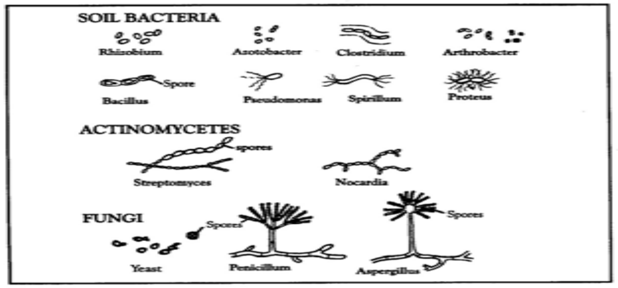
Eco-intensification
Soil Biology

ORGANISM	NUMBER PER ACRE	LBS PER ACRE
Bacteria	800,000,000,000,000,000	2,600
Actinomycetes	20,000,000,000,000,000	1,300
Fungi	200,000,000,000,000	2,600
Algae	4,000,000,000	90
Protozoa	2,000,000,000,000	90
Nematodes	80,000,000	45
Earthworms	40,000	445
Arthropods	8,160,000	830

(Adapted from: L.M. Thompson & F. Troeh, *Soils & Soil Fertility*, 4th ed., 1978, p. 111.)



62 *The Biological Farmer*

Eco-intensification
Soil Biology

How organisms help plants

Make nutrients available

- 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

Composition of Typical Soils

(for a plow layer 6⅔ inches in depth, approximately 2,000,000 pounds)

COMPONENTS	SANDY LOAM (lbs/acre)	SILT LOAM (lbs/acre)	CLAY LOAM (lbs/acre)
Organic matter	20,000	54,000	96,000
Living portion, microbes earthworms, etc.	1,000	3,600	4,000
Nitrogen	1,340	3,618	6,432
Silicon dioxide	1,905,000	1,570,000	1,440,000
Aluminum oxide	22,600	190,000	240,000
Iron oxide	17,000	60,000	80,000
Calcium oxide	5,400	6,800	26,000
Magnesium oxide	4,000	10,400	17,000
Phosphate	400	5,200	10,000
Potash	2,600	35,000	40,000
Sulfur trioxide	600	8,500	6,000
Manganese	2,500	2,000	2,000
Zinc	100	220	320
Copper	120	60	60
Molybdenum	40	40	40
Boron	90	130	130
Chlorine	50	200	200

(Compiled by J.L. Halbeisen & W.R. Franklin.)

Eco-intensification
Soil Biology

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

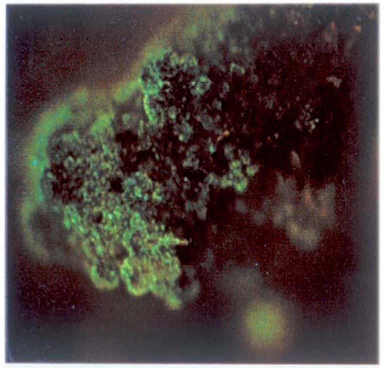
Eco-intensification Soil Biology

How organisms help plants

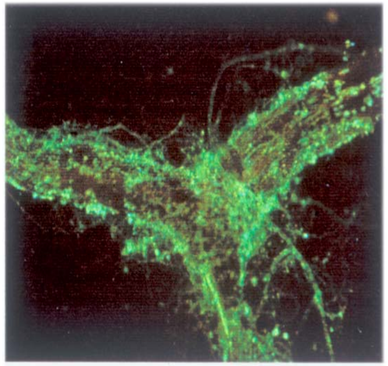
Improving soil structure

- 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 (earth worms 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

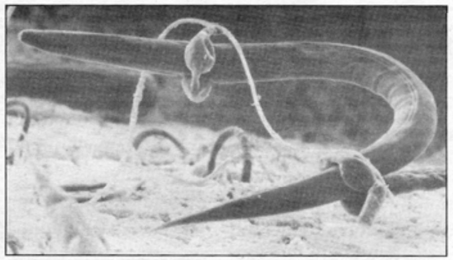
Fight Pests and Diseases

- 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

Eco-intensification Soil Biology

How organisms help plants

ACRES U.S.A.



Parasitic nematodes may fall prey to certain types of fungi, which can be used as biological control agents to fight soil-borne pathogens. These predatory fungi grow through the soil, setting out traps when they detect signs of their prey.

Fungus trapping root eating nematode

Organic Matter

Use Compost Microorganisms to Convert Soil Carbon into Stable Forms

- Convert the carbon compounds that are readily oxidised into CO_2 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

pH	6.0 - 6.8
Organic matter	3 - 6%
Calcium	1,800 ppm
Phosphorous P1	100 ppm
Phosphorous P2	200 ppm
Nitrogen	60 ppm
Magnesium	300 ppm
Potassium	175 ppm
Sulphur	75 ppm

Mineral Balance

Trace Elements

Zinc	12 ppm
Manganese	20 ppm
Iron	20 ppm
Sodium	20 ppm (Keep below 70ppm)
Copper	5 ppm
Boron	3 ppm
Chlorine	3 ppm
Molybdenum	1 ppm
Cobalt	0.5 ppm

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	**4-8%**
Compost	**1-4% av. 2%**
Legumes	**20 – 60 kg per hectare**
Green manures	**0.5-5%**
Fish emulsion	**4-11%**
Microorganisms	**up 40kg per hectare**

Organic Nutrients

Nitrogen

- **Table of the Amount of Organic Nitrogen Held in the Soil**
- 1% SOC = 2,400 kg of organic N per hectare = 1.72% SOM
- 2% SOC = 4,800 kg of organic N per hectare = 3.44% SOM
- 3% SOC = 7,200 kg of organic N per hectare = 5.16% SOM
- 4% SOC = 9,600 kg of organic N per hectare = 6.88% SOM
- 5% SOC = 12,000 kg of organic N per hectare = 8.50% SOM

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

Organic Nutrients

Phosphorous

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

Organic Nutrients

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%

Organic Nutrients

Magnesium

Dolomite	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%

Organic Nutrients

Calcium

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Organic Nutrients

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, ie zinc sulphate, sodium borate, copper sulphate, iron sulphate etc.
- Manures
- Seaweed
- Fish emulsion

Nutrition for Crops

Amount of nutrient needed

- ([recommendation] - [soil test level]) x 2 = [amount of nutrient you need apply] 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

Nutrition for Crops

Example: Calcium

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

- Gypsum contains 22% Ca
- 1600 Ca ÷ 0.22 = 7,270 kg/ha = 7.3 t/ha Gypsum to be applied

- Lime contains 33% Ca
- 1600 Ca ÷ 0.33 = 4,850 kg/ha = 4.85 t/ha Lime to be applied

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)*

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 volatisation.
- The risk is residual chemicals in manure such as, drenches, tickicides, Atrazine, antibiotics etc. that can interfere with breakdown and weed seeds germinating.

Composting Methods

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

Composting Methods

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.

… and after 18 months.

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

Eco-intensification
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 turn over 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.

Eco-intensification
Agroecology

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

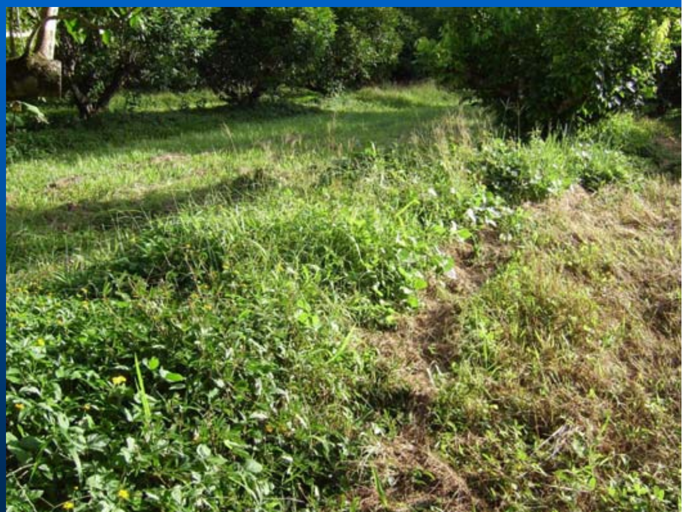
… spraying extracts of plants and other natural compounds against pests and diseases.

… using robust varieties.

Eco-intensification
Agroecology

Insectaries

Refuges Created by Strip Mowing



Eco-intensification
Agroecology

Insectaries

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