Soil Quality Considerations with Agroforestry In the Mariana Islands

Trees for Improving Sustainability, Resource Conservation, and Profitability on Farms and Ranches

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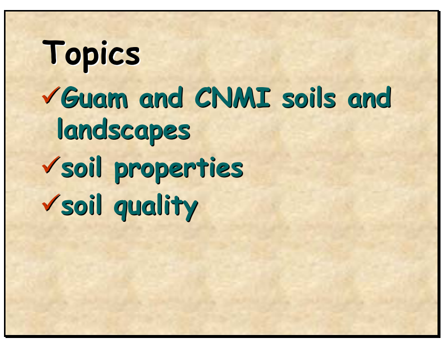
Slide 1

Agroforestry has been successfully practiced in Micronesia for several thousand years. This presentation gives the soils perspective as to why this agricultural system has been sustainable for such a long time.

Slide 2



Slide 3

This is what agriculture is supposed to look like. Well, maybe not. Clean-till agriculture is out of step with natural systems. Steep slopes without vegetative cover are susceptible to water erosion. One good thing here is that the furrows are along the contour. Many farmers in Palau plow up and down the slopes. They supposedly do that to help remove excess water more rapidly.
The system shown here works well if there is no rain, but when the weather moves in . .

Slide 4

And this comes on shore, then . .

Slide 5

This starts to happen. Raindrop impact breaks up soil aggregates, dislodges soil particles and erosion happens.

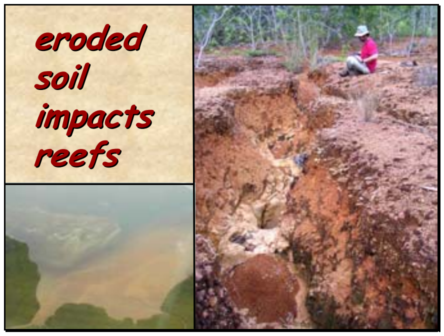
Slide 6

This farm has furrows up and down the slopes. The furrows work well to remove water but the water is removing valuable topsoil. Clean till agriculture on sloping infertile soils is not sustainable in a high intensity rainfall area such as Micronesia. Note that most soils in Micronesia form sand-size stable aggregates of clay. These aggregates are easily eroded from the soil surface.

Slide 7

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.

Slide 8



The land is connected to the sea. Land degradation adversely affects coral reefs by smothering them with sediment. The sediment alters fish habitat and generally lowers fish populations. 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.

Slide 9

Agroforestry system in Yap. Multistory cropping offers good protection against raindrop impact. Harvesting different crops in different areas at different times helps ensure that there will always be a fair amount of groundcover to protect the soil from water erosion. There is also the benefit of continuous additions of organic matter. The benefit of cooler soil temperatures and higher soil organic matter are presumed to be more favorable to soil micro-organisms than clean till agriculture systems.

Slide 10

Agroforestry system in Yap. Multistory cropping offers good protection against raindrop impact. Harvesting different crops in different areas at different times helps ensure that there will always be a fair amount of groundcover to protect the soil from water erosion. There is also the benefit of continuous additions of organic matter. The benefit of cooler soil temperatures and higher soil organic matter are presumed to be more favorable to soil micro-organisms than clean till agriculture systems. Also note how lush the vegetation is. In the Mariana Islands (Guam and CNMI) where there is a pronounced dry season, it seems that the shade provided by trees lowers evapotranspiration and the understory plants appear to have less water stress.

Slide 11

Agroforestry system and taro patch in east Koror, Palau. Note vegetative groundcover on steep hillside to prevent erosion.

Slide 12

Agroforestry system and taro patch in the Ngerikiil Watershed, Airai State, Palau. This farmer takes advantage of slight differences in soil moisture conditions (i.e. better drainage on slightly elevated land) to grow a wide variety of crops. Lesson: don't fight the system with poorly suited crops, choose crops to match soil properties.

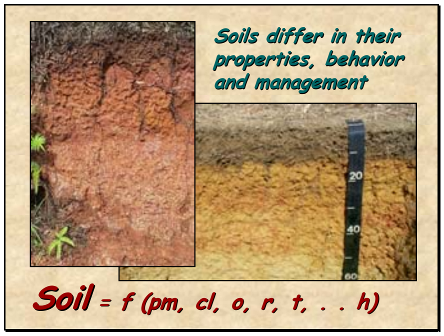
Slide 13

Archeological studies indicate that people introduced agroforestry crops thousands of years ago.

Slide 14

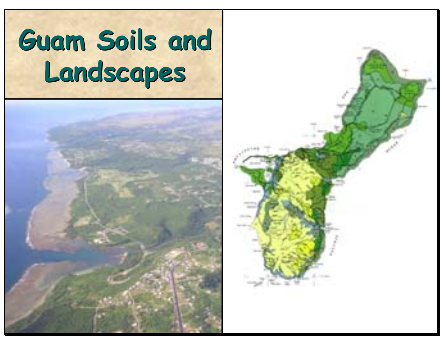
We will look are modern scientific soils data to explain why this system of agriculture is appropriate and successful.

Slide 15



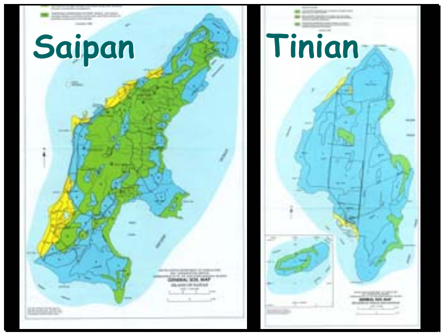
Soils are not randomly distributed across the landscape. Due to differences in the state factors of soil formation (parent material, climate, organisms, relief, time and human influence) there are different soils distributed in a pattern across landscapes. These different soils have different properties that behave differently and therefore respond differently to management.
Reddish Aimeliik-like soil formed in volcanic rock is on the left. Tabecheding soil formed in marine terrace clays is on the right.

Slide 16



From the general soil map we can see that the volcanic upland soils (yellow) are the most extensive soils in the south. Two shades of green map units are for limestone soils, mostly in the north but extending down the southeast coast. Inextensive areas of bottomland soils (blue) in alluvium in valley bottoms and corral sand soils and organic soils along the coast.

Slide 17



From the general soil maps we can see that the volcanic upland soils (a small portion of the green area) are not extensive soils in the CNMI islands. Most of the green and all of the blue map units are for limestone soils. Areas of bottomland soils (yellow) in alluvium in valley bottoms and corral sand soils along the coast.

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Slide 19

Photo of the north Guam limestone plateau. Limestone landscapes are mostly nearly level on the plateau, but very steep along escarpments. In southern Guam the limestone areas adjacent to the volcanic region is hilly.

Slide 20

Photo of the Luta series on Rota. Most limestone soils in the Mariana Islands are shallow over hard limestone like the soil shown here.

Slide 21

Photo of the Saipan series in the Yona area of east central Guam. Moderately deep to very deep soils on limestone are not extensive.

Slide 22

Photo of the volcanic mountains of Guam from the Southern Mountains Overlook a few miles north of Umatac. Several thousands of years of burning have restricted the forest to wetter valley bottoms. These soils were probably more fertile under forest than they are today under grass; probably similar to the forest/grassland soil transformation seen in Palau.

Slide 23

Photo of the Akina series in south central Guam off the Cross Island Road. Depth to the pinkish saprolite (weathered bedrock) is normally 50-100 cm (20 – 40 inches). The Akina series makes up about 13% of Guam.

Slide 24

Photo of the Akina series in south central Guam. The subsoil has high soluble aluminum and few nutrients. The saprolite can be a physical barrier to roots.

Slide 25

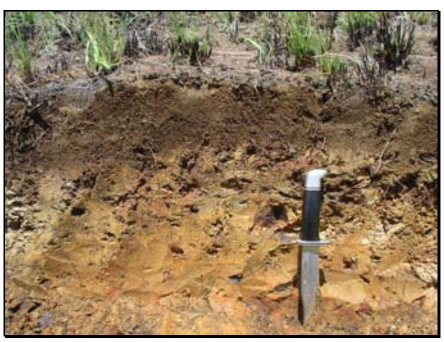


Photo of the Agfayan series in south central Guam off the Cross Island Road. Depth to the saprolite (just above the knife handle) is normally 10-38 cm (4 – 15 inches). The Agfayan series makes up about 8% of Guam.

Slide 26

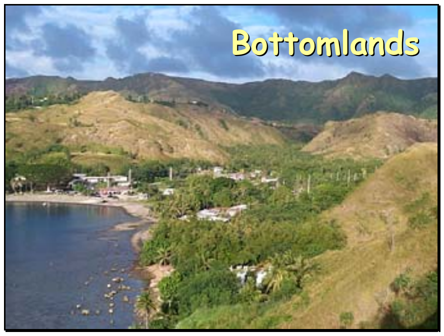
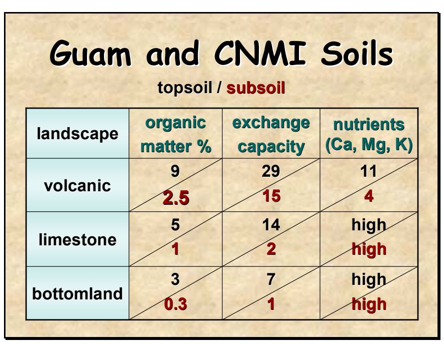


Photo of Umatac. Most of the area in the valley bottomland covered by trees is the Ylig clay formed in alluvium (i.e. water-deposited sediment). These soils have water table at 25 - 100 cm (10 – 40 inches).

Slide 27

Photo of the Inarajan series in the Ija River Valley, southern Guam. These soils formed in alluvial (i.e. water-deposited) sediment in broad valley bottoms. Note the stratification of sediment.

Slide 28



Guam and CNMI Soils

topsoil / subsoil

landscape	organic matter %	exchange capacity	nutrients (Ca, Mg, K)
volcanic	9 / 2.5	29 / 15	11 / 4
limestone	5 / 1	14 / 2	high / high
bottomland	3 / 0.3	7 / 1	high / high

Table is for topsoil (upper 4 inches or 10 cm) / subsoil (4 to 24 inches or 10 to 60 cm) for representative soils on Guam and Saipan. Volcanic = Akina series, Guam. Limestone = Yigo series, Guam. Bottomland = Shioya series, Saipan. Table examines topsoil and subsoil properties of soil organic matter, cation exchange capacity and amount of nutrients.

We measure organic carbon and then convert to percent organic matter by multiplying by 1.724, which assumes that organic matter is generally about 58% carbon. This is called the Van Bemmelen Factor. Akina series under pasture has the highest soil organic matter (SOM) content; Yigo series under cropland has a little more than half as much SOM and Shioya under horticulture has only about a tenth as much. All three subsoils have similar SOM around 1-2%.

Soils have electrical charge and can hold on to both positively and negatively charged ions. Most soils have much more negative charge than positive charge and therefore hold more positively charged ions. This is expressed as Cation Exchange Capacity or CEC. There is also Anion Exchange Capacity (AEC), which may be important in highly weathered soils. There are various ways to express exchange capacity, all related to the pH of the system. CEC can be determined at pH 8.2, 7 or at the field pH. The Effective CEC at field pH is presented here. Raising the pH (as in determining CEC at pH7 in acid soils) will give an artificially high CEC value but it will give some indication of how the soil's charge can be manipulated by liming. Units are in miliequivalents per 100g soil. Emphasize the relative differences among soils. Before discussing exchange capacity look at the following slide that shows the different sources of exchange capacity. Nutrient content of the limestone soil and the bottomland soil (carbonate sands) cannot be determined accurately because the extracting solution dissolves some of the carbonate particles and yields artificially high values for calcium.

Data are from http://soils.usda.gov for Akina series S83GQ-066-003, Yigo series S83GQ-066-007 and Shioya series S91TQ-110-002.

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Cation Exchange Capacity

Component	meq/100g soil
organic matter	200-400
montmorillonite	60-100
kaolinite	2-16
halloysite	5-10
Fe and Al oxides	0

Cations are positively charged ions. The mineral components of most volcanic soils in the Mariana Islands are kaolinite, halloysite and iron and aluminum oxides. Organic matter is obviously important in providing cation exchange capacity (CEC) in these soils. Oxides mostly provide anion exchange capacity (AEC). There is some montmorillonite in alluvial soils. The amount of negative charge on organic matter, kaolinite, halloysite and oxides depends on the pH of the soil. Higher pH (i.e. less acidity) creates more negative charge with which to hold on to positively charged nutrients (cations). Montmorillonite has mostly permanent charge not affected by pH.

Source: Soil Survey Laboratory Information Manual. 1995. USDA NRCS National Soil Survey Center, Soil Survey Laboratory. Soil Survey Investigations Report No. 45 Version 1.0

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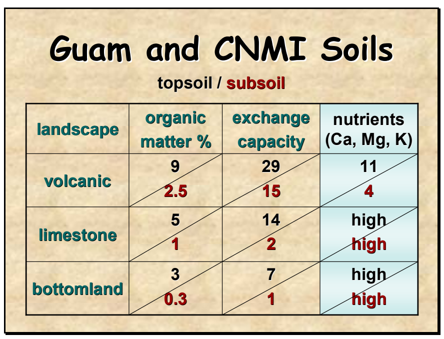

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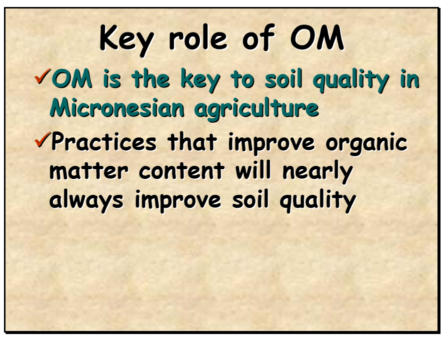

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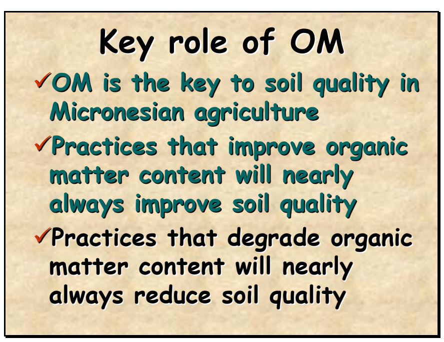

Slide 38

OM vs. fertilizers

- ✓OM improves soil aggregation and structure → better aeration and permeability → less erosion

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- ✓OM improves soil aggregation and structure → better aeration and permeability → less erosion
- ✓OM improves water holding capacity

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- ✓OM improves water holding capacity
- ✓OM increases exchange capacity

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- ✓OM improves water holding capacity
- ✓OM increases exchange capacity
- ✓OM complexes with aluminum

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OM vs. fertilizers

- ✓OM improves soil aggregation and structure → better aeration and permeability → less erosion
- ✓OM improves water holding capacity
- ✓OM increases exchange capacity
- ✓OM complexes with aluminum
- ✓OM acts as slow-release fertilizer

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OM vs. fertilizers

- ✓OM promotes healthy soil environment for beneficial organisms

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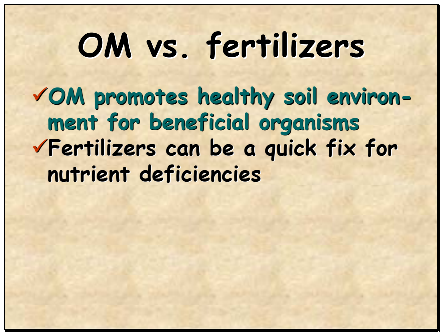

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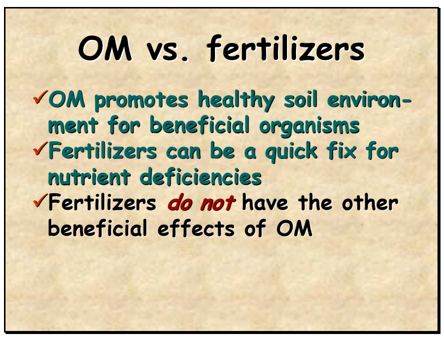

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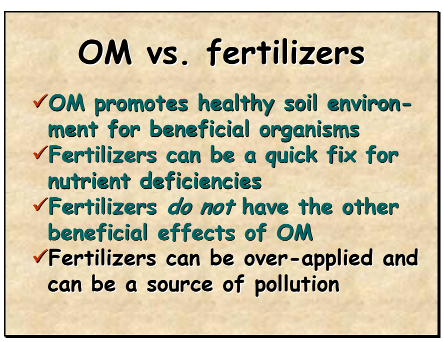

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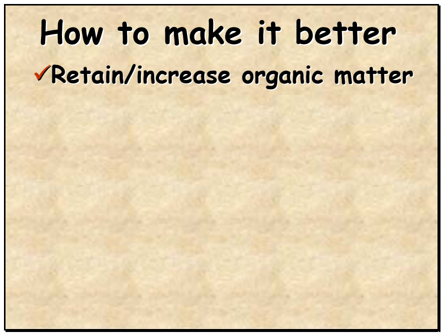

Compost and mulch from off-site can help maintain high SOM. Note that mulch is OM applied to the surface and compost can be either added to the surface or incorporated into the soil. The difference is that compost has decomposed OM with a low C:N (carbon:nitrogen) ratio similar to what is already in the soil (usually 10-15). Mulch is usually undecomposed and has a high C:N (sawdust, for example, is about 400). If a high C:N material is mixed into the soil the micro-organisms have a virtually unlimited supply of carbon and they will utilize all the nitrogen that is released through organic matter competition, leaving no nitrogen for the plants.
These points are the principles of traditional Micronesian agroforestry and account for its long-term sustainability.

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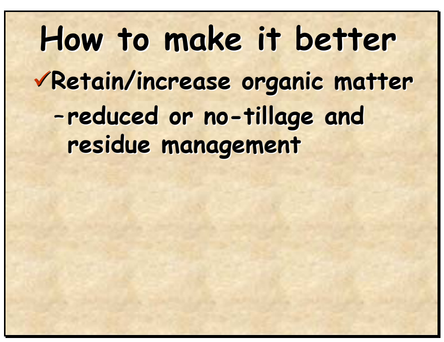

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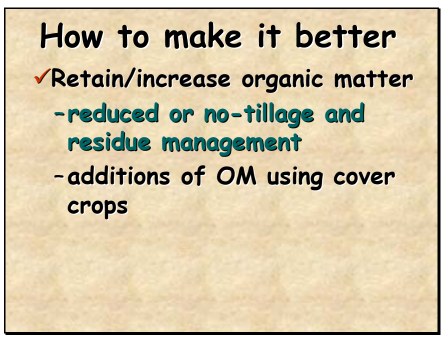

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How to make it better

✓Retain/increase organic matter
- reduced or no-tillage and residue management
- additions of OM using cover crops
- additions of organic matter from off-site

Compost and mulch from off-site can help maintain high SOM. Note that mulch is OM applied to the surface and compost can be either added to the surface or incorporated into the soil. The difference is that compost has decomposed OM with a low C:N (carbon:nitrogen) ratio similar to what is already in the soil (usually 10-15). Mulch is usually undecomposed and has a high C:N (sawdust, for example, is about 400). If a high C:N material is mixed into the soil the micro-organisms have a virtually unlimited supply of carbon and they will utilize all the nitrogen that is released through organic matter competition, leaving no nitrogen for the plants.
These points are the principles of traditional Micronesian agroforestry and account for its long-term sustainability.

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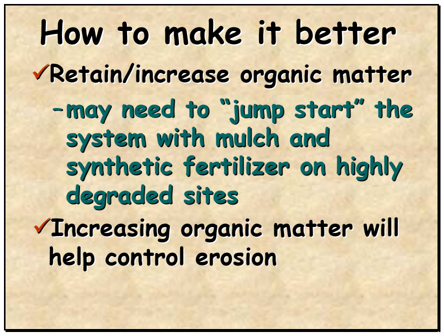
How to make it better

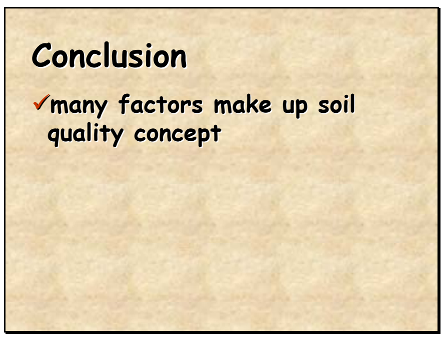
✓Retain/increase organic matter
- may need to “jump start” the system with mulch and synthetic fertilizer on highly degraded sites

Slide 52

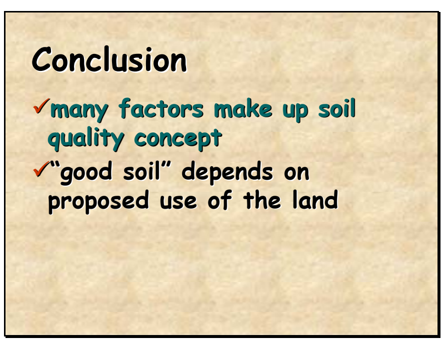


Protection from erosion is just a natural byproduct of practices that increase soil organic matter.

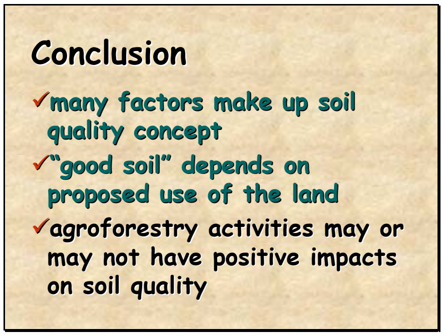
Slide 53



Slide 54

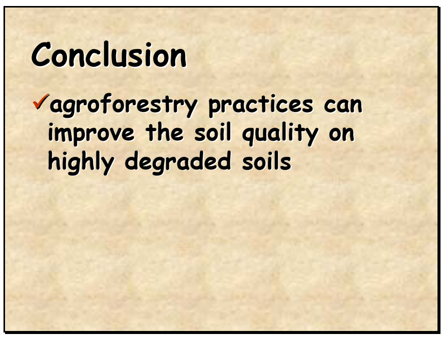


Slide 55



But the way agroforestry is practiced in Micronesia it usually has positive impacts on the soil.

Slide 56



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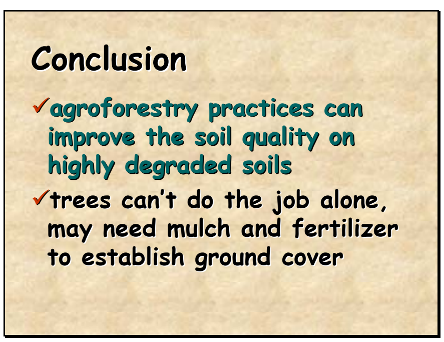

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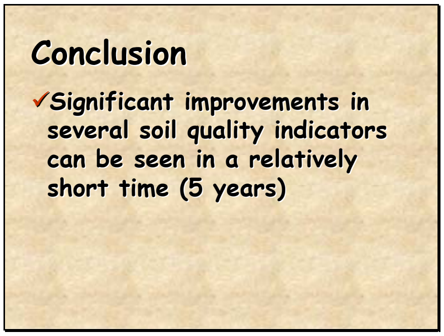

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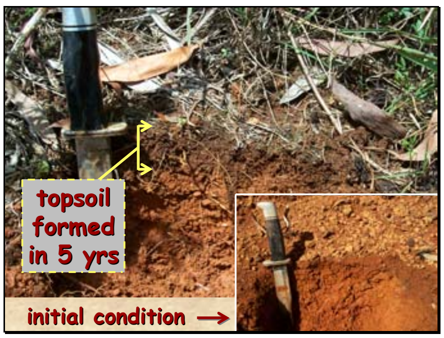

Additions of mulch and some synthetic fertilizer have been demonstrated to produce an inch of topsoil in less than 5 years in Palau. Point out morphological differences between topsoil within and outside of plot ("initial condition"). Although this is a promising result, it would be difficult to reclaim large areas in this way. The best path to follow is to ensure that topsoil is not degraded or lost.

Slide 60

Modern soils data can explain why traditional agroforestry management is appropriate and sustainable.

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USDA-NRCS soils data and much more soils information of all kinds are available on the internet.

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Contact your local NRCS office for assistance.

Slide 63

Questions?

Slide 64

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