Eco-intensification
Soil Biology

How organisms help plants

- Decompose Organic Matter and release nutrients
- Dissolve minerals from rock
- Chelating and complexing nutrients
- Free living organisms fixing nitrogen from the soil air into plant available – Azobacteria & Cyanobacteria

How organisms help plants

- Plant Health:
  - Creating enzymes, vitamins, amino acids, and plant growth factors
  - Stimulating plant immune system
- Nutrition:
  - Rhizobia - Fixing soil nitrogen into plant usable forms
  - VAM (Vesiculum Arbusular Mycorrhizal) fungi - Directly feeding nutrients into plants
Eco-intensification
Soil Biology

How organisms help plants
Improving soil structure
- Building peds by disturbing and stirring clay and other particles into open random forms and gluing them together with humus, organic polymers and fungi hyphae.
- Macro-organism (earthworms and beetles etc) make large pores for drainage
- 'Cultivating' the soil, breaking into hard pans and moving soil particles around and making pores.

Soil Aggregation
A Biological Process

Glomalin is the green material on this soil aggregate.

An arbuscular mycorrhizal fungus colonizing a root. Hyphae are the thread-like filaments. The green coating on hyphae is glomalin.

Eco-intensification
Soil Biology

How organisms help plants
Fight Pests and Diseases
- Predating pathogens eg, eating pests and diseases
  - Protozia eating bacteria wilt
  - Fungi eating nematodes
  - Nematode eating nematodes
- Producing compounds that kill pathogens
- Suppressing pathogens through outnumbering them
- Detoxifying synthetic chemicals and poisons

Fungus trapping root eating nematode

Paraquat nematodes are killed when they contact zones of fungus, which can be used as biological control agents to fight soil borne pathogens. These parasites fungi grow through the soil, killing root bugs when they detect signs of their prey.
**Organic Matter**

Use Compost Microorganisms to Convert Soil Carbon into Stable Forms

- Convert the carbon compounds that are readily oxidised into CO2 into stable polymers
- The stable forms of soil carbon such as humus and glomalin are manufactured by microorganisms.
- Can last thousands of years in the soil.

**Mineral Balance**

The Yield of any Production System is Limited by Mineral/s that are Deficient

- A balanced mineral rich soil is essential to obtain optimum yields
- Conventional Agriculture usually only focuses on 3 elements – NPK
- Plants need around 30 elements
- Just one deficient element will limit yield
- A complete analysis soil test is used to assess the mineral balance of the soil

**Mineral Balance**

**Soil Test Minimum Nutrient Levels**

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>Minimum Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>6.0 - 6.8</td>
</tr>
<tr>
<td>Organic matter</td>
<td>3 - 6%</td>
</tr>
<tr>
<td>Calcium</td>
<td>1,800 ppm</td>
</tr>
<tr>
<td>Phosphorous P1</td>
<td>100 ppm</td>
</tr>
<tr>
<td>Phosphorous P2</td>
<td>200 ppm</td>
</tr>
<tr>
<td>Nitrogen</td>
<td>60 ppm</td>
</tr>
<tr>
<td>Magnesium</td>
<td>300 ppm</td>
</tr>
<tr>
<td>Potassium</td>
<td>175 ppm</td>
</tr>
<tr>
<td>Sulphur</td>
<td>75 ppm</td>
</tr>
</tbody>
</table>

**Trace Elements**

<table>
<thead>
<tr>
<th>Element</th>
<th>Minimum Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zinc</td>
<td>12 ppm</td>
</tr>
<tr>
<td>Manganese</td>
<td>20 ppm</td>
</tr>
<tr>
<td>Iron</td>
<td>20 ppm</td>
</tr>
<tr>
<td>Sodium</td>
<td>20 ppm (Keep below 70ppm)</td>
</tr>
<tr>
<td>Copper</td>
<td>5 ppm</td>
</tr>
<tr>
<td>Boron</td>
<td>3 ppm</td>
</tr>
<tr>
<td>Chlorine</td>
<td>3 ppm</td>
</tr>
<tr>
<td>Molybdenum</td>
<td>1 ppm</td>
</tr>
<tr>
<td>Cobalt</td>
<td>0.5 ppm</td>
</tr>
</tbody>
</table>
Mineral Balance

Examples of some critical mineral interactions

**Calcium**
- High calcium soils have a more friable structure and suppress disease pathogens in soils and plants

**Boron**
- Boron is essential for plants to transport calcium. Calcium is relatively immobile in plant cells and every cell needs calcium

**Molybdenum**
- Plants need small amounts of Molybdenum as a catalyst in the enzyme that converts nitrate and glucose into amino acids. It increases nitrogen use efficiency

Mineral Balance

The required nutrients are obtained as:

**Ground minerals**
- Lime, dolomite, gypsum, rock phosphate, basalt, quarry dust

**Soluble minerals**
- Trace elements and naturally mined potassium sulfate.

**Organic forms**
- Legumes, manures, organic mulch and naturally occurring free bacteria for nitrogen.

Composting speeds up the process of turning the minerals into plant available forms.

Organic Nutrients

**Nitrogen**
- Manure
- Compost
- Legumes
- Green manures
- Fish emulsion
- Microorganisms

<table>
<thead>
<tr>
<th>Source</th>
<th>Nitrogen (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manure</td>
<td>4-8%</td>
</tr>
<tr>
<td>Compost</td>
<td>1-4% av. 2%</td>
</tr>
<tr>
<td>Legumes</td>
<td>20 – 60 kg per hectare</td>
</tr>
<tr>
<td>Green manures</td>
<td>0.5-5%</td>
</tr>
<tr>
<td>Fish emulsion</td>
<td>4-11%</td>
</tr>
<tr>
<td>Microorganisms</td>
<td>up 40kg per hectare</td>
</tr>
</tbody>
</table>

Table of the Amount of Organic Nitrogen Held in the Soil

<table>
<thead>
<tr>
<th>SOC</th>
<th>Nitrogen Held (kg) per hectare</th>
<th>SOM (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1%</td>
<td>2,400</td>
<td>1.72%</td>
</tr>
<tr>
<td>2%</td>
<td>4,800</td>
<td>3.44%</td>
</tr>
<tr>
<td>3%</td>
<td>7,200</td>
<td>5.16%</td>
</tr>
<tr>
<td>4%</td>
<td>9,600</td>
<td>6.88%</td>
</tr>
<tr>
<td>5%</td>
<td>12,000</td>
<td>8.50%</td>
</tr>
</tbody>
</table>
## Organic Nutrients

### Nitrogen
- Nitrogen levels increase as soil organic matter (SOM) increases.
- SOM Carbon/Nitrogen Ratio = Between 12/1 to 9/1
- Every 1% increase of SOM per 20 cm/Ha holds about 4,000 kgs of N
- Most of this N is in amino acid form.
- The latest science shows that plants directly utilise amino acids and that biologically active soils convert it into nitrate and ammonia.
- Building up SOM is the best way to increase soil nitrogen.

### Phosphorous
- Manure: up to 2%
- Compost: up to 1%
- Rock phosphate: 24-30%
- Bone meal: 21-30%
- Fish emulsion: 1%

### Potassium
- Potassium Sulphate: 50%
- Basalt dust: 4%
- Granite dust: 3.6-6%
- Kelp: 4-15%
- Wood ashes: 7%
- Manures: 0.3-2%
- Compost: 1%
- Sawdust: 1%
- Fish emulsion: 1%

### Magnesium
- Dolomites: 20%
- Granite dust: 6%

### Sulphur
- Elemental Sulphur: 100%
- Potassium Sulphate: 18%
- Gypsum: 17%
- Manures: 0.1 – 0.2
Organic Nutrients

**Calcium**
- Calcium Carbonate (lime) 30-40%
- Gypsum 22%
- Dolomite 22%
- Rock Phosphate 16-30%

Trace Elements
- Rock Dusts – basalt, granite, rock phosphate, gypsum, lime and dolomite contain a wide range of trace elements.
- Compost
- Soluble forms are allowed to correct a recognised deficiency, i.e., zinc sulphate, sodium borate, copper sulphate, iron sulphate etc.
- Manures
- Seaweed
- Fish emulsion

Organic Nutrients

**Calcium**
- Calcium Carbonate (lime) 30-40%
- Gypsum 22%
- Dolomite 22%
- Rock Phosphate 16-30%

Nutrition for Crops

**Amount of nutrient needed**

\[
\text{Amount of nutrient you need apply} = \left(\text{[recommendation]} - \text{[soil test level]}\right) \times 2
\]

\[
\text{kg/ha}
\]

- [2 is a conversion factor based on 150 mm of soil depth]
- Get soil test in ppm (Parts per million) = mg/kg
Nutrition for Crops

**Amount of Organic Fertiliser to apply**

- Units of the nutrient ÷ % concentration of nutrient in fertilizer
- = amount of fertiliser to be applied to the paddock per ha

**Example:** Calcium

- Soil test indicates 1000 ppm
- Recommendation is 1800 ppm
- $(1800 - 1000) \times 2 = 1600$ units of Ca needs to be applied

- Gypsum contains 22% Ca
- $1600 \text{ Ca} \div 0.22 = 7,270 \text{ kg/ha} = 7.3 \text{ t/ha Gypsum to be applied}$

- Lime contains 33% Ca
- $1600 \text{ Ca} \div 0.33 = 4,850 \text{ kg/ha} = 4.85 \text{ t/ha Lime to be applied}$

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Eco-intensification

Agroecology

**Biodiversity**

- 'Organic agriculture has demonstrated its ability to not only produce commodities but also to "produce" biodiversity at all levels.' Food and Agriculture Organization of the United Nations (FAO 2003)

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Eco-intensification

Soil Biology

**Biodiversity**

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Nutrition for Crops

**COMPOST**

- Humus: Inoculates soil with humus building microorganisms
- Beneficial micro-organisms
- Suppresses soil pathogens
- Detoxifies poisons
- Feeds plants and soil life
- Builds soil structure

Composting Methods

**Sheet composting**

- Cover crop or crop residue spread with fresh manure and then cover crop sown and composting process occurs in soil.
- One advantage is very little nutrients are lost through leaching or volatilisation.
- The risk is residual chemicals in manure such as, drenches, tickicides, Atrazine, antibiotics etc. that can interfere with breakdown and weed seeds germinating.

**Aerobic compost**

- Ideal C:N ratio 25 – 35 : 1
- Moisture 60% at point of making (when squeezed hard moisture appears on outside of bolus)
- Temperatures that reach up to 70 degrees C.
- Constant supply of oxygen by turning at least weekly
- Well mixed
- Piles up to 2mtrs. high with 45 – 60 degree slump angle.
- Addition of high pH rock dusts such as lime and dolomite cause nitrogen losses

**Techniques to improve compost**

- Add worms (especially local soil worms) to digest and aerate - there is no need to turn.
- Add sticks, wood and coarse material. The lignin makes better humus
- Cover with wood chips, broken sticks and coarse material to prevent loss of methane, ammonia and nitrous oxide (nitrogen loss)
- Add subsoil clay to prevent ammonia and potassium losses
Transforming the Desert – 34 Years of SEKEM

The first SEKEM building in 1979
The same building in 2009

A SEKEM field in 1987
The same field in 2009

Innovative SEKEM: Aiming for the impossible...

Opening ceremony of the Sinai Project 2008

The land before...

...and changing our world...

SEKEM: Land Reclamation in the Desert
Minya, Upper Egypt, September 2010

...and after 18 months.
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Agroecology

- Full sun systems. Phase of establishment with plantains as temporary shade.
- Agroforestry system with shade leguminous trees.
- Successional agroforestry system with the same shade trees of the agroforestry treatment and in addition natural regeneration and crops.
- Taking into account natural plant species succession, the high turnover of carbon typical for the conditions of humid tropics, self regulation processes with high biodiversity, to use all storeys and provide as much as possible ecosystem services beside the cocoa production.

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Agroecology

... using high diversity nature for promoting beneficial insects and combating pests.

... spraying extracts of plants and other natural compounds against pests and diseases.

... using robust varieties.

Eco-intensification
Agroecology

**Insectaries**

- Refuges Created by Strip Mowing

- Borders of flowers create refuges for beneficial insects
**Eco-intensification**

Agroecology

*Insectaries* Perimeter plantings acts as barrier for pests and windbreaks

4 Rows of multiple crops in rotation

**Eco-intensification**

Living Mulch

• Conserves water
• Maximises solar capture
• Fixes nitrogen and soil carbon
• Flowers attract beneficial insects

**Eco-intensification**

Maximises solar capture
Fixes nitrogen and soil carbon
Flowers attract beneficial insects

Legume vines in fruit trees

**Conclusion**

A large body of published science shows:
• Organic agricultural systems can ameliorate Climate Change
• Reduce greenhouse gases
• Sequester carbon into the soil
• Use less water
• Reduce soil erosion and nutrient run off
• No chemical run off
• More resilient in adverse weather events
• Achieve good yields of high quality produce
Thank You