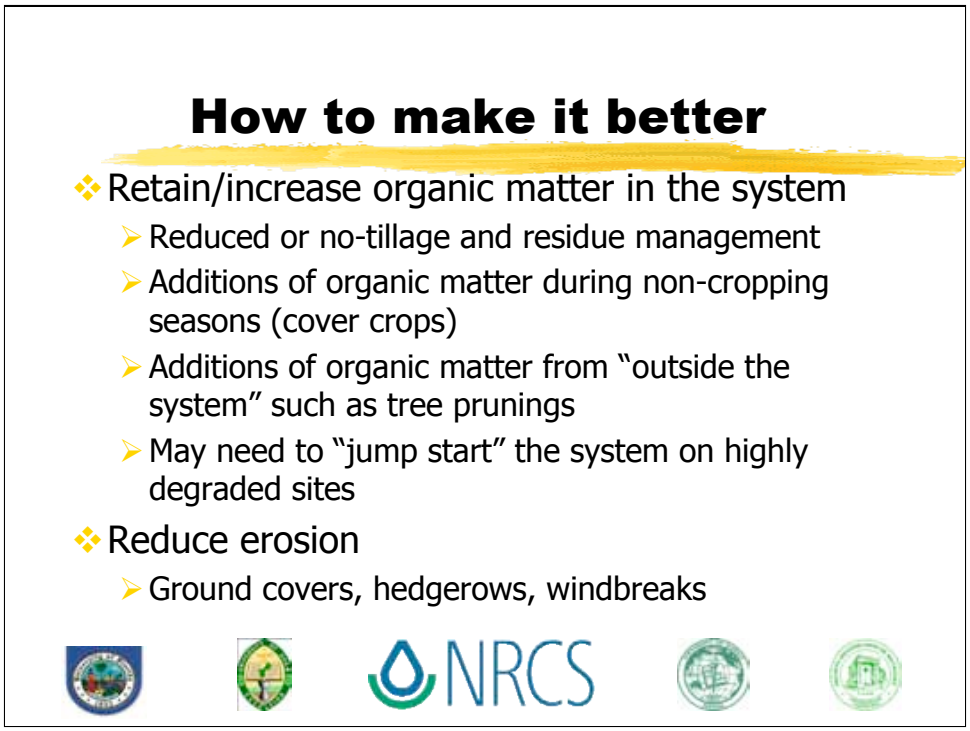
Key role of organic matter

- Organic matter is the key to soil quality in many (most) tropical agroecosystems
  - Structure, CEC, water holding capacity, ability to complex metals (Al), habitat for micro-organisms, etc.
- Practices that improve organic matter status will nearly always improve soil quality
- Practices that degrade organic matter status will nearly always reduce soil quality

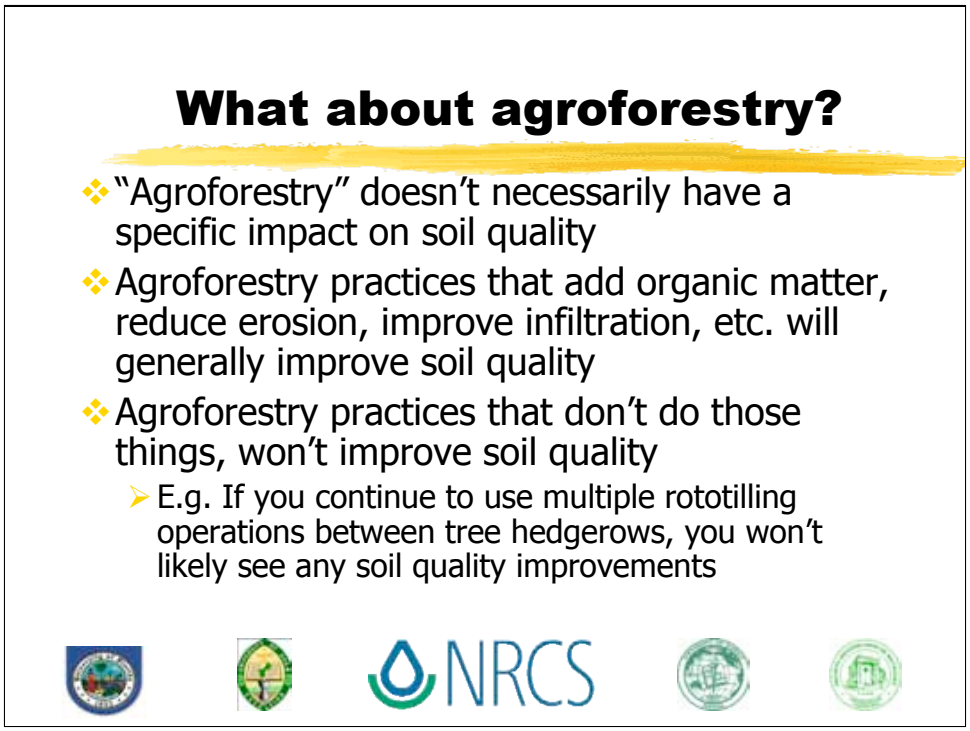


Cropping doesn't necessarily reduce soil quality, but, in most cropping systems, the goal is to remove biomass in the form of grain, vegetables, fruits etc. In many systems, even the non-harvested biomass is not retained for a variety of reasons (cultural preference, disease control, ease of subsequent cropping, etc.).

Mechanical tillage (and other operations such as mechanical harvests) can have a huge, negative impact on soil quality.

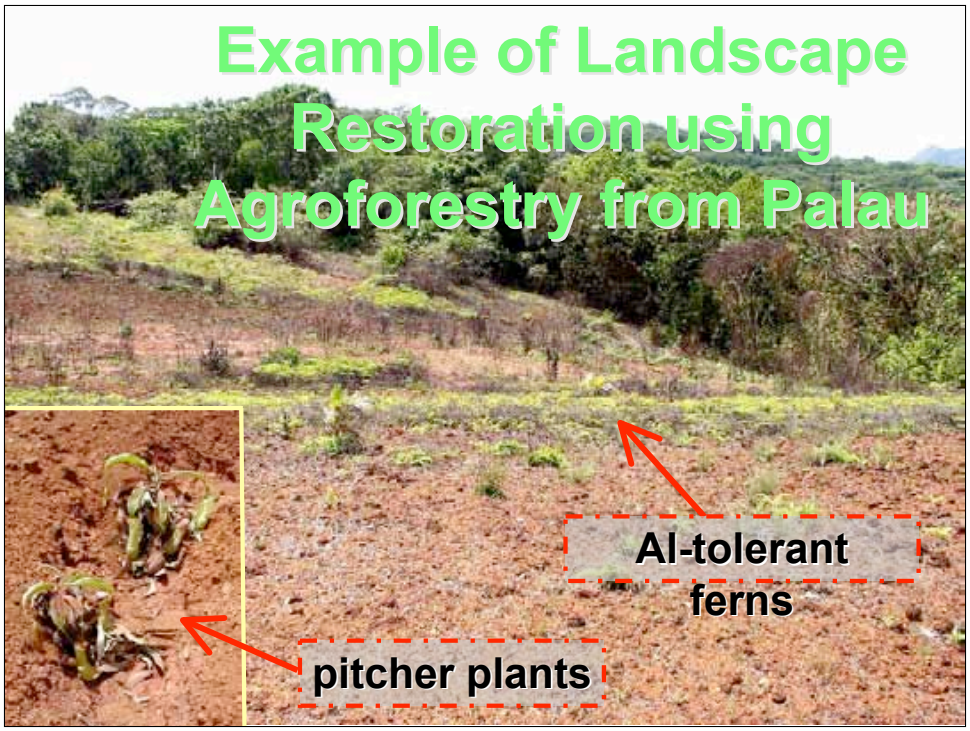


Organic matter is really the key to soil quality in most tropical systems (as will be illustrated in the upcoming example from Palau). Keeping the soil in place (reducing erosion) is the other major way to enhance soil quality.



It is impossible to talk about a general impact of "agroforestry" on soil quality. One needs to examine the components of any given agroforestry system and then look at how those individual components and their interactions impact the things that we are pretty sure affect soil quality (like organic matter status and erosion).

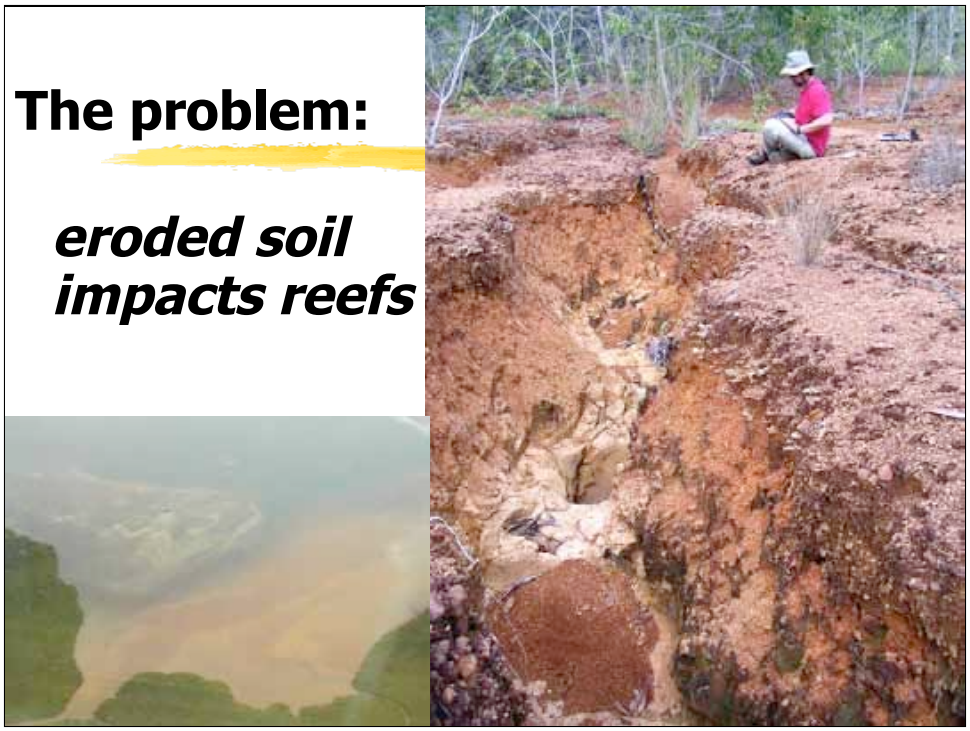
Many "linear" agroforestry systems like hedgerows and windbreaks, may have very localized soil quality improving effects from increased nutrient cycling and leaf drop, but, may have very diffuse (and often minimal) soil quality impacts on the field or farm scale unless measures are deliberately taken to create those positive effects.



Is it possible to make soils like the Babelthuap series productive again?

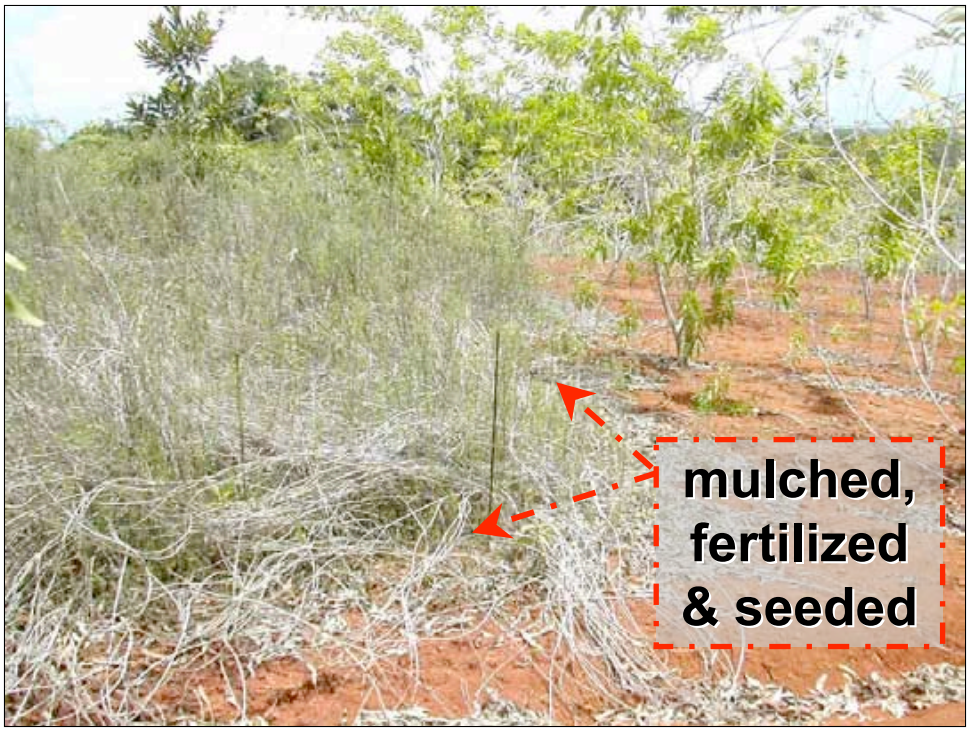
Note that the main plant vegetating this site is false staghorn fern (*Gleichenia linearis*), which tolerates high soluble aluminum levels.

Insectivorous pitcher plants (inset) are also common on these highly degraded soils.

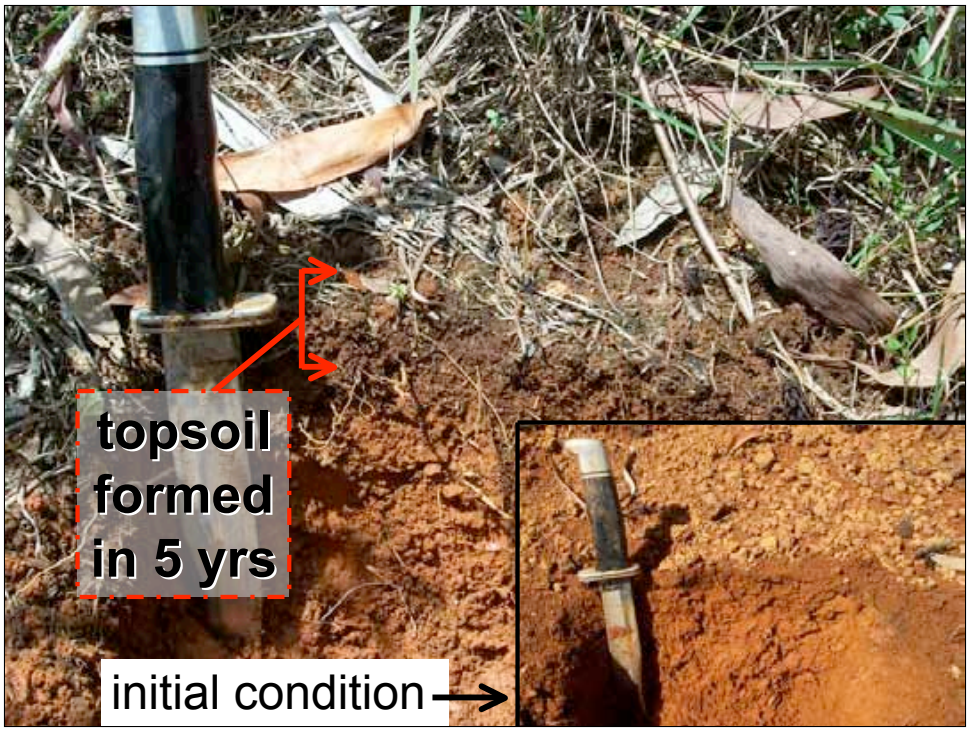


The land is connected to the sea. Land degradation adversely affects coral reefs by smothering them with sediment. The water source for these gullies is rainfall on slopes beginning only 50 meters uphill. Forest clearing followed by grassland maintenance through continued burning starts the downward spiral of land degradation. This situation is more easily prevented than it is solved after gullies start to form.

Planting trees alone without establishing an understory will not prevent further degradation of sites like this. Even these nitrogen-fixing *Acacia* trees have a difficult time surviving on this site. The leaves they drop do not add organic matter to the soil because the leaves, along with soil, are washed away by the rain. Gullying and surface erosion still occur because the soil is still unprotected, which increases runoff and erosion. The watershed for these gullies starts only about 50 meters upslope. Note the poor condition of the *Acacia* trees, which are about 10 years old. The gullies formed after the trees were planted.



The vegetated area on the left had a 6-inch thick layer of mulch, fertilizer and seeds applied to the eroded soil surface. This photo shows the plot five years after mulch etc. application.



Additions of mulch and some synthetic fertilizer have been demonstrated to produce an inch of topsoil in less than 5 years. Point out morphological differences between topsoil within and outside of plot.

Although this is a promising result, it would be difficult to reclaim large areas in this way. The best path to follow is to ensure that topsoil is not degraded or lost.

The next slide shows data on soil properties from inside and outside of the vegetated plot.

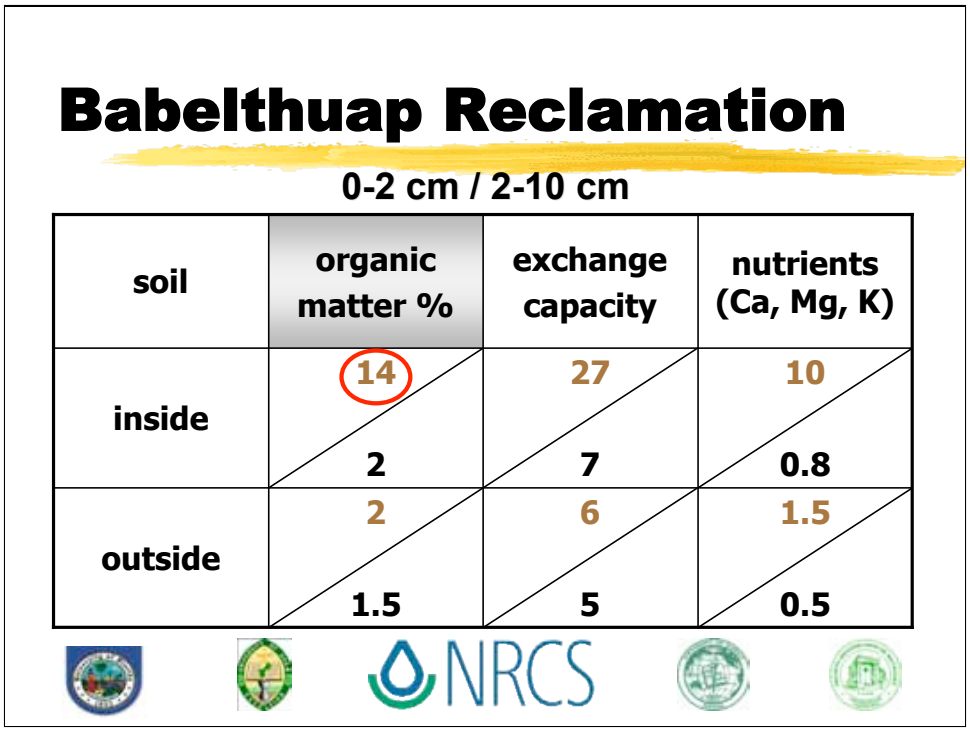
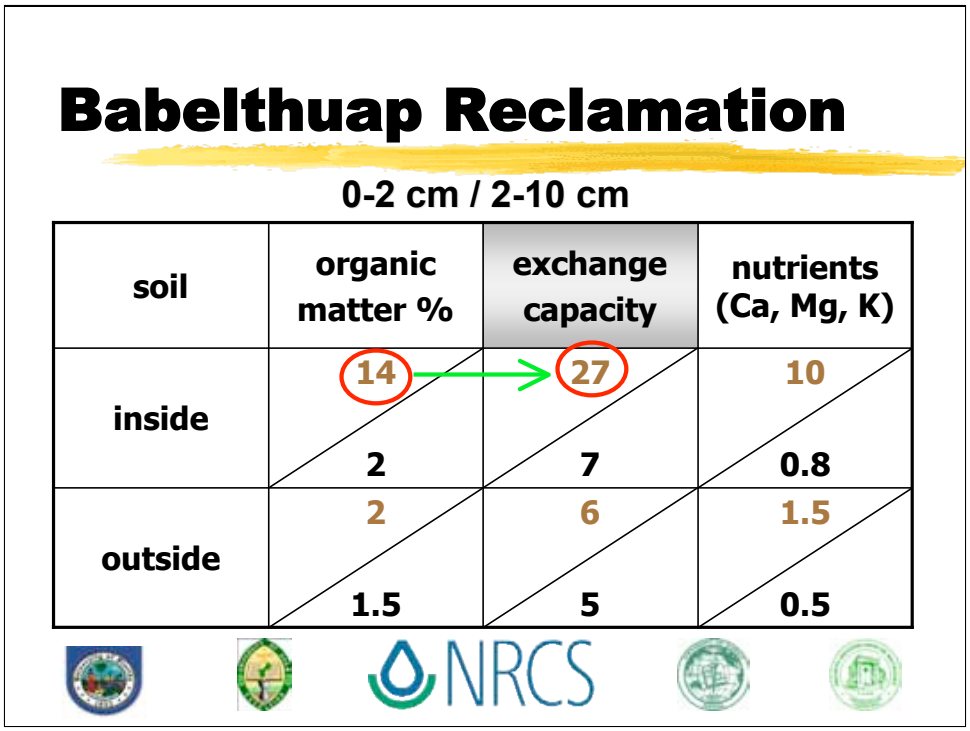
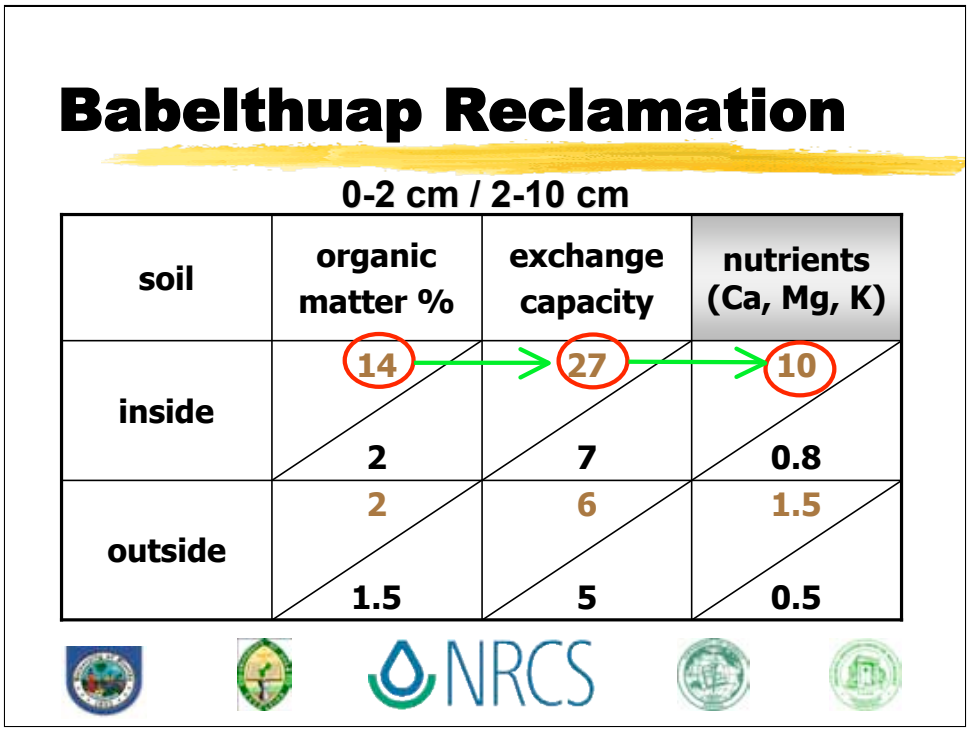


Table is for topsoil (0-2 cm) / subsoil (2 to 10 cm) for three averaged samples within and outside of the vegetated plot on the Babelthuap soil series. Soil location is indicated in the far left column. Table examines topsoil and subsoil properties of soil organic matter, cation exchange capacity and amount of nutrients. Data are unpublished.

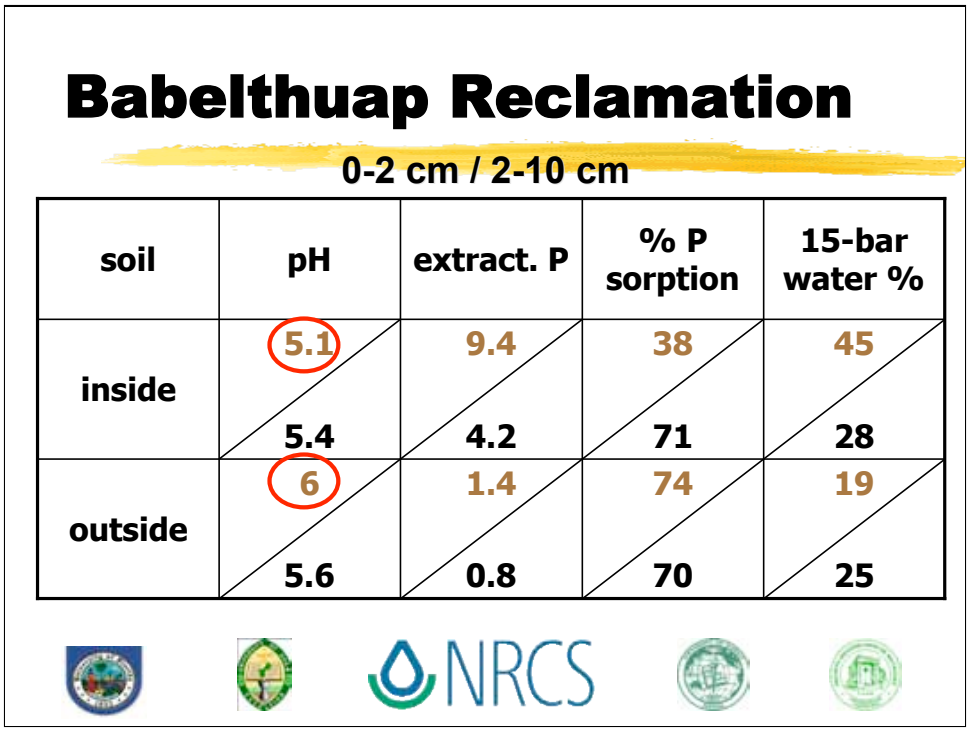
Organic matter is significantly higher inside the vegetated plot area.



High SOM produces high CEC so the ability of the soil to hold on to nutrients is improved to about 4 times greater than minimally vegetated areas.



The increase in CEC by the addition of SOM allows nutrients to be held and recycled. There is probably a healthier soil environment inside the vegetated plot that allows for more beneficial organisms (like mycorrhizal fungi).



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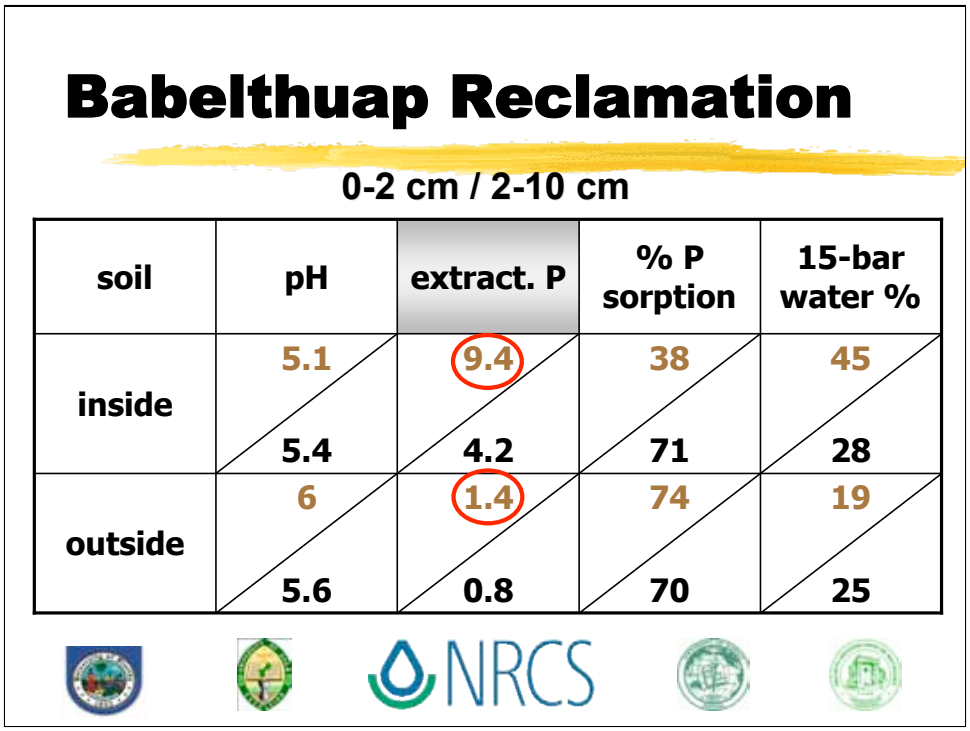
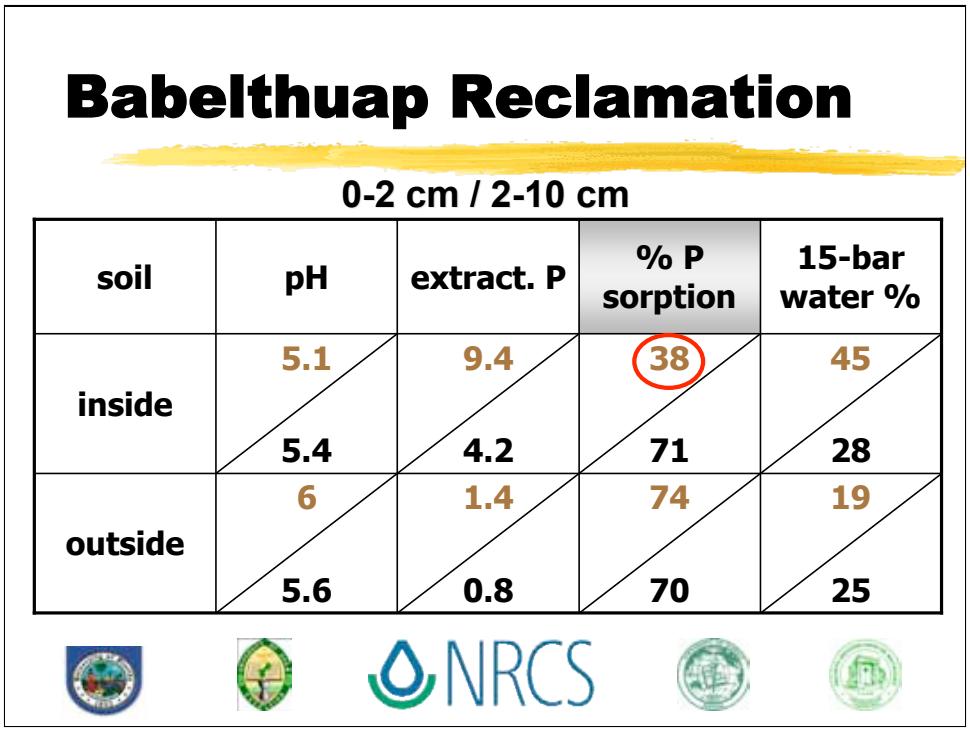
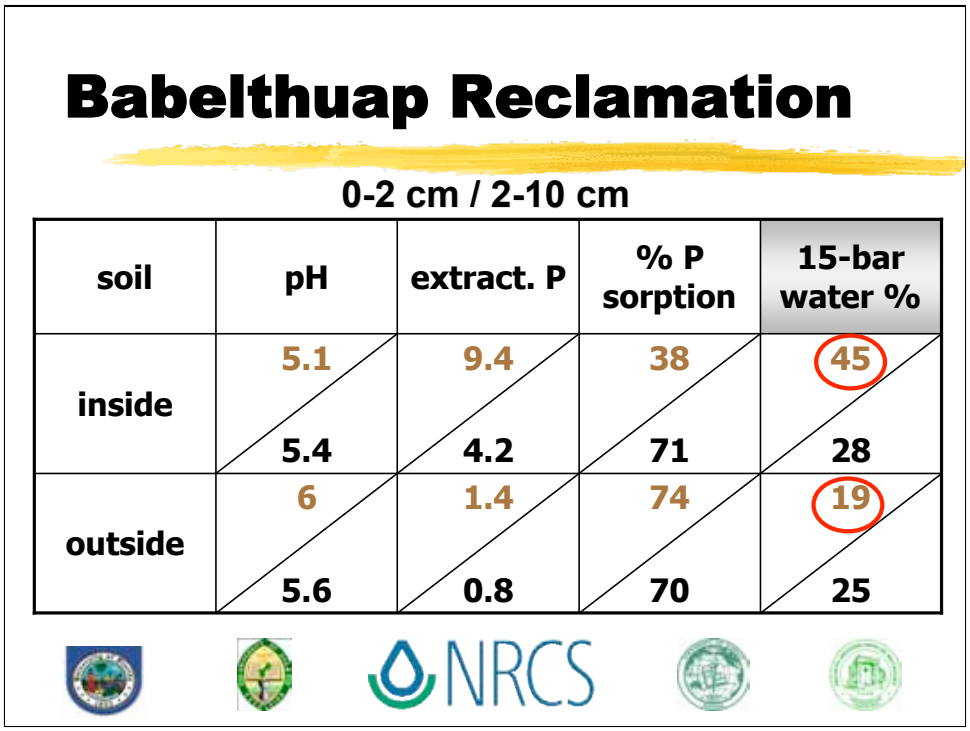
pH has been lowered by the acidifying effects of SOM and possibly by the initial application of fertilizer.



Extractable P is much greater in the vegetated plot but how much is due to fertilizer application? Regardless of that, the P is sticking around and available for plant use.



Phosphorus is commonly sorbed on to highly weathered soil minerals (especially oxides). Humus has been observed elsewhere to inhibit P sorption and that appears to be what's happening here. The high SOM topsoil within the vegetated plot has the lowest P sorption, about half as much as topsoil outside the vegetated plot..



High organic matter content in vegetated topsoil more than doubles the water holding capacity compared with same unvegetated layer.

15-bar water is the value used to approximate wilting point.

Take home points -- Palau

- Agroforestry practices can potentially be used to significantly improve the soil quality on a highly degraded landscape
- Trees can't necessarily do the job alone
  - In this case they needed both mulch and starter fertilizer to "jump start" the process
- Significant improvements in several soil quality indicators can be seen in a relatively short time (5 years)

Take home points -- overall

- Soil quality is a multi-faceted concept
- Definition of "good soil" depends on proposed use of the land
- Agroforestry-related activities may or may not have positive impacts on soil quality
- Used correctly and as a part of a larger integrated strategy, agroforestry practices can have strongly positive impacts

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