

Building healthy soils with cover crops and farmer-to-farmer learning



Henry Anton Peller

henryantonpeller@gmail.com – 627 7683

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What are cover crops?

Exceptionally vigorous plants that quickly cover the soil



3 month old mucuna
climbed over 15 feet



3 month sunn hemp
over 8 feet tall

Cover crops build living, fertile topsoil!



Left: small milpa with long-term mucuna cover crop in coastal Honduras, 4-5K lbs / acre corn

Right: 1000 acre corn farm with long-term cover crop mix in Ohio Valley, up to 14K lbs / acre corn

ZERO FERTILIZER OR TILLAGE



Horrific drought in Madagascar. Traditional maize farm.



Right next to it, maize with 'lojy be' cowpea cover crop.

Credit: Roland Bunch

**Control weeds, reduce
herbicides & labor input**

**Conserve soil moisture,
protect from erosion**

**Produce human food
and animal fodder.**



Many cropping systems



Annual grains, roots
& vegetables



Orchards &
agroforests



Integrated
livestock

Used by millions of farmers at every scale

Review cover crop species in detail

CLIMBING	UPRIGHT	COVER	TREE
Mucuna	Pigeon pea	Jackbean (bush)	Madre/glircidia
Jackbean (vine)	Sunn hemp	Arachis/Peanut	Inga
Lablab	Hemp/cannabis	Cowpea	Moringa
Rice, mung, urd beans (Vigna)	Oats, corn, sorghum...	Tillage raddish	Pigeon pea

Basic principles & practices to
manage them to build healthy soil

Reflect on...

Ways for people to
organize & learn
from one another to
change their reality.



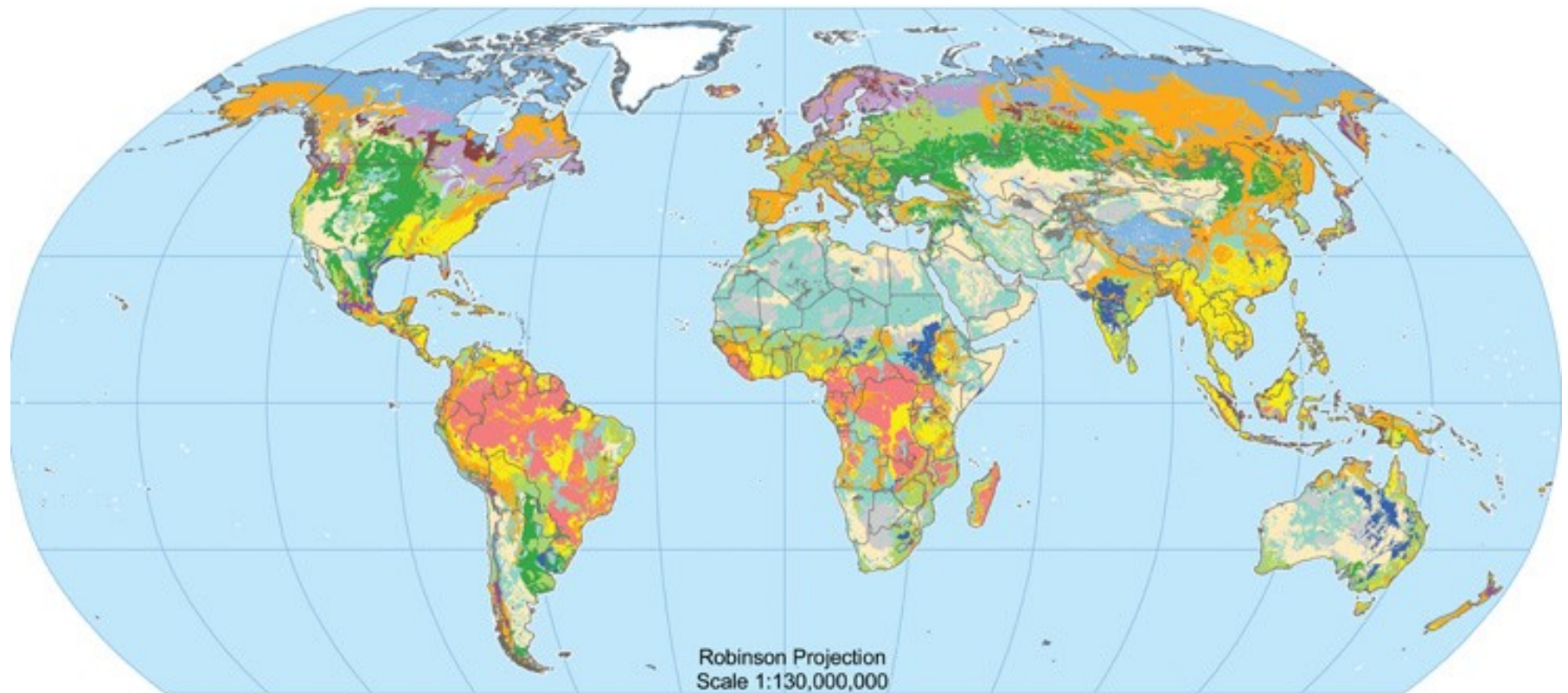
Relationships of
soil ecology to
political struggle &
climate change.


















Contents

1. Soil ecology
2. Tropical cover crops & practices
3. Learning & organization

Global Soil Regions



Soil Orders

 Alfisols	 Entisols	 Inceptisols	 Spodosols	 Rocky Land
 Andisols	 Gelisols	 Mollisols	 Ultisols	 Shifting Sand
 Aridisols	 Histosols	 Oxisols	 Vertisols	 Ice/Glacier

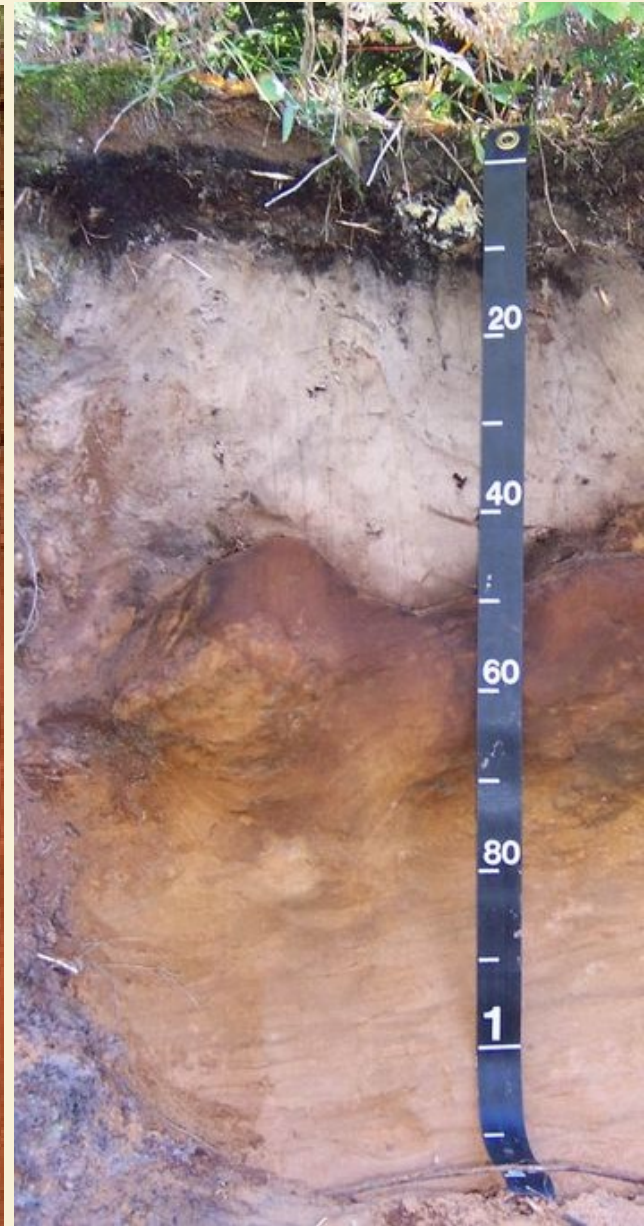
Diversity of soils in the world



Mollisol



Oxisol



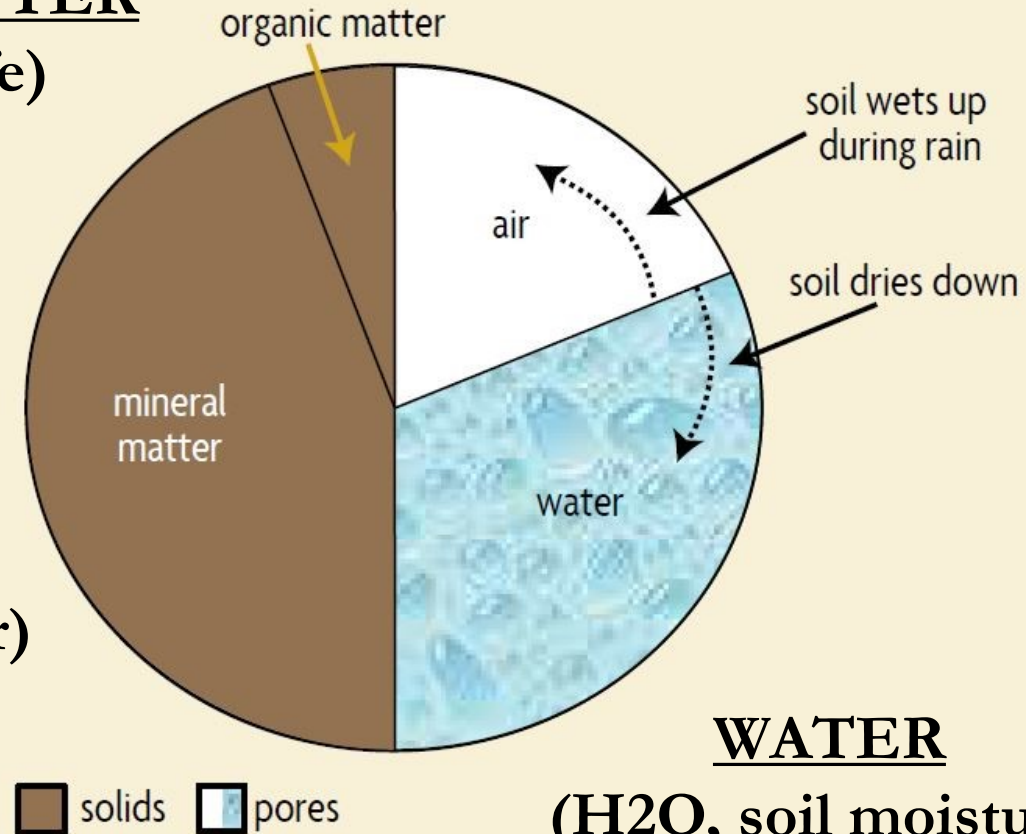
Spodosol

Basic elements of soil

ORGANIC MATTER
(Biological life)

AIR
(H, O, C, N based gases)

ROCK MINERALS
(‘soil texture’ and color)



WATER
(H₂O, soil moisture)

Scale of Miles



1	Biotite Granite
1A	Muscovite Granite
1B	Porphyrite
2	Quartzite, Sandstone
2A	Shale
2B	Phyllites, Slate
3	Interbedded Calcareous Sandstone, Shale
3A	" " " " , Sandy Mudstone
3B	Shale with thin cover of Coastal Sand
4	Dense White Limestone (Cretaceous)
4A	Siliceous Limestone (")
5	Fragmented Limestone & Chalk (Eocene)
5A	" " " " (") with Tuff
5B	" " " " (") " Flints
5C	" " " " (") " Silica Sand
6	Coral Limestone (Pliocene)
6A	" " (") with Tuff
6B	Stranded Coral Gravels
7	High Terrace (Pleistocene & Post-Pleistocene)
8	Coastal Sediment (Pleistocene)
8A	" " shallow over Eocene Limestone
8B	Consolidated Weathered Dune Sand
9	Calcareous Clays
9A	Non-Calcareous Clays
9B	Recent Alluvium
10	Stranded Coral Limestone & Mangrove Peat
10A	Recent Dune Sand & Mangrove Peat

Local soil diversity in one village of Toledo District



River Soil



Hill soil

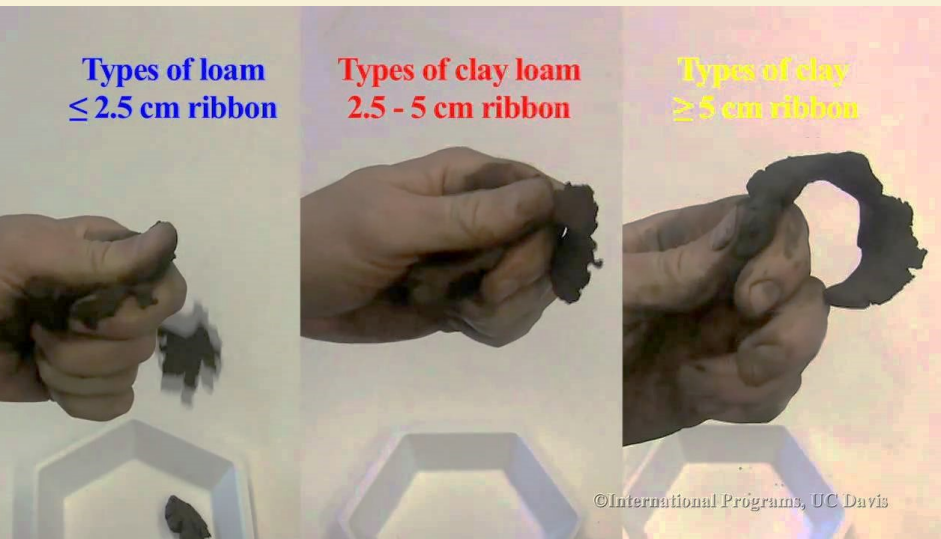
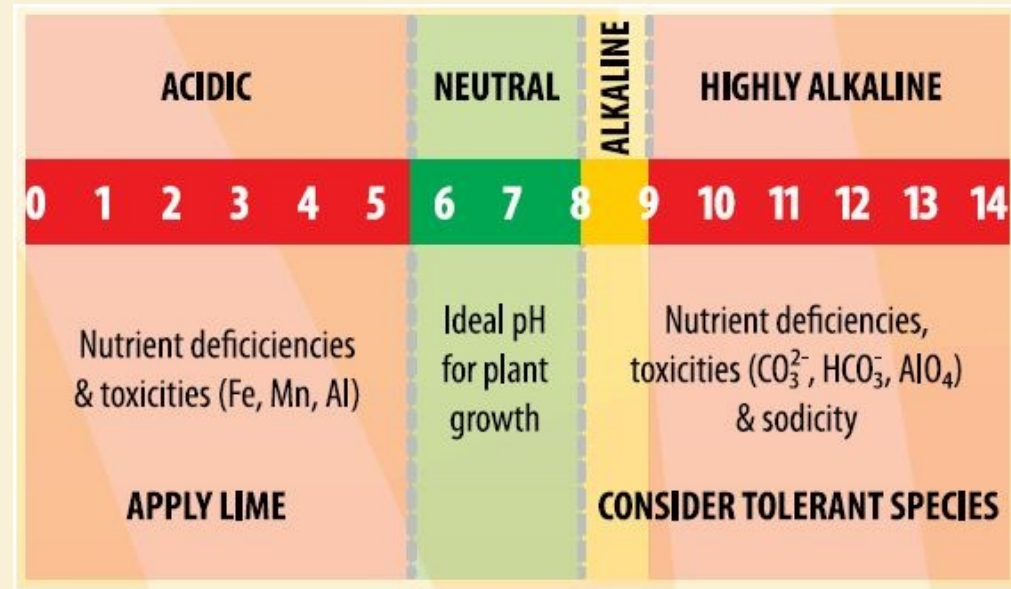
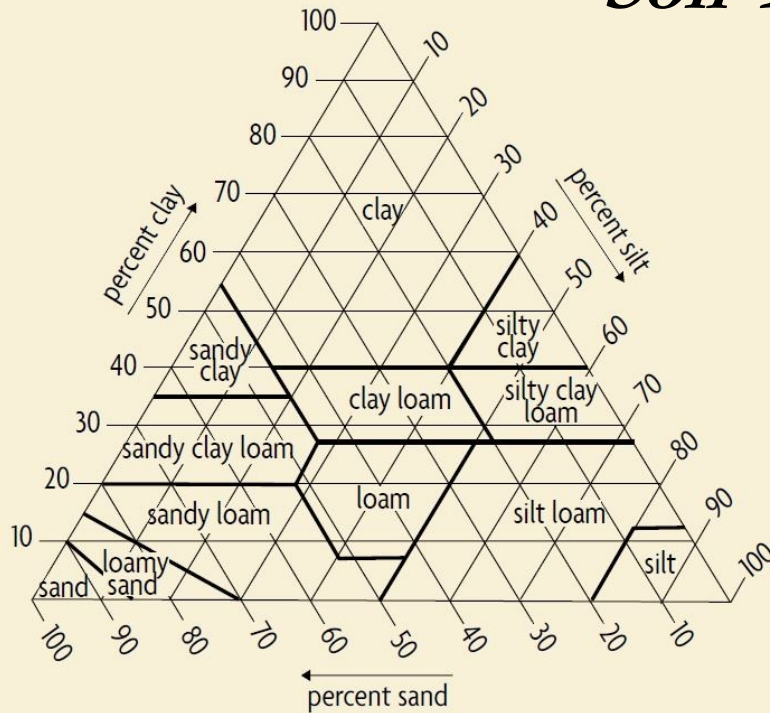


Limestone soil



Lowland soil

Soil Texture & pH



Collect soil from several locations & depths (topsoil, subsoil, deep subsoil). Simple tests:

1. Texture: Roll a ball and squeeze into ribbon. Longer ribbon = clay. Wet a piece of soil and rub between fingers. More grit = sandy.

2. pH: Break soil into small pieces. Mix 1 part soil to 1 part DEIONIZED (battery) water, mix completely, let settle for ~15 minutes, test with meter



Humus & mulch O

Topsoil A

Transition AB

Subsoil B1

Subsoil B2

Transition soil-rock C

Rock R

Interpret mineral & water components, across profile

Rock Type – what rock type is under & around the soil? What is pH?

Texture – is the soil sticky clay, soft loam, gritty sand? Combination?

Structure – is the soil soft & crumbly, hard & dense?

Slope – is the place steep or flat, does water & sediment run off or gather?

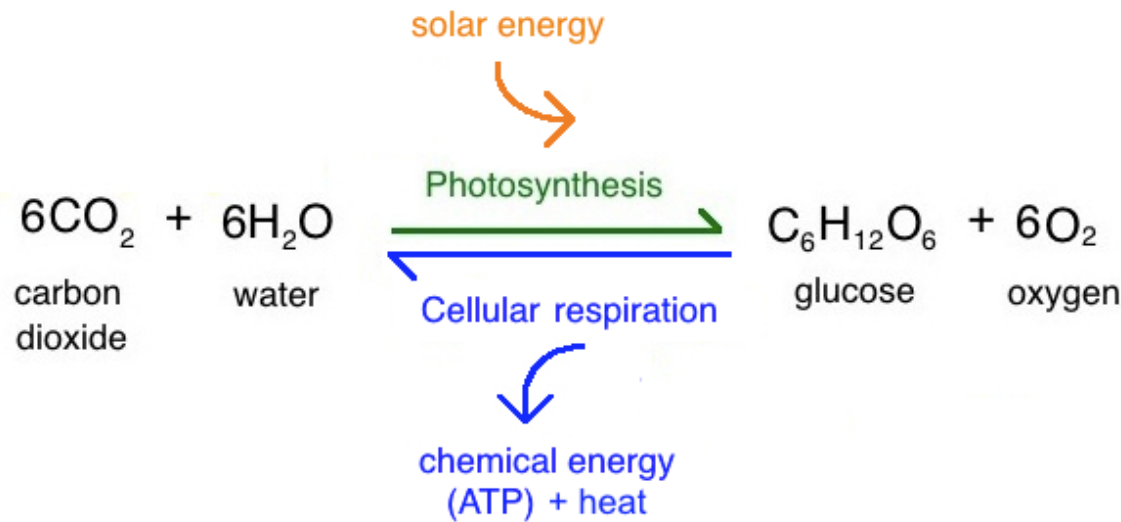
Water – is the soil wet or dry? how high is water table? does water go into the soil or sit on top?

Interpret the living component



Powered by Photosynthesis

Sunlight, carbon, and water combine in chloroplast of the plant (the green fluid). **Photosynthesis** produces carbon compounds that are energy source for most of Earth's ecosystems.

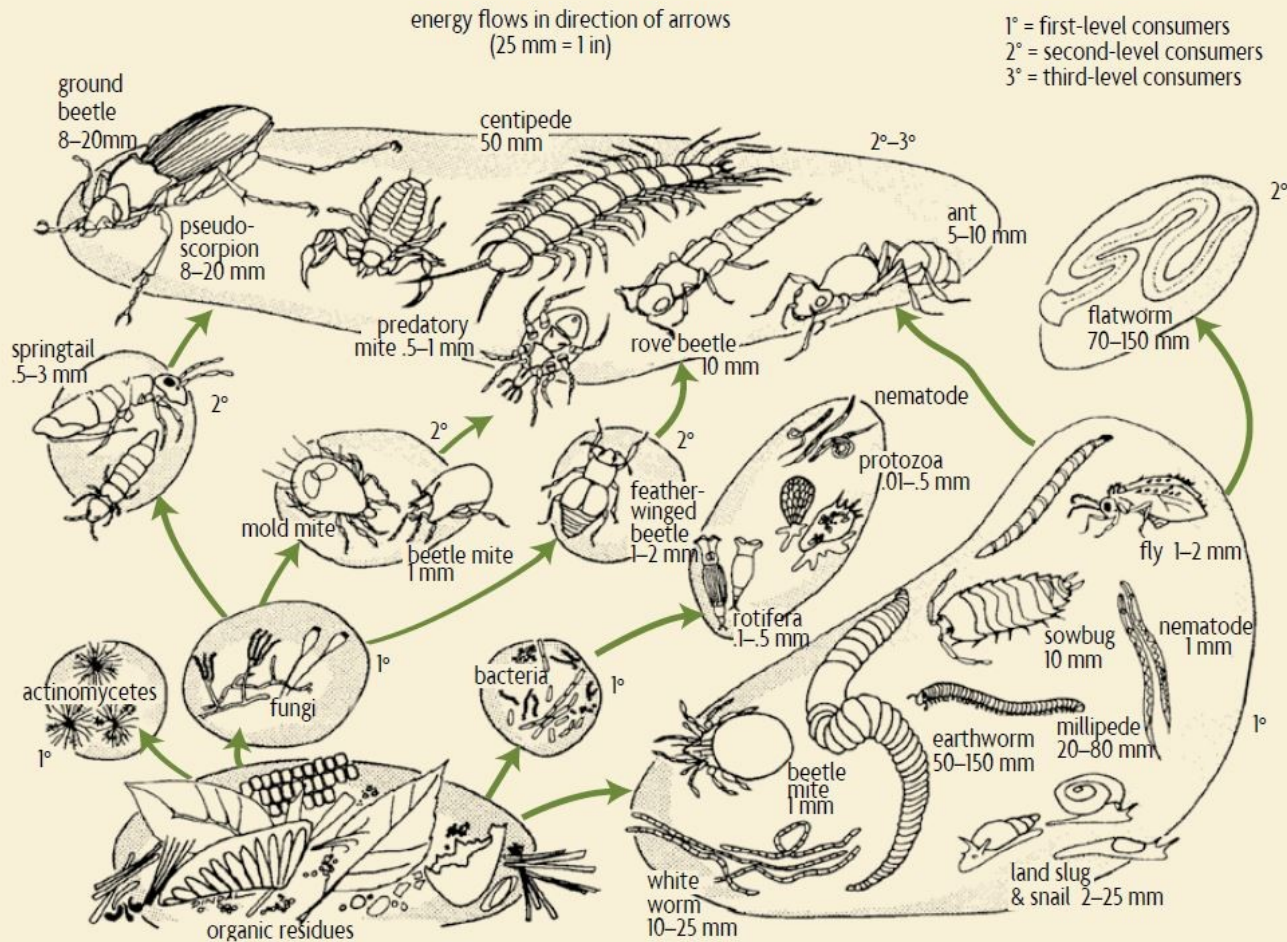


1. Decomposition: “Dead Carbon”

Plant roots, leaves & branches die. Forms mulch layer on soil.

Fungi, bacteria, insects, and more consume dead plant material.

Carbon energy compounds transform & cycle through the system



2. Rhizosphere: “Living Carbon”

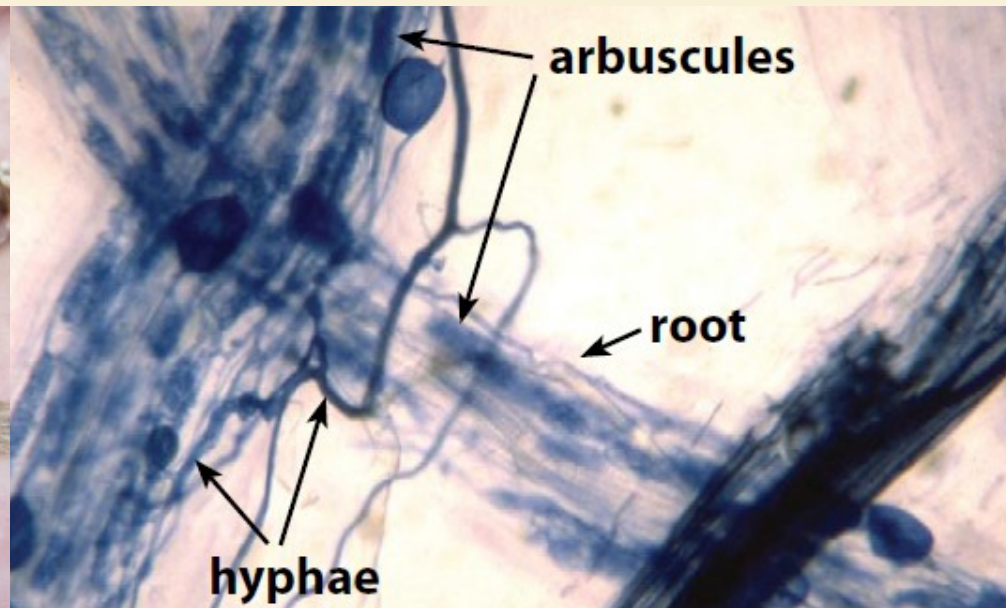
Plants feed micro-organisms through their roots.

Micro-organisms concentrate around root zone, called ‘rhizosphere’

Exchange water & nutrients for carbon sugars.



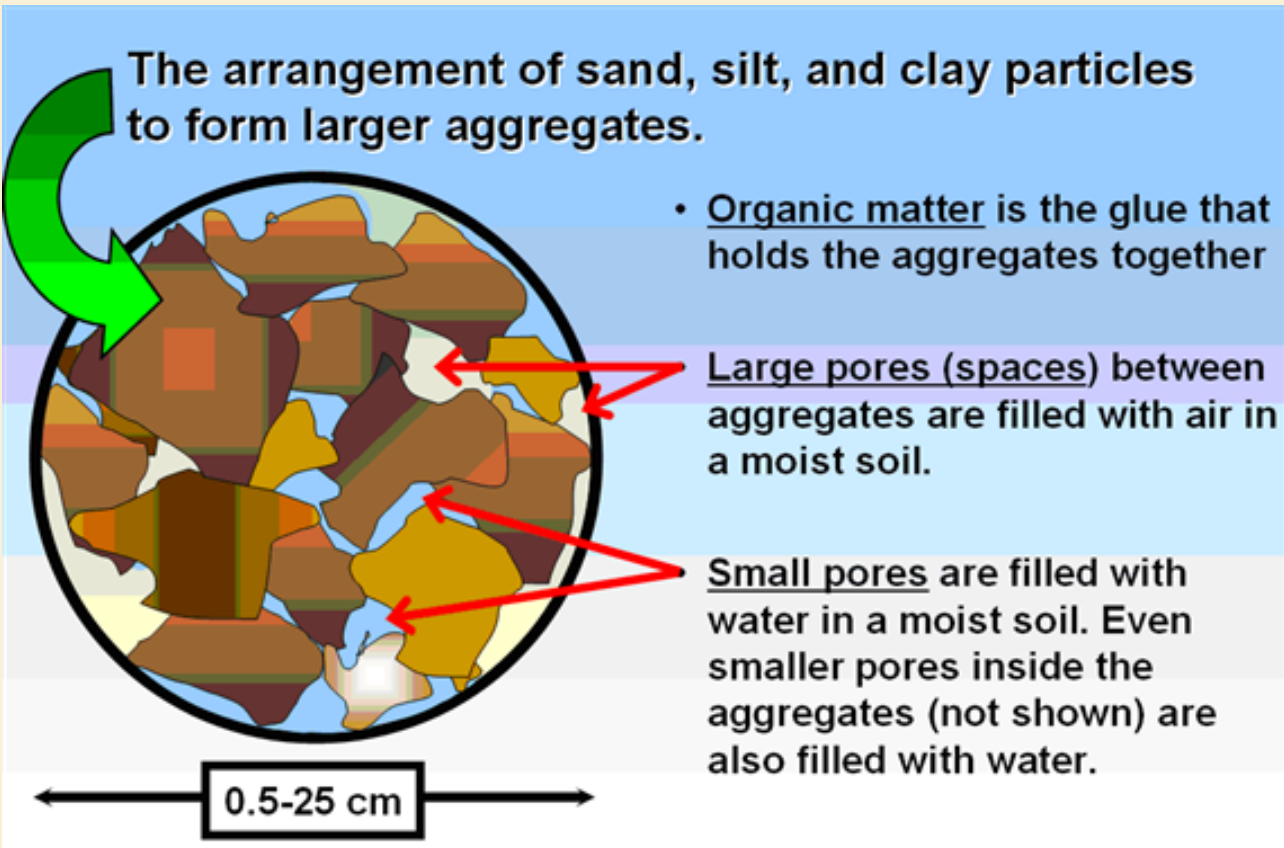
Legume-Rhizobacter
nitrogen fixation



Arbuscular Mycorrhizal Fungi
phosphorous & water

Soil Structure

Biological carbon glues soil minerals together into a crumbly, soft soil structure (“aggregates”) that hold water



What does a forest soil feel like?



Humus & mulch O

Topsoil A

Transition AB

Subsoil B1

Subsoil B2

Transition C

Interpret the living component

- What color is the topsoil? Is it significantly darker than the subsoil?
- Do you see roots, fungi, life?
- Is the topsoil crumbly and well-aggregated? Too powdery or compacted (disturbed)?
- If you can, do periodic laboratory test for **soil organic matter / carbon**.
- Can also test for nutrients. If the soil is healthy, with high organic carbon, then many nutrient problems go away.
- If healthy soil still has deficiencies, add amendments & minerals (lime, phosphate, micro-orgs, compost, etc.)

What hurts the soil ecosystem?

Disturbances:

Bare, exposed soil

Ploughing & tillage

Synthetic fertilizers

Anti-biotics (fungicides, herbicides)

Too much fire

Kill soil life, destroy structure

Cause erosion & drought



Monocultures

Limited plant species

Suboptimal photosynthesis

Poor quality rhizosphere

Pest & weed infestations



Rarely do we find monocultures outside of low-quality farms.

Most ecosystems have complex mixes of plants.



Regenerating healthy soils

1. Reduce disturbances

- Zero/low tillage & chemicals
- Wise use of fire

2. Soil covered & living

- No bare soil
- Always grow something

3. Promote diversity

- Annuals & perennials, polycultures, rotations
- Integrate livestock, wildlife habitat

**Cover crops are a proven way to move
principles of soil ecology into PRACTICE.**

CLIMBING	UPRIGHT	COVER	TREE
Mucuna	Pigeon pea	Jackbean (bush)	Madre/glircidia
Jackbean (vine)	Sunn hemp	Arachis/Peanut	Inga
Lablab	Hemp/cannabis	Cowpea	Moringa
Rice, mung, urd beans (Vigna)	Oats, corn, sorghum...	Tillage raddish	Pigeon pea

**And MANY more... for humid to semi-arid
tropical ecosystems (Belize & Mesoamerica).**

Goal: build living, fertile topsoil!



Tools for Milpa & Garden

1. Seeds: locally adapted
(best from your farm)

2. Blade / machete
(herbicides if bad weeds)

3. No-till seed drill
(sharpened stick)





For machine tractors

ROLLER CRIMPER
(crushes cover crop)

+

NO-TILL SEED DRILL
(culter disc to cut mulch)

See: Rhodale Institute





For horses

Cover crop crimper + No-till drill
ZERO PLOUGHING

Healthy soil, weed control

Left: Ariel Espinoza, Nicaragua
Bottom: Orchard Hill Farm



Check roots for nodules:
Where there are nodules, the legume-
Rhizobia association is working

Badly damaged soils or new legume
species may need one-time Rhizobia
inoculation for that soil. Use broad
spectrum inoculation, with many
Rhizobia species.

Of course there are many other
beneficial micro-organisms & effective
inoculants, but that's another story...



Mucuna – *Mucuna* spp.

- Name: abon, mucuna, velvet (bean/frijol)...
- One of most popular tropical cover crops in world
- Rapid growth, soil restoration, nitrogen, weed control, animal food
- Tolerates most soils, except strong acid ($\text{pH} < 5$), very wet/swampy



Mucuna establishment

- If no/low weed competition, broadcast seeds ~10 lbs / acre. Easy, free weed control.
- If high weed competition, drill close spaced ~20-30 lbs / acre. May need to spray or till weeds before planting, but move to eliminate this with sustained cover cropping.
- Controls *Impertea cyclindrica* and most other difficult weeds. Struggles with common 'itch grass' *Rottboellia cochinchinensis*.



Mucuna – inter-crops & rotations

- Planted 30-60 days after corn or other grains. Will climb up corn stalks at harvest time.
- Otherwise, excellent in rotation with vegetables, roots, any annual. Suppresses nematodes.
- Can be used as a ground cover under trees but most species require pruning.



Cover crop termination

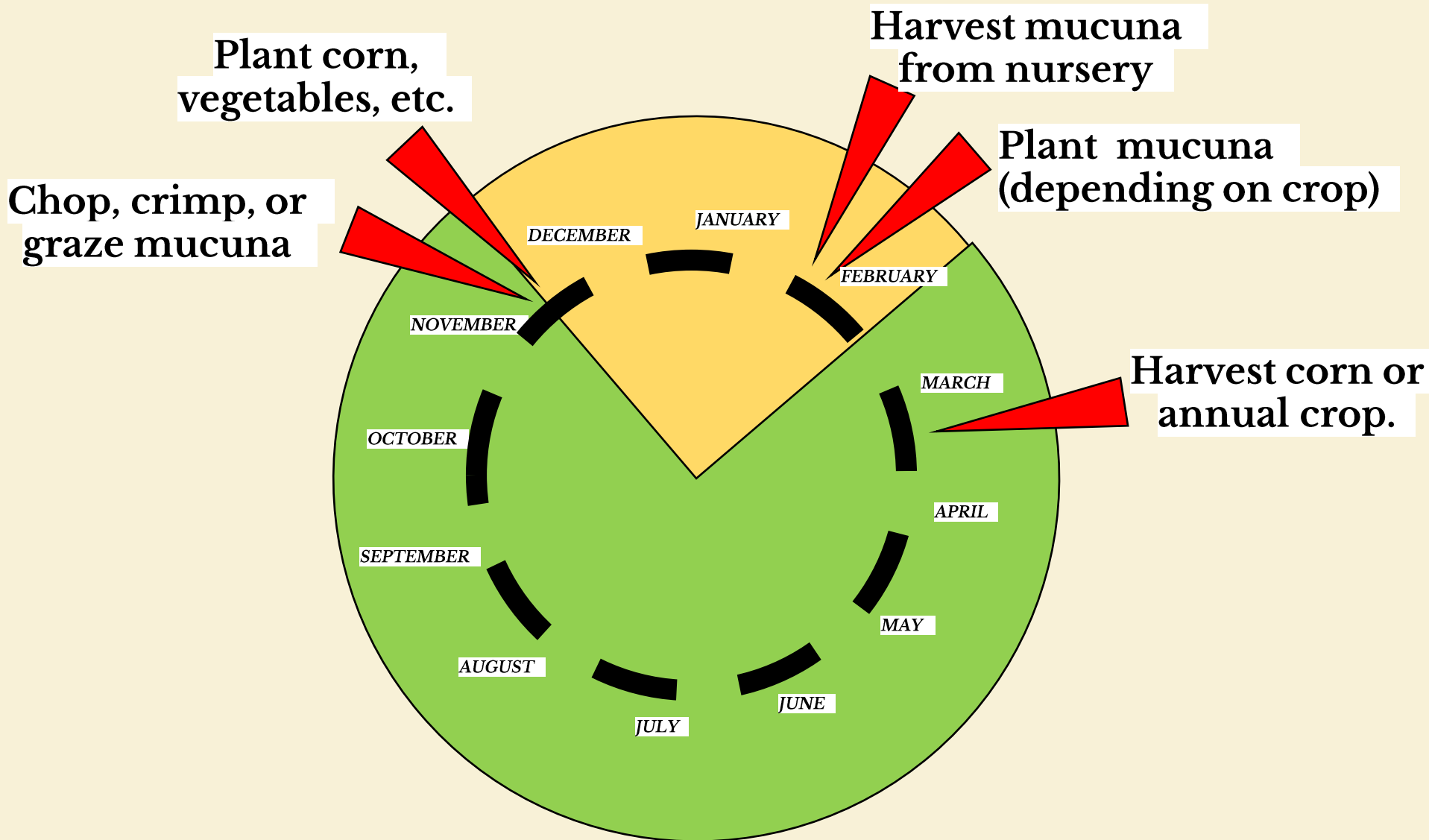
Many options to kill the cover crops.

- Chop with machete or mower
- Graze with livestock for high-protein fodder & pods
- Crimp with roller-crimper
- Or simply dies after bearing, re-seeding itself. This can be good or bad, depending on your crop. Corn planted right after mucuna dies in January works very well.
- **If terminated before bearing seed, excellent weed control for annual crops. After several years of this practice can greatly reduce weed seeds in the soil (but weed seeds can still blow or flood in...)**

Mucuna – termination

- If you kill cover before seeding, you must keep a nursery, or buy from seed producer, and RE-PLANT the cover crop.
- Most cover crops bear more seed in drier, sunnier weather. Climbing cover crops also bear best when they have a trellis (cohune palm). Time your nursery planting & harvest to get a good seed yield.
- Keep your nursery in one, well-managed part of the farm. Keep a physical, dry stored back-up of all seeds, a “seedbank.” This is the mother for the rest of the farm.

Mucuna – calendar



Mucuna – seeds

- Phototropic: regardless of planting time, bears as day-length shortens (Nov-Jan).
- Beans make high protein animal feed if boiled 1-2 times, draining water before consuming. Also try sprouting them in water.
- Can bear huge amounts of seed, especially when climbing.



Jackbean – *Canavalia* spp.

- Names: kenq cabay, horse bean... Vine & bush species/varieties
- Excellent growth, nitrogen, weed control, repels *Atta* spp. (weewee) ants, somewhat edible.
- Extremely drought tolerant. Grows in most soil types and pH, except very wet/swampy soil. Thrives in Belize.



Jackbean

- Broadcast or drilled, depending on weed competition (same as mucuna). May need 1 weeding for best establishment.
- Bush variety is excellent intercrop for almost anything: corn & millet, cacao & coffee, vegetables, cassava.
- Vine variety used same as mucuna with corn, except it grows through dry season, unlike mucuna. Excellent for Belize's dry-season fallow period.



Jackbean

- Chop, mow, or crimp to terminate (poor for grazing).
- Edible green pods (eaten as vegetable), but seeds inedible.
- Begins to bear seed ~5 months.
- Repel weewee ants in field where planted. Can be planted right on top of nests. Or can cover nest in leaf several times to poison nest.



Lablab bean – *Lablab purpureus*

- Excellent growth, N fixation, weed control, delicious beans, animal feed. Less vigorous than mucuna and jackbean.
- Grows in most soils, except very wet soil. Drought tolerant.
- In Belize, seem to be damaged by insects at height of rains, especially in south. Need to keep selecting & adapting seed.



Lablab bean

- Broadcast or drilled 2-4 weeks after corn, 10-20+ pounds per acre.
- Mature seed pods ~6 months. Excellent green or dry beans.
- Like mucuna can over-take vegetables, trees, etc.
- Highly edible leaves & pods for grazing.



Rice bean

Vigna Umbellata

- Names: cho kenq
- Excellent weed control, N-fixation, highly edible seed & leaves.
- Bear seed ~6 months, but can become weed. Try early termination.
- Similar to mung, urd, and other *Vigna* beans.
- See especially cowpeas (*Vigna unguiculada*)



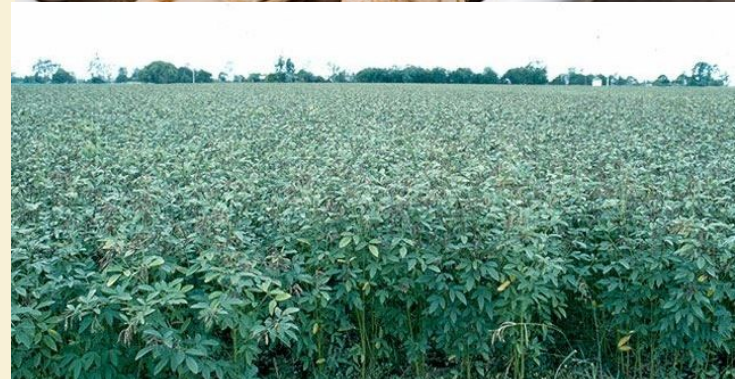
Pigeon Pea – *Cajanus cajan*

- Name: Che kenq, congo pea, gandules
- Slow to start then rapid growth, N fixation, delicious beans.
- Grows in most any soil, except wet/swampy
- Inter-cropping with most any annual crop.



Pigeon Pea

- Plant at same time as corn (& most annuals), 1m apart in rows spaced between main crop. Need to be weeded 1-2 times, then take off quickly.
- Most begin to bear seed ~6+ months, some bred to bear seed much faster.
- Grow for several years, producing most beans for first 2. Other crops can be maintained under/around them.
- Excellent for establishing agroforests, cacao plantations, etc.
- Or, strait cover crop similar to hemp and sunn hemp.



Sunn Hemp

Crotalaria juncea

- Rapid growth
- N-fixation
- Excellent forage
- Or crimp & plant crop
- Plant ~25 lbs / acre
- No known use in Belize, need locally adapted seed & system



Perennial peanut

Arachis pintoii

- Best ground cover for orchards, banana groves, vanilla farms. Tolerates partial (not total) shade.
- Fixes N and controls weeds.
- Work to establish. But once it is in, basically management-free.
- Transplant cuttings spaced as close as possible into cleaned area.
- Biggest limitation is source of cuttings, need nursery first.



Photo -Werner Stur ©



Tillage Radish

Raphanus sativus L.

- Daikon, oilseed, ‘sodbuster’
- Quickly grow very larger tubers, very. Loosen soil without damaging it, for free.
- Scavenge nitrogen. Decompose & release it for next crop.
- Flowers & bears seed with longest day (June 21).
- Plant **after** longest day of year (June 21) to grow big tuber (no flowering).



Madre de cacao

Gliricidia sepium

- Easy to plant by stick
- Rapid growth
- N-fixation & leaf nitrogen
- Live fence posts
- Firewood
- Mulch & browse



Madre de cacao

Planted in rows for mulch, fertilizer, and dispersed shade (climate change = too much heat!!) in gardens & farms. Similar idea as “Inga alleycropping” but faster start-up, less effective mulch. Needs other cover crops in combination.



Inga – *Inga spp.*

- Bitz, bribri, chawchuck
- Tremendous leaf mulch
- Excellent weed control
- Fruit & firewood
- More work to establish
- 2-3 year rotation if used by itself
- Can be combined w/ other cover crops



Polycultures: planting them together

Farmers & scientists all over the world are finding best performance with diverse mixes of cover crops. More photosynthesis & carbon, biomass production, thriving rhizosphere, better weed control.

Mimic a tropical forest ecosystem: no monocultures.

- Combine species that fill difference niches
- Climbers, runners, uprights, perennials
- Drought tolerant & wet tolerant
- Rotations between cover crops, main crops, livestock



3 month old mix of mucuna, jackbean, and madre cacao mix in low-fertility soil of Aguacate, Belize.



40 species and many mixes grown by Dave Brandt in Ohio with no-till, zero fertilizer, little herbicides. Incredible soil health and yields.

TROPICAL COVER CROP SELECTION CHART

Drought Tolerant

Adapted to Humidity

Grass

Broadleaf

Grass

Growth Habits:

- ↑ - Erect
- ↗ - Semi-erect
- ↔ - Spreading
- ⤵ - Climbing

Use:

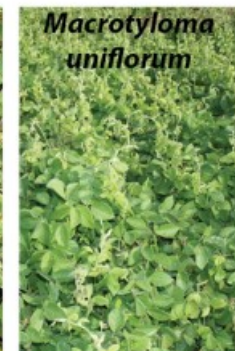
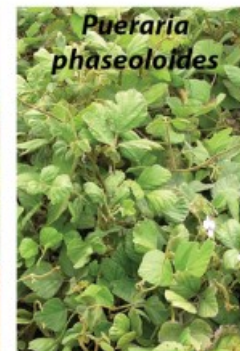
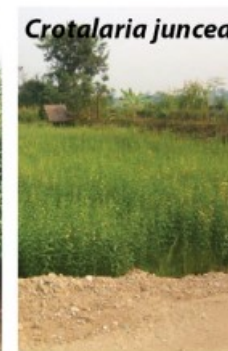
Residues of crops when left on the field, replenish soil organic matter and nutrients. Legumes have higher potential to add Nitrogen to the soil than non-legumes.

- 👤 - Human Consumption
- 🐮 - Forage

Growing Duration:

- A - Annual
- P - Perennial

Sorghum <i>Sorghum bicolor</i> ↑ 👤 🐮 A											Growth Habits: ↑ - Erect ↖ - Semi-erect ↔ - Spreading 🌀 - Climbing		Use: <i>Residues of crops when left on the field, replenish soil organic matter and nutrients. Legumes have higher potential to add Nitrogen to the soil than non-legumes.</i> 👤 - Human Consumption 🐮 - Forage		Growing Duration: A - Annual P - Perennial											
Teff <i>Eragrostis tef</i> ↑ 👤 A	Amaranth <i>Amaranthus cruentus</i> <i>Amaranthus hypochondriacus</i> ↑ 👤 A											Leguminous				Fruit Trees (star fruit, papaya) <i>Averrhoa carum bota</i> , <i>Carica papaya</i> ↑ 👤 🐮 P	Job's Tears <i>Coix lacryma-jobi</i> ↑ 👤 A/P									
Fonio <i>Digitaria exilis</i> ↑ 👤 A	Lagos spinach <i>Celosia argentea</i> ↑ 👤 A													Perennial peanut <i>Arachis pintoi</i> ↔ 🐮 P	Coconut <i>Cocos nucifera</i> ↑ 👤 P	Sugarcane <i>Saccharum officinarum</i> ↑ 👤 🐮 P										
Guinea grass <i>anicums maximum</i> ↑ 🐮 P	Spiderplant <i>Cleome gynandra</i> ↑ 👤 A																									
Finger Millet <i>Eleusine coracana</i> ↑ 👤 A	Moringa <i>Moringa oleifera</i> ↑ 👤 🐮 P	Fish Bean <i>Tephrosia vogelii</i> ↑ P	Stylo <i>Stylosanthes guianensis</i> ↔ 🐮 P	Sunnhemp <i>Crotalaria juncea</i> ↑ A	Sunnhemp <i>Crotalaria ochroleuca</i> ↑ 🐮 A	Hariy Indigo <i>Baptisia arachnifera</i> ↑ 🐮 A	Velvet Bean <i>Mucuna pruriens</i> ↔ 🌀 A	Oil palm <i>Elaeis guineensis</i> ↑ 👤 P	Rice <i>Oryza sativa</i> ↑ 👤 A																	
Pearl Millet <i>Pennisetum glaucum</i> ↑ 👤 A	Buckwheat <i>Fagopyrum esculentum</i> ↑ 👤 🐮 A	Pigeon Pea <i>Cajanus cajan</i> ↑ 👤 🐮 A/P	Peanut <i>Arachis hypogaea</i> ↔ 👤 🐮 A	Cowpea <i>Vigna unguiculata</i> ↔ 🌀 👤 🐮 A	Jack Bean <i>Canavalia ensiformis</i> ↑ 🌀 A	Tropical Kudzu <i>Pueraria phaseoloides</i> ↔ 🐮 P	Siratro <i>Macroptilium atropurpureum</i> ↔ 🐮 P	Coffee <i>Coffea arabica</i> ↑ 👤 P	Corn <i>Zea mays</i> ↑ 👤 🐮 A																	
Signalgrass <i>Brachiaria sp.</i> ↔ 🐮 P	Sunflower <i>Helianthus annuus</i> ↑ 👤 🐮 A	Moth Bean <i>Vigna aconitifolia</i> ↔ 👤 🐮 A	Lablab <i>Lablab purpueus</i> ↑ 🌀 👤 🐮 A	Horse Gram <i>Macrotyloma uniflorum</i> ↔ 👤 🐮 A	Rice Bean <i>Vigna umbellata</i> ↖ 👤 🐮 A	Mung Bean <i>Vigna radiata</i> ↔ 👤 🐮 A	Soybean <i>Glycine max</i> ↑ 👤 🐮 A	Cassava <i>Manihot esculenta</i> ↑ 👤 🐮 P	Napier Grass <i>Pennisetum purpureum</i> ↑ 🐮 P																	



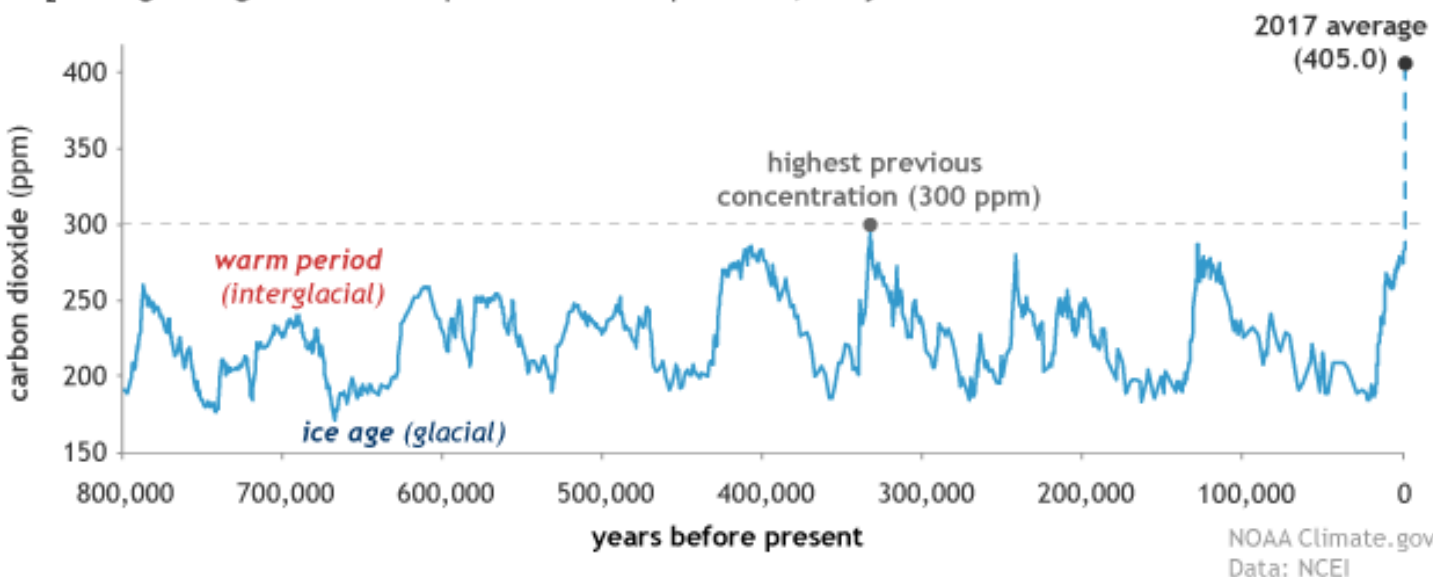
Finding seeds in Belize

- So far I know that Central Farm and also me (Henry) are trying to make seeds more available. Get in touch. All you need is a handful to start with.
- Many can be found across Belizean farming communities, especially mucuna, jackbean, madre, inga. Mennonite and Maya communities often have mucuna.
- See the end of Roland Bunch's *Restoring the Soil* (link on last page) for international seed sources.
- There is real business potential in selling cover crop seeds in bulk wholesale. Make a community seedbank & nursery: share seed.

Strategy

- Good news: Cover crops (and many more methods) regenerate soil health. Draw down carbon, build resilience, produce food.
- Bad news: We are facing an ecological crisis of Biblical proportions. Climate change will destroy reefs, flood cities, cause crop failures, create extreme storms & drought, generate epic refugee crisis. It is petrifying, turns us to stone.
- How can we scale-up with godspeed?

CO₂ during ice ages and warm periods for the past 800,000 years



Farmer-to-farmer

- Start slow through dialogue & meetings, one-on-one and in groups.
- Farmers and support network (agronomists, scientists, community leaders) identify problems & practices
- Build trust, communication, shared vision, democratic process:

SOCIAL ORGANIZATION



Farmer-to-farmer

- Translate to easy-to-begin, on-farm, small-scale experiments that farmers can do right away. Testing new seeds is easy place to start.
- Where funds & interest exist, make public experimental learning & nursery farms. Work with your family & community.
- Critical to start with an early success (like mucuna). The learning process can build to more complex practices & projects.



Farmer-to-farmer

- Amplify successful innovations. Farmers are best teachers for farmers. Farms are the best classrooms.
- Exchange regularly between communities, across differences. Build scale & solidarity of learning process.
- Share seeds. Build seedbank and live nursery wherever possible.
- Is this enough?



Struggle

- Some of us dream about a “Green New Deal,” a massive, global, government investment for the climate. Some of that optimism fuels this conference.
- Rightward lean to fascism, perpetuation of imperial war, monopoly capitalism in energy & agri-business... indicate that our revolution is not on the horizon.
- If a ‘green social democracy’ does take shape, it will only be because of social movements of organized & united people that aspire for more.
- Wherever possible, we must organize our families and communities to confront climate crisis, resist violence & hatred, practice love & kindness, heal ourselves & earth, build global movement & solidarity.

Organize!



<https://viacampesina.org/en/>

Conclusion

- Cover crops are powerful, proven tools to build topsoil, increase productivity, reduce costs...
- We reviewed many useful species: mucuna, jackbean, lablab, pigeon pea, madre, inga, and more.
- Lots of work to do to experiment, breed, and mix species for Belizean farmers & environment.
- Let's connect, henryantonpeller@gmail.com 627 7683
- Organize, experiment, and never give up!

Key References

- Roland Bunch, 2012, *Restoring the Soil*,
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