Soil Rejuvenation in Malawi

Presentation developed by

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For

Ministry of Hope – Malawi

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Soil Rejuvenation in Malawi

- Ministry of Hope's Matapila Garden
- Chicken manure was mixed with the soil in the right hand rows of the garden.
- Note significant difference in plant heights.
- Soil condition makes a difference!

Soil Rejuvenation in Malawi

Overview

- Soil Condition in Malawi
- Plant Growth Requirements
- Soil Improvement Options
- What is Composting?
- Limitations in Malawi
- Evaluation of Malawi Composting
- Improving Malawi Composting

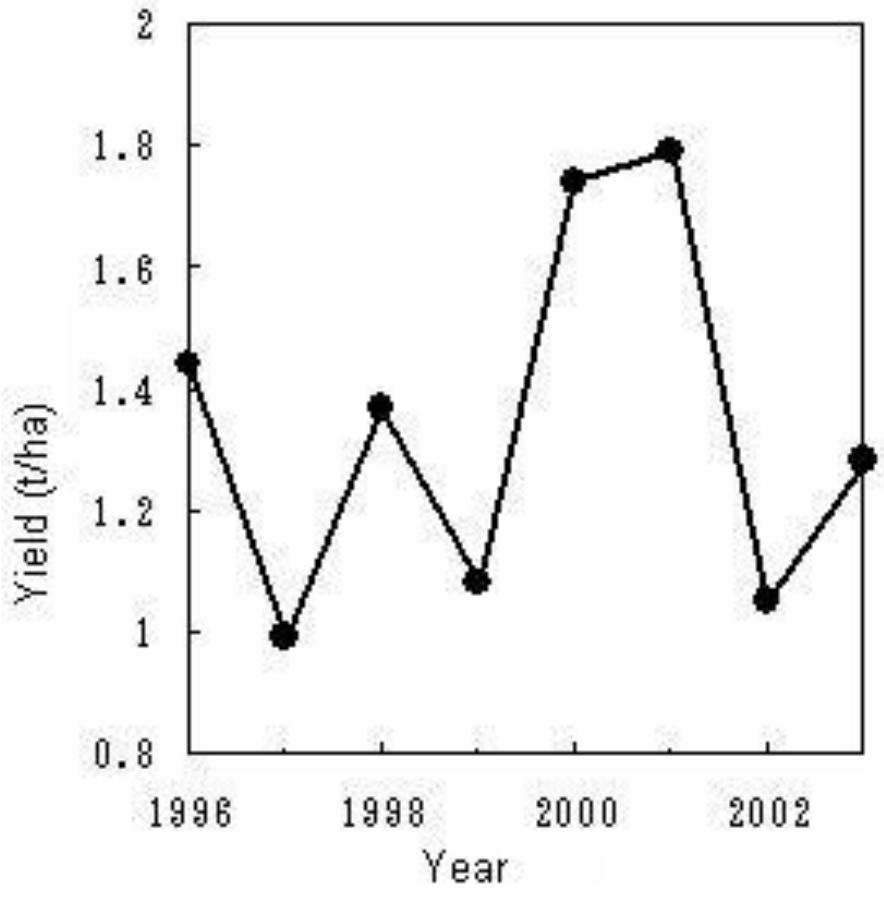
Soil Condition in Malawi

What is the situation?

- Crisis in soil fertility due to farming practices
  - Maize yield well below world average
  - No soil fertility replenishment system
- Declining productivity: Need to rejuvenate soils
- Great deal of research over past 20 years on soil in Sub-Saharan Africa
  - Information in technical papers, conferences, reports
  - Lots of academic, NGO, and government agency study
- Little transfer of information to smallholder farmers.
- Little change from ineffective traditional procedures

Maize Yield in Malawi

World average yield is 4.4 ton/hectare



Soil Rejuvenation in Malawi

The Need

- Malawi soils dangerously depleted in nutrients and organic matter
- Farming situation in Malawi and neighboring countries is "unsustainable"
- Productivity will continue to decline: Can become "irreversible"
- Evidence of declining soil productivity:
  - Fall in unfertilized maize yields
  - Parallel decline in response to fertilizer

Soil Rejuvenation in Malawi
Overview

- Key concept:
  - Many factors involved in maintaining soil fertility, productive plant growth & effective composting
  - Problems are created when some factors are focused upon, and others ignored
  - Must consider the entire system, and how the factors are interrelated

Plant Growth Requirements

Plant Needs

- Good soil
  - Organic matter
  - Nutrients: N, C, P, K, S
- Water
- Air
- Sunlight

Plant Growth Requirements

Need to Recycle Nutrients

- Plant growth removes nutrients from the soil
- Unless those nutrients are returned to the soil, (recycled) soil continues to lose those nutrients.
- Over time, as nutrients and organic matter is removed, fertility of soil is reduced.
- Analogy to "mining" depletion

Plant Growth Requirements

How are nutrients recycled?

- Plant residues plowed under, or left on surface
- Grazing animals deposit manure
- Planting of "green fertilizer" crops in rotation
- Local communities recycle organic waste
- Composting
- Inorganic fertilizers used in small amounts

Plant Growth Requirements

Fertilizer History

- Recycling used for centuries to return plant residues to maintain the soil
- 20th century scientists discover key plant growth nutrients
- Chemical companies manufacture chemical fertilizer: Inorganic fertilizer
- Little attention to organic content and overall requirement of soils
- Ideas difficult to change / farmers avoid risk
- Chemical companies want to sell fertilizer
- Organic vs. inorganic fertilizer farming is controversial in U.S.

Plant Growth Requirements

Inorganic Fertilizers

- Chemically produced
  - Contain specific nutrients: N, P, K,S
- Do not contribute to soil organic content
  - Provide no long term benefit to soil
- Immediate release of nutrients
  - Short term: Used up in several weeks
  - Often more needed later in growth cycle (sidedressing)
- Leads to soil chemical "burning"
  - Chemical intensity, particularly of urea, degrades other soil nutrients and biological activity critical to long-term soil maintenance

Inorganic Fertilizers, con't

- Expensive to manufacture, and transport
  - Availability is uncertain
  - Control lies out of the hands of farmers
  - Price in Malawi 4-6 times that in South Africa
- Net result:
  - Short term boost in productivity
  - Long term deterioration of soil fertility

Organic Fertilizers

- Crop residues, manure, food production wastes, green crops
  - "Macro" nutrients: N, P, K, S
  - Organic material
  - Micronutrients from soil
- Lower in nutrient concentration than inorganic fertilizers
- Slower release of nutrients during decomposition
- Valuable organic material added to soil
- Added in larger batches over longer time
- Local materials

Organic Fertilizers, con't

- Time required to release nutrients
  - Mineralization: Nutrients converted from organic to inorganic form
  - Release time can be months
  - Direct addition of N lean organics can have detrimental effect
  - Composting used to reduce time requirement, and avoid negative effects of mineralization
- Inorganic fertilizers added for current growth, in early stages
- Objectives
  - Stop deterioration of soil fertility
  - Rebuild and main soil health and productivity

Improving Malawi Soils

Ministry of Hope's Matapila Garden

Chicken manure was mixed with the soil in the right hand rows of the garden.

Note significant difference in plant heights.

Plant Growth Requirements

India's Experience

- In 70's India government began subsidies of urea (N) fertilizer to farmers
- Initially large increase in growth and production
- Over time, increasing use of urea to maintain productivity
- After 30 years, productivity very low with food shortages
- Urea (N) without other nutrients deteriorates soil
- Studies in northern Zimbabwe shown very low response to N fertilizer for maize growth, but little growth at all without it.
- Similar problems in Malawi: effectiveness of fertilizer declining

Plant Growth Requirements

Advantages of Organic Fertilizers

- Improves soil structure
- Introduces macro, and micro nutrients
- Long-term, slower release of nutrients
- Stimulates biological activity (microbes, earthworms, etc)
- Stabilizes soil acidity (pH)
  - reduces aluminum solubility: toxic to root growth
  - Increases absorption of other nutrients
- Improves utilization of inorganic fertilizers (less needed)
- Improves soil's ability to absorb, utilize, and hold water
- Not tied to price and transportation costs: independence

Soil Conditions in Malawi

Common Problems

- Little or no organic materials returned to the soil.
  - Crop residues are "exported", used as animal fodder, fuel, roof thatching
  - Burning to ease land preparation
- Continuous cropping due to scarcity of land
- Few animals to generate manure
- Little intercropping or rotation with N rich plants
  - Low rainfall for second growth
- Ineffective composting
- Soil Tillage (Ridging)

Soil Conditions in Malawi

Burning Residues

- Purpose (commonly held)
  - kill weed seeds
  - recover nutrients via ash
  - clear fields
  - reduce termites

Soil Conditions in Malawi

Burning Residues

- Reality:
  - Burning removes 95% of nitrogen from residues
    - Also sulfur and carbon lost to the atmosphere
  - Removes potential organic materials
  - Ash remaining easily lost thru erosion
    - 55% of P and 74% of N lost
  - If residues allowed to remain on field, would have decomposed
  - Loss of field cover
    - Greater water evaporation from soil
    - Soils ability to receive water reduced
    - Soils ability to absorb and hold water reduced

Soil Conditions in Malawi

Burning Residues, 2

- Reduce termite population by destroying organic food?
  - Termites will be there anyway
  - Would eat residue left in fields
  - Provide useful purpose burrowing in field
- Consequence
  - Have to weed the fields

Soil Conditions in Malawi

Ridging

- Plowing's purpose: weed control and aeration of soil
- Ridging: plowing employed without tractor or animal power
  - Digging and moving the previous years ridges in to the previous years furrows to make new ridges
- Plowing (tillage) affects different soils in different ways
  - Cannot apply same methods universally to all soil types and locations
- In England plowing was traditionally used to reduce weed growth
  - When English colony, required use of ridging under threat of fines and imprisonment,

Soil Conditions in Malawi

Ridging , 2

- In tropical soils, plowing is particularly damaging
  - Loss of moisture to air
  - Damage to developing soil
  - Erosion
- No-till farming becoming increasingly accepted in U.S.
- Eliminates huge labor effort
- Weeding required

Soil Improvement Options

Why Compost? Just bury everything?

- Composting : control natural decomposition of organic matter.
  - Decomposition occurs by microorganisms
  - Attention and control of factors that enhance biological activity
- By controlling composting conditions, rich soil is produced in shorter time, with better organic quality, than if simply buried in existing soil.
- Beware: Nitrogen immobilization can occur, starving plants for N, if insufficient N in recycled organics
  - if C/N > 30, N depression can last from days to months

Soil Improvement Options

Advantages of Composting

- Quicker organic breakdown than burying
- Store organic materials without odor problems until used
- Smaller volume and more uniform material after composted
- Nitrogen competition avoidance
- Slows decomposition of nutrients
- Partial sterilization of weed seeds

What makes composting work?

- Controlled factors to make good compost
  - Correct starting materials
  - Proportion of starting materials
  - Proper particle size
  - Adequate oxygen (air)
  - Sufficient moisture
  - Correct temperature range

What is Composting?

Particle Size

- Microbial activity occurs on the surface of the particles
- Chopping and shredding increases surface area: speeds up composting
  - Also breaks cell walls to make easier for microbes
- If too large pieces, too slow breakdown
  - If too small, bed is too dense, impeding air flow
  - Recommended size = ½ to 2 inches (1 to 5 cm)

What is Composting?

Feedstock: C/N Ratio

- Carbon and Nitrogen are the "food" for the microbes
- Microbes naturally use carbon for energy, and nitrogen to build cell protein
- Optimum starting ratio is 30
- Select materials to compost to achieve an average of this ratio
- If ratio significantly different, little or non-effective composting
  - If C:N > 40, slow rate because too little N
  - If C:N < 20, odor, ammonia smell, loss of nitrogen
- A well run compost pile will end up at a ratio of about 12.

What is Composting?

Raw Materials: Low C/N Ratios

(Low Carbon, High Nitrogen)

Grass/Clover	13
Legume hay	16
Vegetable produce	19
Tree trimmings	16
Shrub trimmings	53
Ground nut hulls	28
Cottonseed meal	7
Soybean meal	5

Manure: cow	13
Manure: horse	30
Manure: chicken	6
Manure: pig	14
Compost/soil	12
Vegetable wastes	12
Coffee grounds	20

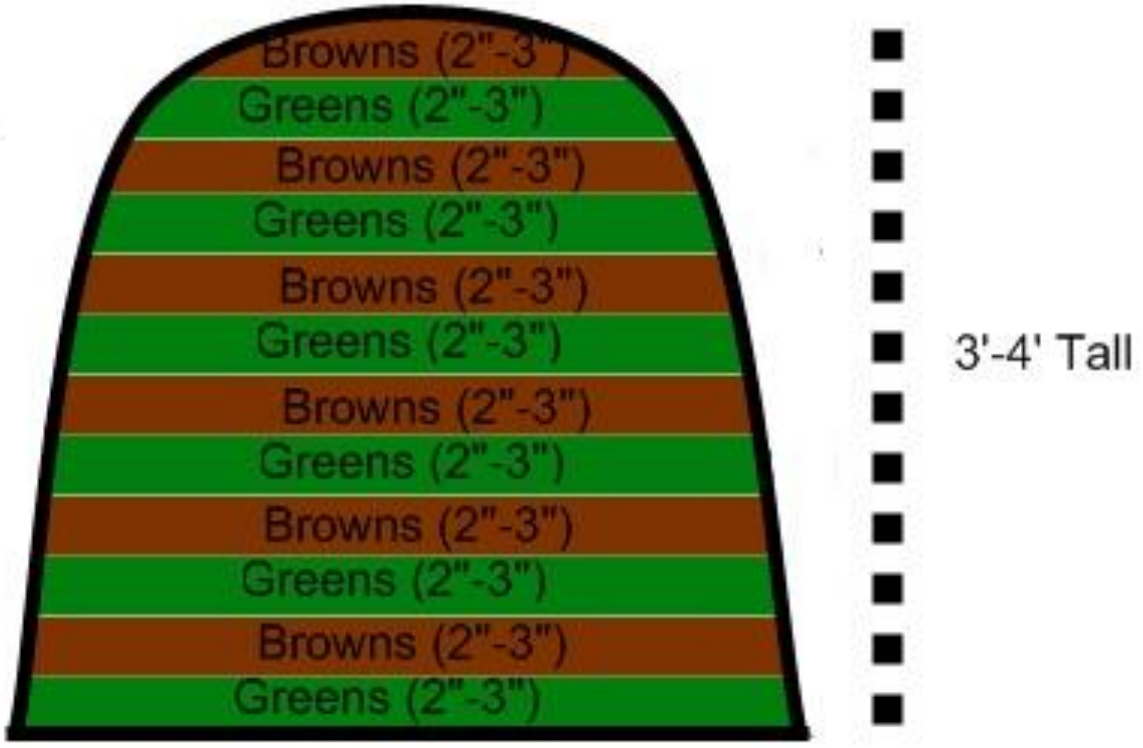
Raw Materials: High C/N Ratios

(High Carbon, Low Nitrogen)

Corn Cobs	100
Corn Stalks	66
Wheat Straw	60
Straw	80
Leaves	60
Wood chips	550-650
Sawdust	450
Newspaper	400-850

Constructing a compost pile

Alternate carbon and nitrogen rich layers



Constructing a compost pile

Establishing compost pile

Constructing a compost pile

Establishing compost pile

Note distribution of green (high N) and brown (high C) materials

Constructing a compost pile

Building a compost pile

Constructing a compost pile

Building a compost pile

Constructing a compost pile

Building a compost pile

Constructing a compost pile

Building a compost pile

Evaluation of Composting in Malawi

Building a compost pile

A well operating pile will become very hot!

Constructing a compost pile

Building a compost pile

What is Composting?

Moisture

- Sufficient water must be added to coat the composting material
- If water content too low, microbial activity slows down
- If too much water, water fills up air pockets, and limits oxygen needed by microbes.
- Quick squeeze test:
  - If you can squeeze a few drops with some difficulty, moist enough

What is Composting?

Oxygen

- Oxygen based (aerobic) biological composting is most efficient.
- In absence of oxygen, aerobic bacteria cannot thrive, and anaerobic bacteria take over, causing fermentation
  - Bad odor
  - Slower decomposition
  - Incomplete composting
- Turning pile needed to restore oxygen
- Covering pile contributes to oxygen starvation

What is Composting?
Temperature

- When proper initial conditions are established, temperature rises rapidly due to microbe activity

- Highest temp during the first week
  - Average bed temp 140 F (60 C)
  - If temp above 131 F (55 C) for 3 days: kills all pathogens
  - If temp above 145 F (63 C) for 3 days: kills all weed seeds

- Temp drops after several days due to consumed oxygen
  - Re-aerate and temperature will increase

- Complete when temp declines to 105 F (43 C) even after aeration

What is Composting?
Time

- Completion depends upon proper conditions and maintenance
- Nitrogen rich materials decompose fastest
- Aeration
  - Frequent turning: 2 months
  - Infrequent turning: 6 months
  - Passive: 6 months to 2 years

Evaluation of Composting in Malawi

- In 2009, Prof. Weil, U.S. soil fertility expert and textbook author, visited Malawi to evaluate composting methods, and provide training
- Collected and published photo images of locally generated compost to document techniques in Malawi
- Overall Conclusions
  - Government is encouraging use of composting to improve soil fertility
  - Insuffucient training provided in proper techniques
  - Great deal of effort and expense devoted to move materials without significant benefit
  - Number of improvements can be made

Evaluation of Composting in Malawi

"The farmers say that the pile of maize stover will be transported a couple of km to the home by ox cart, placed in the corral and trampled and urinated on by cattle and eventually returned to the field as "compost manure."

This practice represents an incredible investment".

And it doesn't work!

Evaluation of Composting in Malawi

Reasonably good quality.

But, still has a lot of soil in it.

Evaluation of Composting in Malawi

Excellent compost!

Evaluation of Composting in Malawi

More good compost

Evaluation of Composting in Malawi

Mainly undecomposed crop residues.

Dominated by corn stover.

Lot's of soil; little sign of decomposition

Evaluation of Composting in Malawi

Summary of Shortcomings Observed

- No sizing into smaller pieces
- Too much carbon, too little nitrogen
  - Lack of nitrogenous material available to improve feedstocks
  - Feedstocks primarily maize stover
- Piles are 50% and greater dirt
  - Dirt introduced when piles are made by use of hoes
- Little or no turning for aeration

Evaluation of Composting in Malawi

Summary of Shortcomings Observed, cont

- Piles dried out
  - Insufficient watering
- Little or no decomposition
  - Incomplete degradation retards utilization of available N
- Great deal of effort with little advantage

Evaluation of Composting in Malawi

"An ox cart delivery of another load of manure to a field: 40 to 80 loads are applied to an acre!

Collecting, preparing and transporting manure & residues is a major part of crop production.

Paying a days wage (MK 200) to transport a load of mostly soil to the field is an enormous waste. "

Evaluation of Composting in Malawi

"Composting Systems in Malawi"

- Changu System
  - Turned and watered regularly
  - Produces higher organic content
  - More effort to turn and water
- ChimatoSystem
  - Common in Malawi
  - Covered with mud and static
  - Intent is to retain moisture and heat
  - Suffers oxygen limitation w/o aeration
    - Fermentation; odors; incomplete degradation

Evaluation of Composting in Malawi

One method of making compost: Chimata Method.

Layers of chopped up crop residues and what little goat manure can be found are piled up, moistened and then covered with mud to keep the pile from drying out. I examined 7 of these piles and all had dried out as some breaks small or large had occurred in the packed mud covering.

Evaluation of Malawi Composting

Too Much Soil in Pile

- Using hoe to create and turn piles scrapes-in too much soil.
- Rake and garden fork are much better for this purpose.
- Too much soil prevents decomposing of residues
- Money and time spent moving soil from homes to the field.
  - Farmers lose interest when no benefits realized
- Un-decomposed residues tie up nutrients

Evaluation of Composting in Malawi

Garden fork for turning compost

Evaluation of Composting in Malawi

Using garden fork instead of hoe to lift organic residues.

Evaluation of Composting in Malawi

Comparing a pile of residues gathered by hoe vs a pile gathered by rake.

Evaluation of Composting in Malawi

Pile of residues gathered by scraping with a hoe. Soil will be mixed in.

Evaluation of Composting in Malawi

Pile of residues gathered with a rake.

Almost no soil

Evaluation of Malawi Composting

Pile too dry

- Mud cap is thought to keep moisture trapped inside:
  - But often inside dries due to breaks in mud.
- Use multiple holes inpile to distribute water
- Use bath waste water to keep compost piles moist
- Water in several spots to distribute moisture

Evaluation of Composting in Malawi

"Serious composting?. Every household has an active compost pit. Each household has bath house where family members take bucket baths, and bath water drains into the compost pit. Although the distribution of the water within the compost pile could be improved, this is excellent re-use of the water and assured that the compost---at least portions of it ---was kept fairly moist even in the dry season.

Could do the same for urine from a urinal.

Evalution of Composting in Malawi

"Another compost pit -- this one with the compost still in it --- connected by a small ditch to the bathing house.

Note also the pile of ashes added to the compost

-- again a good practice, but lacking awareness of the importance of mixing".

Evaluation of Composting in Malawi

"A compost pit full and covered with soil (I never could get good reason for doing that) and fed bath water through a pipe. Unfortunately the water come all to one spot.

The farmers need to be instructed to emphasize much more mixing of their compost to get a more uniform product and better decomposition."

Evaluation of Malawi Composting

Particle size too large

- Chop residues with panga knife
- Residues no larger than 2 inches long
- Result:
  - Better reactivity
  - Quicker breakdown

Evaluation of Composting in Malawi

Fresh corn stover dumped into pit.

Could really be helped by chopping it first

Evaluation of Composting in Malawi

Improper C/N Ratio

- Common situation: farmers . . .
  - collect dry maize stover & dry grass,
  - Add chicken manure (if available)
  - Put in pit or heap
  - Add water and soil

  - . . . . . .and expect good compost . . . But doesn't work!

- Need organic N source (green matter) to obtain C/N < 30

Evaluation of Composting in Malawi

"Finished compost"

But is mainly soil and undecomposed residues

C/N ratio is probably 50!

Evaluation of Composting in Malawi

Piles are full of undecomposed residue

Evaluation of Composting in Malawi

Examples of poor compost piles

Front pile is almost all undecomposed residues, which can immobilize nutrients when mixed back with soil.

Back piles are almost half soils with undecomposed residues

Evaluation of Composting in Malawi

Owner had just spread agricultural lime on the soil.

The pH was 4.77 -- so the lime was indeed needed.

Improving Malawi Soils

- Organic sources alone are not enough to replace nutrients that have been lost and are being removed
  - Severely depleted soils
  - Continuing inefficient practices
  - Inadequate supply of organic inputs
- Begin rejuvenating soils with organic materials in conjunction with modest use of inorganic fertilizers
- Introduce more effective farming practices

Improving Malawi Soils
Suggestions

- Chemical analysis to determine nutrient needs and pH
- Apply lime/ash as needed to adjust pH (acidity)
- Implement improved composting procedures
- Regular addition of composted organic material
  - Local recycling and collection
  - Import commercial AG byproducts

Improving Malawi Soils
Suggestions, 2

- Integrate livestock
  - Collect and spread/compost manure
  - Grazing
  - Chicken cages
- N building cropping systems
  - Legumes for N fixing
  - Green manure
  - Rotations, intercropping,

Improving Malawi Soils

Suggestions, 3

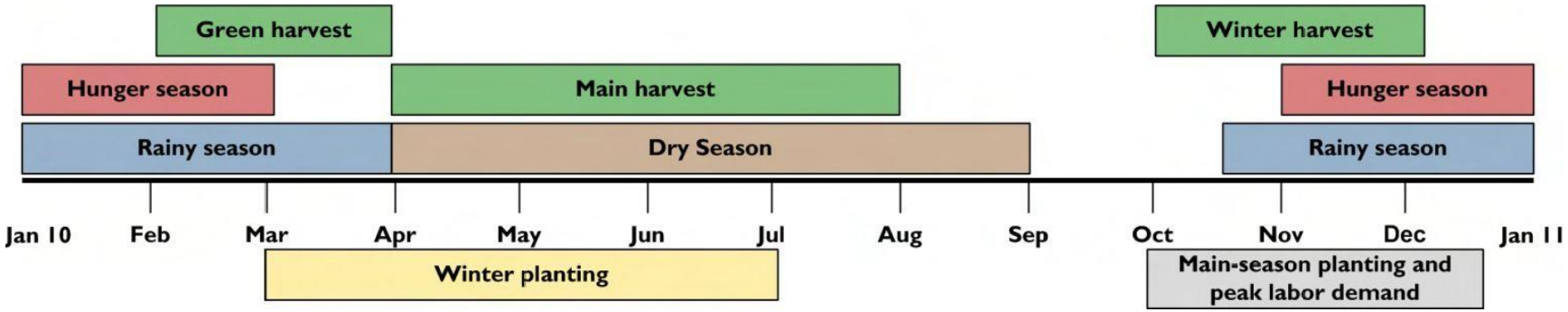
- Don't burn crop residues
- Minimize tillage
- Use mineral fertilizer as needed
- Education: technology & attitudes of farmers
  - Chitedze Agricultural Research Station, Lilongwe

Improving Malawi Soils

"Very well nourished tomato and other vegetables in a compost/manure fertilized kitchen garden.

Now if we can teach this gardener about pruning tomatoes…"

Improving Malawi Soils
Malawi Growing Seasons



Improving Malawi Soils

Organic Nitrogen

- Intercropping or rotating "green manure"
  - Increase maize production 30%
  - Buckwheat in infertile soils
- Legume plants: highest N content
  - Capable of utilizing or "fixing" N from air for their growth
  - Some plant tissues richer in N than other species
    - Highest N: Pigeon pea, Velvet bean, Fish poison bean
    - Others: Ground nuts, Cowpeas, soybeans
- Agroforestry in hedgerows

Improving Malawi Soils
Organic Nitrogen Issues

- Proper mix of low C/N material and high C/N material

Improving Malawi Soils

Increasing organic nitrogen through intercropping.

"Wider spacing makes sense to allow in light for inter-cropped beans"

Improving Malawi Soils

Increase organic N thru agroforestry.

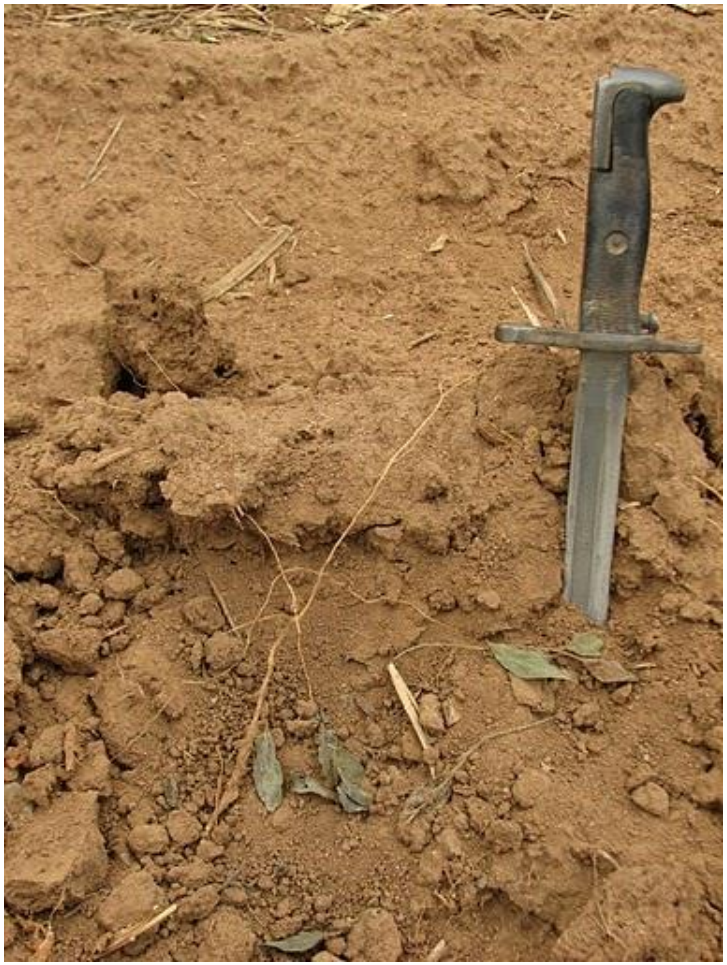
"Stumps of Gliricidia trees in a field planted in alley cropping.

This farmer has continued to prune the leafy branches that sprout from these stumps and use them as green manure. She reports better maize growth. The field has 0.5 units higher pH than the adjacent field without Gliricidia prunings."

Improving Malawi Soils

Increase organic N thru Agroforestry

Gliricidia leaves incorporated into the ridge before planting maize. When the rains come, the leaves will decompose, releasing N and P and other nutrients brought up by the trees from deep in the soil. They will also add to the SOM and buffer acidification."



Improving Malawi Soils

The stunted maize appears to suffer from aluminum toxicity which is stimulated by soil ph below 5.0 and low organic matter. The soil colors indicate much lower organic matter in the upper part of the field. What about the ph?

The ph was 4.7 around the stunted maize and 5.8 around the healthy plants. so we discussed how this farmer could apply ashes and compost to the upper part of the field to help the maize there grow as well as in the other areas.

Improving Malawi Soils
Organic Nitrogen Issues

- Plants can't use organic N
  - Must be converted to inorganic N
- If sufficient N in organic mix (C/N < 20):
  - intense microbiological activity
  - Quick composting: no N depression
- If insufficient N (C/N > 20): can make N situation worse
  - Microorganism become active because of C
  - Need N: will absorb from soil and growing plants, worsening N deficiency
  - Called immobilization: can tie up availability of N for several weeks to months

Improving Malawi Soils

Composting

- Local recycling
  - Community gathering center
  - Household and feeding center residues of organic materials
- Import local AG waste products
  - Malawi primary commercial crops: tobacco, tea, cotton, sugar
  - Cottonseed Meal
  - Sugar Cane
    - Trash
    - Press mud
  - Tobacco Dust

Improving Malawi Soils

Monitor pH

- Acidity of soil affects wide variety of soil properties
  - Controls the availability of nutrient elements for root uptake
  - More acidic soil
    - lower amount of N, P, K, S that can be absorbed
    - greater absorption of other nutrients that can become toxic
  - Hence effective utilization of fertilizer is reduced if pH is too low

Improving Malawi Soils

Monitor pH, con't

- Combination of low pH and low organic matter increases solubility of aluminum in soil
- Soil acidity common in most parts of Malawi
  - Very acid soils in Lilongwe ADDs.
  - Acidity can vary within same field
- Aluminum toxicity stunts root growth and reduces plant growth. Occurs when pH<5.5
  - Studies show 40% of Malawi soils has pH less than 5.5
  - Experiencing low crop yields
- Addition of lime to soil needed to raise pH
  - Collecting and spreading ashes from cooking fires raises pH and recycles nutrients

Improving Malawi Soils

Monitor pH

Healthy Maize Roots

Stunted (Al Toxicity) Roots

Improving Malawi Soils

Monitoring pH

"The difference in the maize roots was quite striking when held side by side."

Improving Malawi Soils

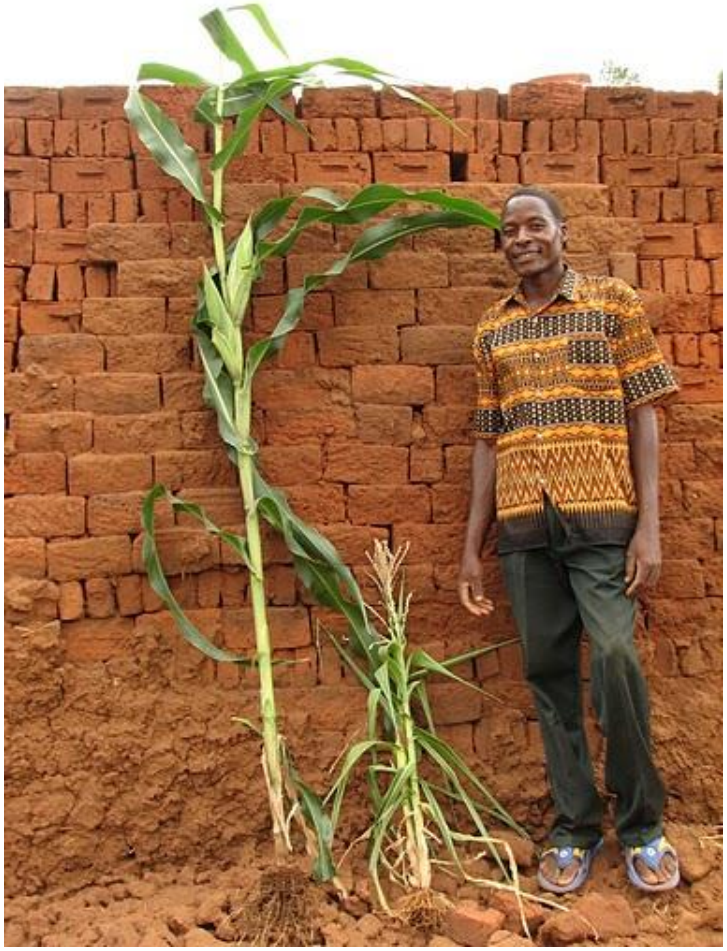
Monitor pH, cont

What a difference the soil makes!!!

Plant #1: higher organic matter, higher pH (pH=5.2)

Plant #2: stunted plant lower organic matter, more acid soil (pH = 4.7).

We discussed the need for this farmer to concentrate their compost on the eroded soils and also to collect and add ashes to the compost or directly to the soil.



Improving Malawi Soils

Monitoring pH, con't

Soil effect on maize produced!

Improving Malawi Soils

Keep Soil Covered

- Covering bare soil dramatically increases rain that enters soil, and decreases runoff (causing flooding and erosion)
- Even 10-30% soil cover yields substantial improvement
- Close growing vegetation or mulch of dead vegetative material
  - Managed fallows
  - Inter crops
  - Relay crops
  - Crop rotation
  - Mulch and crop residues

Improving Malawi Soils

Minimize Tillage

- Tillage
  - destroys soil cover
  - slows breakdown of organic materials
  - diminishes biological activity
  - Very costly in time and energy
- If tilled, allow 30% of surface covered by plant residues
- Downside is required weeding

Improving Malawi Soils
Conventional vs. Conservation Agriculture

- Conventional agriculture has been found to be a destructive practice in tropical soil environments
  - Gradual degradation of water and chemical deficit buffering capacity
  - Loss is a long process, so not immediately recognized
  - Dramatic reduction in crop yield
- Current practices will lead to more famine and poverty
- Conservation agriculture has been successful in Zambia and Brazil
  - Sustainability
  - Improved yields
  - Less labor
  - Increased profit
  - Crop diversification

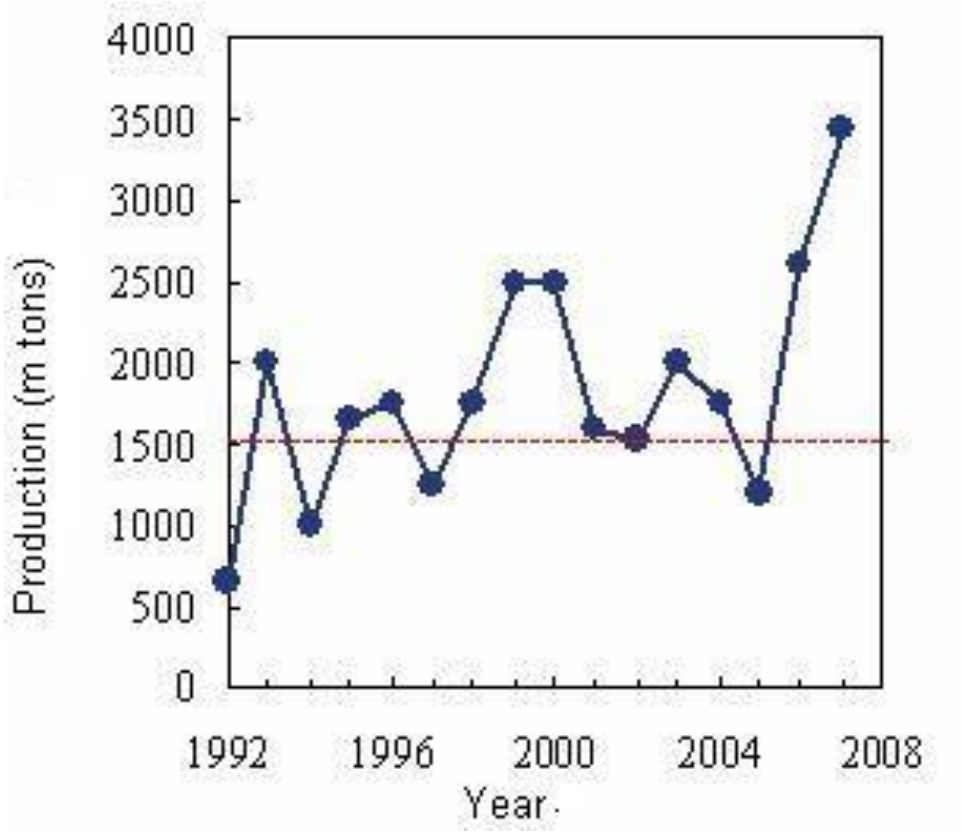
Improving Malawi Soils

Choice of Crops

- Maize is not native to Africa
  - was introduced in East Africa in the 16th century
  - Originated from South America, brought back to Spain
  - Promoted by colonial powers
  - Initiated maize monoculture
- Sorghum and millet are indigenous African grains
  - were staple crops for 1000's of years
  - Steep decline, now less than 10% of total planted area in Malawi
- May be good backup grain source

Maize Production in Malawi

Production below 1.5 million tons indicates a famine



Improving Malawi Soils
Choice of Crops, page 2

- Malawian maize production varies widely
  - Requires good deal of water; susceptible to drought
  - depends upon soil fertility
  - Food security of entire country depends upon Maize
  - Difficult to maintain self-sufficiency
  - Famine has occurred every 2-3 years
- Sorghum and millet are suited to African conditions
  - Drought tolerant
  - Sorghum requires 30% less water
  - Thrive in hot climates, poorly fertilized, and dry soils
  - Back-up grain source in difficult years

Improving Malawi Soils
Choice of Crops, page 3

- Yellow vs. White Maize
  - White maize is cultural preference
    - Yellow maize is animal fodder
  - Nectalopia due to vitamin A deficiency, and anemia due to iron deficiency, are widely observed in Malawi
  - Yellow maize would be effective in addressing problems because contain precursor to vitamin A

Improving Malawi Soils
Choice of Crops, page 4

- Pearl Millet
  - 6th largest cereal crop in the world
  - Staple crop to 1/3 of world's population (China, Japan, etc)
  - Most tolerant grain to heat and drought
  - Known since Old Testament times
  - Bread, cereal
  - Lower productivity yield than Maize; equivalent protein
  - Backup food
- Sorghum
  - 5th most important grain

Improving Malawi Soils
Choice of Crops

- Successful Malawian vegetables
  - Peanuts
  - Cassava
  - Sweet potatoes
  - Mustard greens
  - Cabbages
  - Tomatoes
  - Potatoes
  - Rape
  - Okra
  - beans

Improving Malawi Soils

Choice of Crops, con't

- Other Indigenous crops
  - Stigma of going backwards
  - Amaranth
  - Eggplant

Production of Staple Crops in Malawi