CLIMATE CHANGE ADAPTED AGRICULTURE

GREEN MANURE/COVER CROPS

Patrick Trail

Research and Technical Associate
ECHO Asia Impact Center
ptrail@echonet.org

Lessons Learned thus Far:

- Conservation Agriculture:
  i. Reduced or Minimum Tillage
  ii. Crop Rotation and/or Diversity
  iii. Year-round organic soil cover
- Integrated Pest Management
  i. Breaking up of pest cycles
  ii. Need for crop rotation/species diversity

What are the Goals of Climate Adapted Agriculture?

- Resiliency (to extreme weather events, pest outbreaks, etc…)
- Reduced reliance on fossil-fuel derived inputs
- Carbon sequestration
- Erosion and run-off prevention
- Reduced water usage

Profitability

Productive

Practicality

Manageable

Locally Adapted

Sustainability

The Question is:

How do we achieve all of these objectives when land is limited/degraded, inputs are unavailable or unattainable, labor is scarce, and profits/surpluses need to be made?

Green Manure/Cover Crops

What is a Cover Crop?

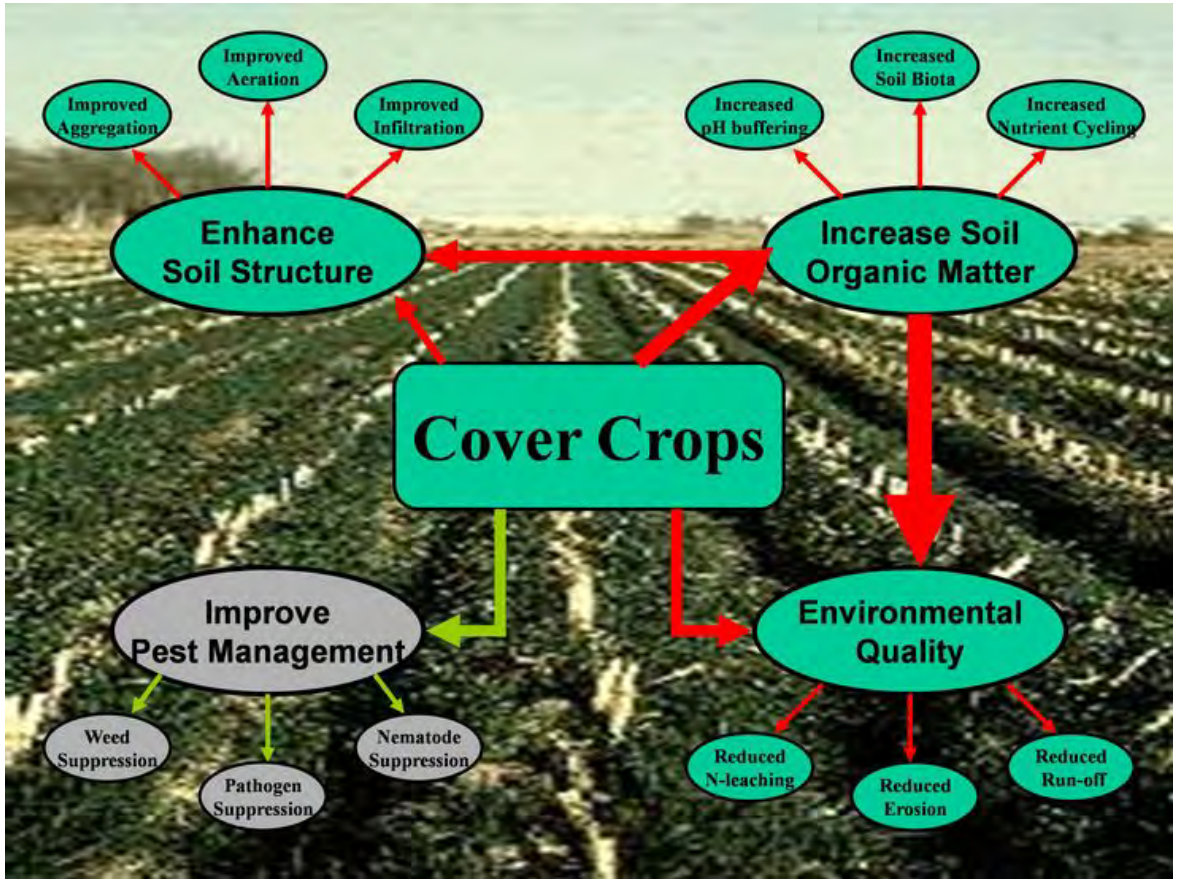
"A crop grown for the protection and enrichment of the soil"

"Typically grown in the 'off-season' or at times when the 'primary' crop cannot be grown"

What is a Cover Crop?

"A crop grown for the protection and enrichment of the soil"

- Addition of organic matter
- Weed suppression
- Soil water holding capacity
- Infiltration
- Temperature reduction
- Break pest cycles
- Improve soil fertility through
  N2 Fixation (legumes)



The Question is:

How do we achieve all of these objectives when land is limited/degraded, inputs are unavailable or unattainable, labor is scarce, and profits/surpluses need to be made?

How do we achieve all of these objectives when ***land is limited***?

Monoculture

Intercropping

Involves two or more crops planted *simultaneously* on the same piece of land

Rows

Intercropping

Advantages:

- Chances for success with intercrop systems may be increased, risk is spread across multiple crops
- Total yields *can* be increased
- A fast-growing, early maturing crop may fit well with one that grows slowly

Disadvantages:

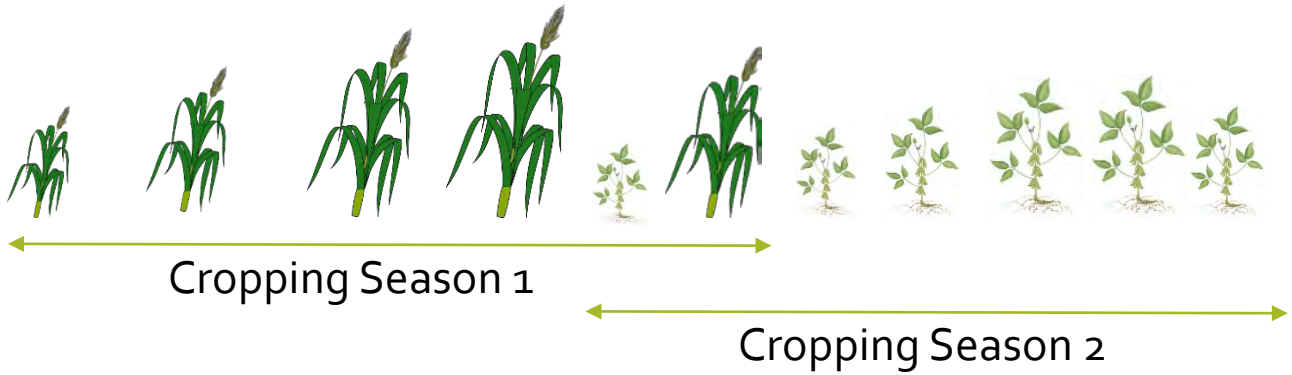
- Planting, spraying, and harvesting of individual species can be challenging
- Individual species can compete with one another for light, water, and nutrients

Strip Cropping

2-4-2 (rows) Maize-Legume System

Relay Cropping

The inter-planting of a second crop **before** the harvest of a maturing crop.



Relay Cropping

- Timing of the planting of the relay crop and of the harvest of the first crop is essential.
- Examples of relay crops:
  - Sorghum planted in early monsoon stages in semi-arid tropics and inter-planted with pigeon peas.
  - Soybeans grown between young rubber trees

Red clover relay cropped with winter wheat.

An Example from the Uplands of Northern Thailands

The second crop (e.g., rice bean) is often planted after the first crop (e.g., field corn) has reached its reproductive phase, but before the fruits of the first crop are ready to harvest.

field corn

rice bean

May **Aug/Sept.** **Dec.**

Establishing relay-cropped gm/ccs (August - September)

2-3 week old rice bean seedlings have been established in a mature stand of field corn about **one month before the September corn harvest**.

Establishing relay-cropped gm/ccs (October)

The same stand of rice bean (about 1 ½ months old) not long after the corn harvest. By this point, the rice bean (not yet flowering) has attained coverage of the soil surface.

Relay cropping (December)

By December, during the beginning of the dry season, both rice bean (pictured) and black bean are mature and ready for harvest.

At the same time, the slower-maturing, longer-lived lablab bean crop is still green and and just beginning to flower.

Relay cropping (January)

While other field crops have been harvested, the lablab bean fields remain green despite dry conditions. Of the three main gm/ccs grown in northern Thailand (rice bean, lablab bean and black bean), lablab bean produces the most vine growth and provides the longest period of soil coverage, often through March or April.

More relay cropping (January – April)

Many farmers pile gm/cc residues around young fruit trees to serve as a dry season mulch.

Additionally, farmers often arrange the residues into soil-conserving, contoured rows when preparing the ground to plant crops.

Including upland rice in upland relay cropping systems

In some locations in northern Thailand, with relay cropping, not only has corn production been sustained in permanent hill fields for over 20 years, but upland rice crops are often grown for 1–3 seasons in these fields following 3–4 years of growing relay-cropped gm/ccs and corn.

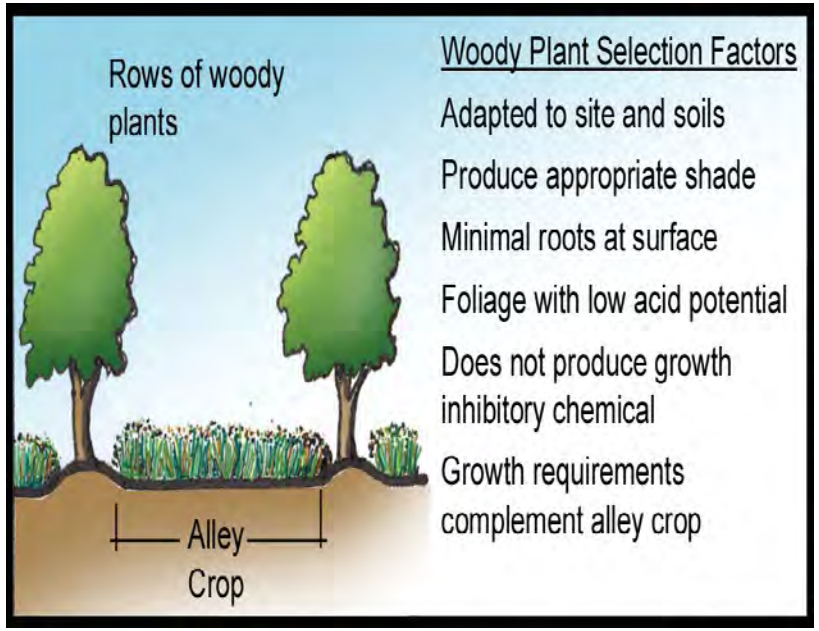
By monitoring not only crop yield and vigor, but soil condition as well, these farmers are able to manage the rotation of occasional upland rice crops between regular plantings of relay-cropped gm/ccs and corn.

Alley Cropping

Alley Cropping is the cultivation of crops grown in between rows of woody plants.

Design considerations include

- Selecting woody plants that provide marketable products
  - Crop timing and management, crop sunlight requirements
  - The alley crop can be changed as tree canopy closes over time.



Alley Cropping

Alley Cropping

Advantages:

- Short-term crops like corn, wheat, oats, can be grown annually while long-term commodities (such as timber) are maturing
- Certain trees can fix nitrogen to be used by annuals

Disadvantages:

- Increased shading and competition for resources
- Harder to use heavy equipment

How do we achieve all of these objectives when *inputs are unavailable or unattainable*?

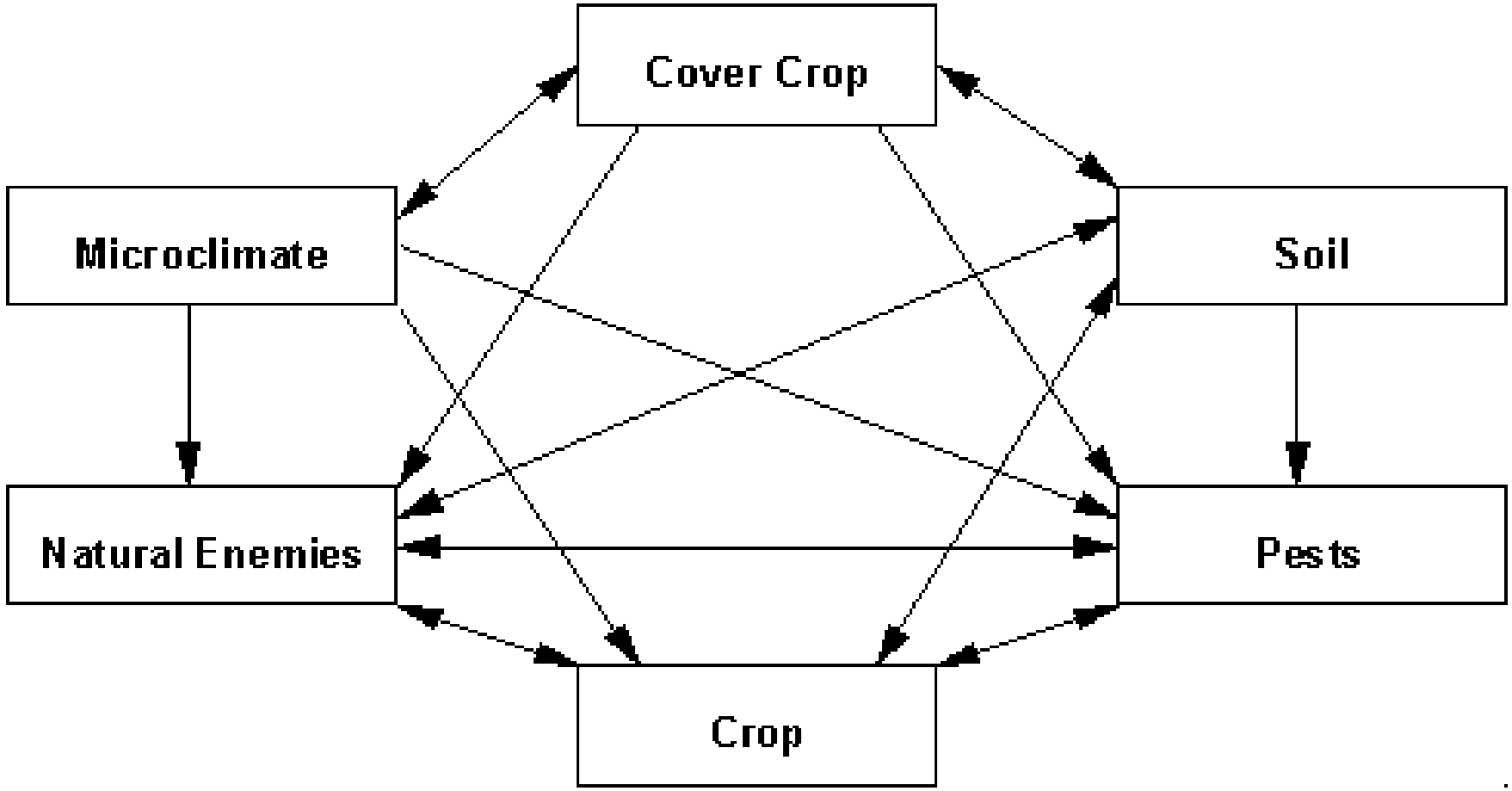
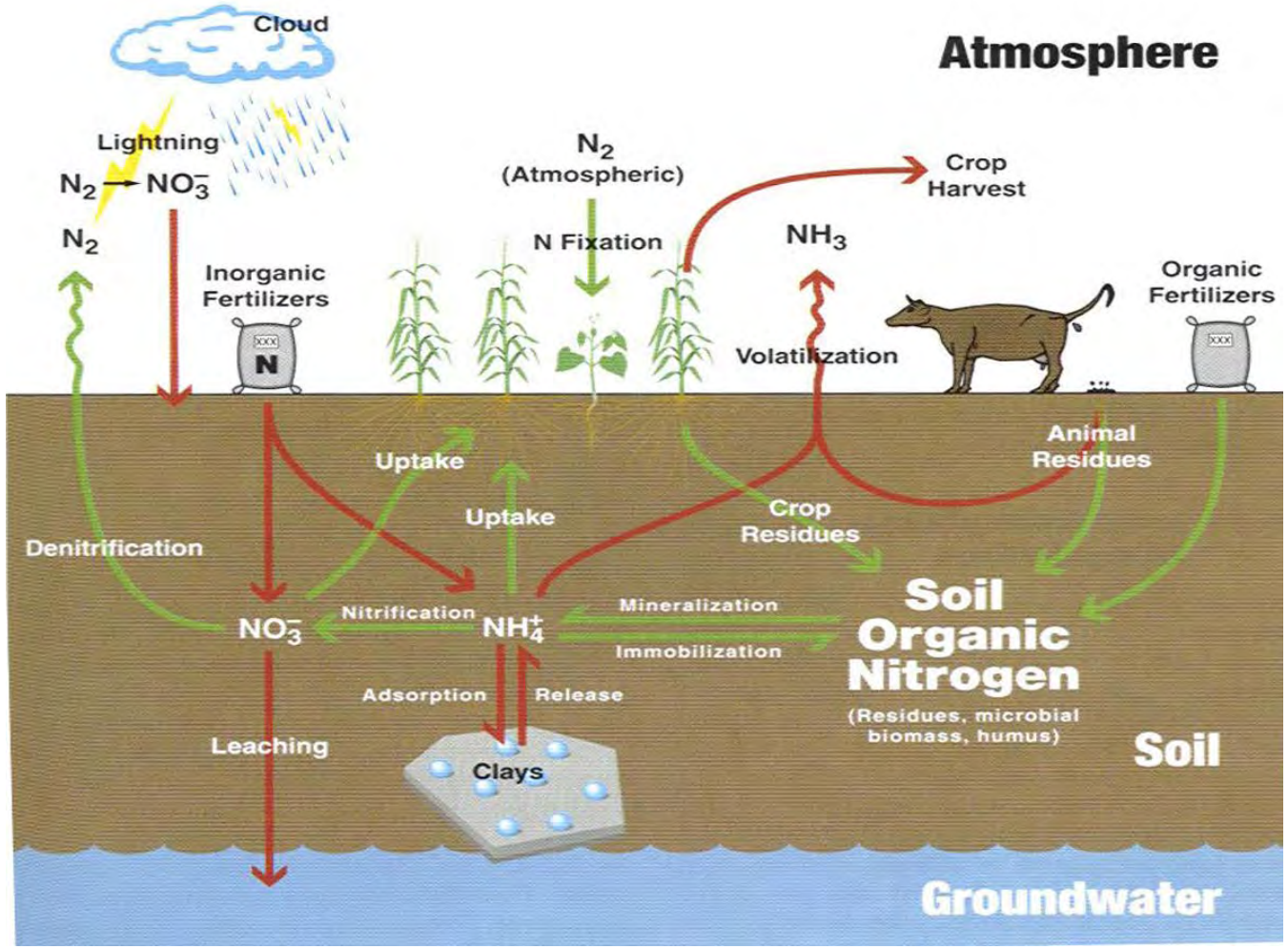
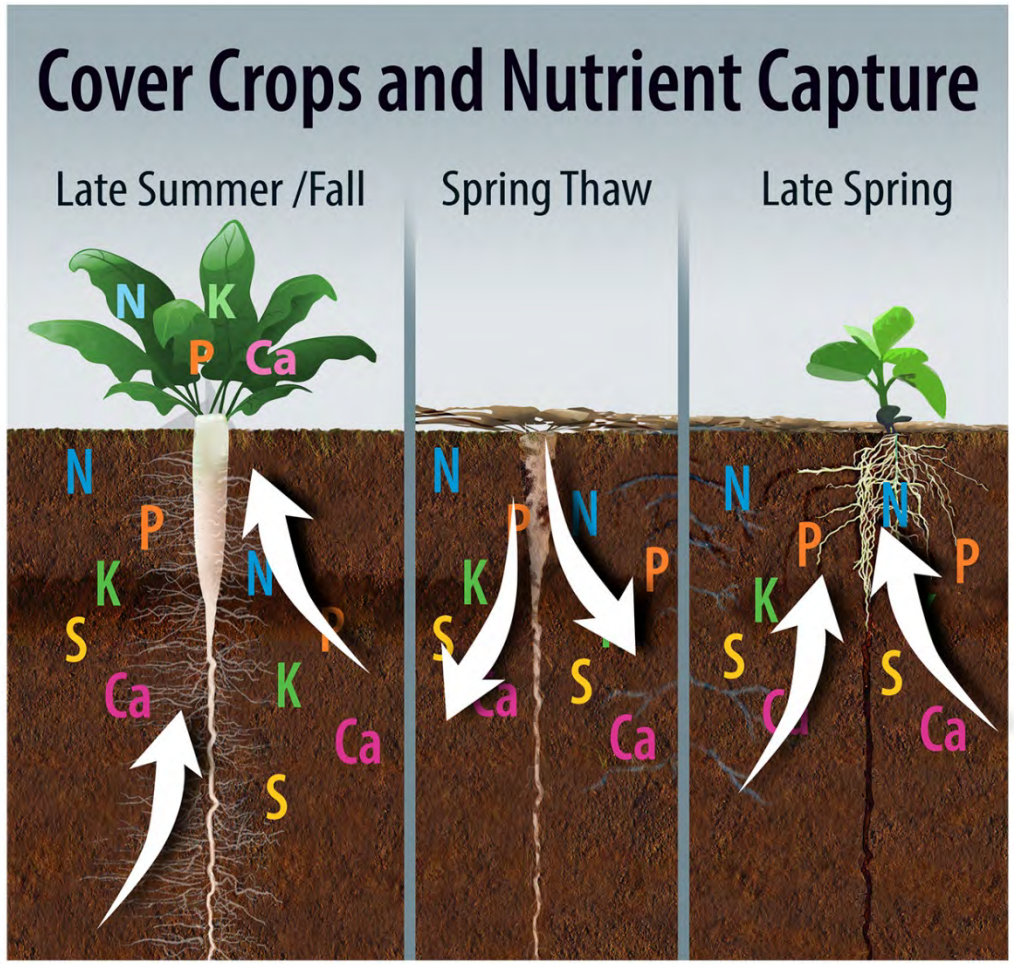


Figure 1. Diagram showing effects of cover crops on agroecosystems.

www.sarep.ucdavis.edu

Table 1. Essential elements for plant growth			
Macronutrients		**Micronutrients**	
	The chemical form most commonly taken up by plants		The chemical form most commonly taken up by plants
Carbon	CO_2	Copper	Cu^{2+}
Hydrogen	H_2O	*Cobalt	Co^{2+}
Oxygen	O_2, H_2O	Iron	Fe^{2+}
Calcium	Ca^{2+}	Manganese	Mn^{2+}
Magnesium	Mg^{2+}	Nickel	Ni^{2+}
Nitrogen	NH_4^+, NO_3^-	*Sodium	Na^+
Potassium	K^+	Zinc	Zn^{2+}
Phosphorus	$H_2PO_4^-$, HPO_4^{2-}	Boron	H_3BO_3, $H_4BO_4^-$
Sulphur	SO_4^{2-}	Chlorine	Cl^-
*Silicon	H_4SiO_4, $H_3SiO_4^-$	Molybdenum	MoO_4^{2-}
* Elements only essential for some, but not for all plants			





Cover crops can increase the amount of nutrients available for the next crop by taking up nutrients that remain in the soil and holding them in plant tissue until they are released the next spring, when they can be used by the following crops. *Courtesy: Cover Crop Solutions*

Common name	Resistance to shade	Resistance to drought	N-fixation kg/ha	Controls weeds	Local market
Cowpea/black bean (*Vigna unguiculata*)	3	Some vars. 4	80	3	yes
Rice bean (*Vigna umbellata*)	3	3	80	3	yes
Jack-bean (*Canavalia ensiformis*)	4	4	240	3-4	limited
Lablab bean (*Lablab purpureus*)	3	4	130	3-4	yes
Peanut/ground nut (*Arachis hypogaea*)	2	2	72-124	2	yes
Pigeon pea (*Cajanus cajan*)	3	4	168-280	2	no

Key: 4 – excellent; 3 – good; 2 – fair; 1 - poor

Partially adapted from "*Achieving the Adoption of Green Manure/Cover Crops: Systems that are Attractive to Farmers*"

How do we achieve all of these objectives when profits need to be made?

A Theoretical Example

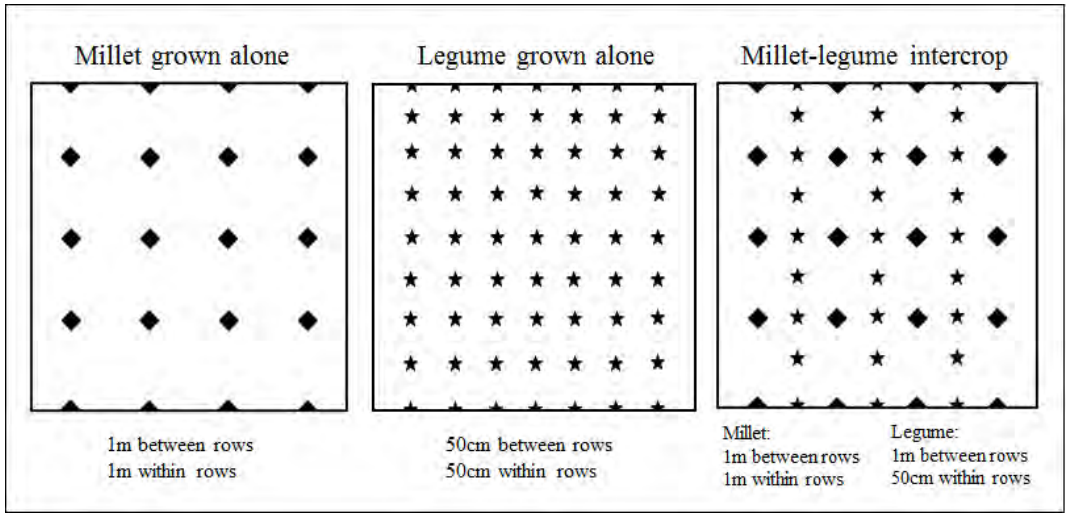
10 10 10 10 = 40

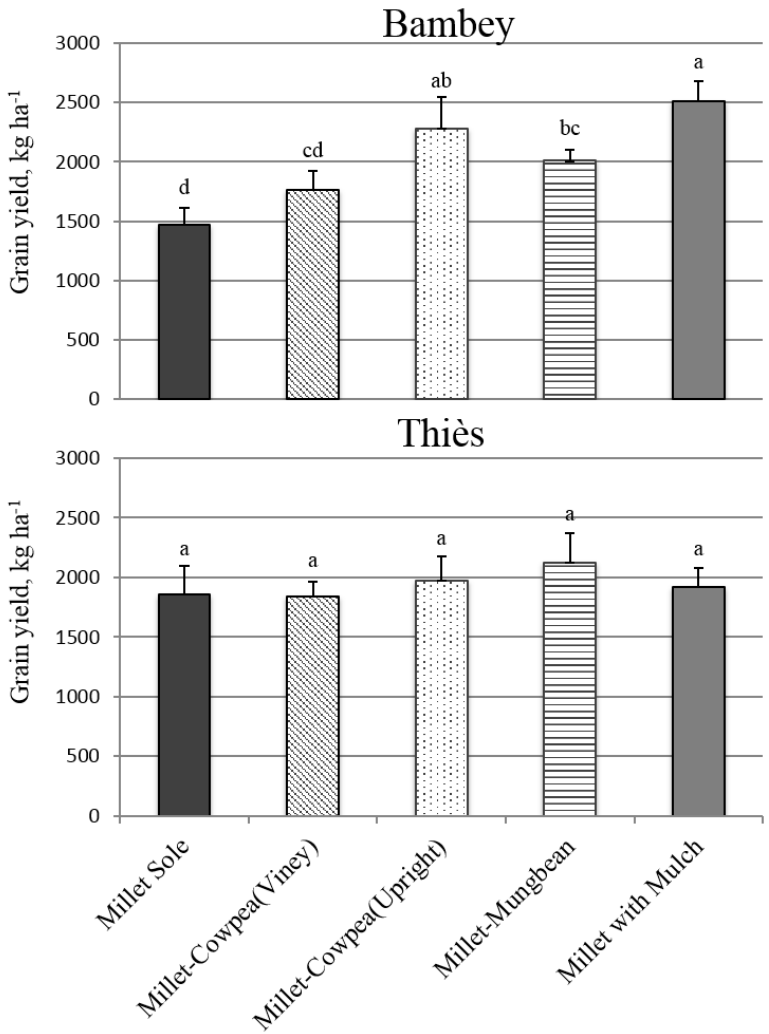
5 5 5 5 5 5 5 5 = 40

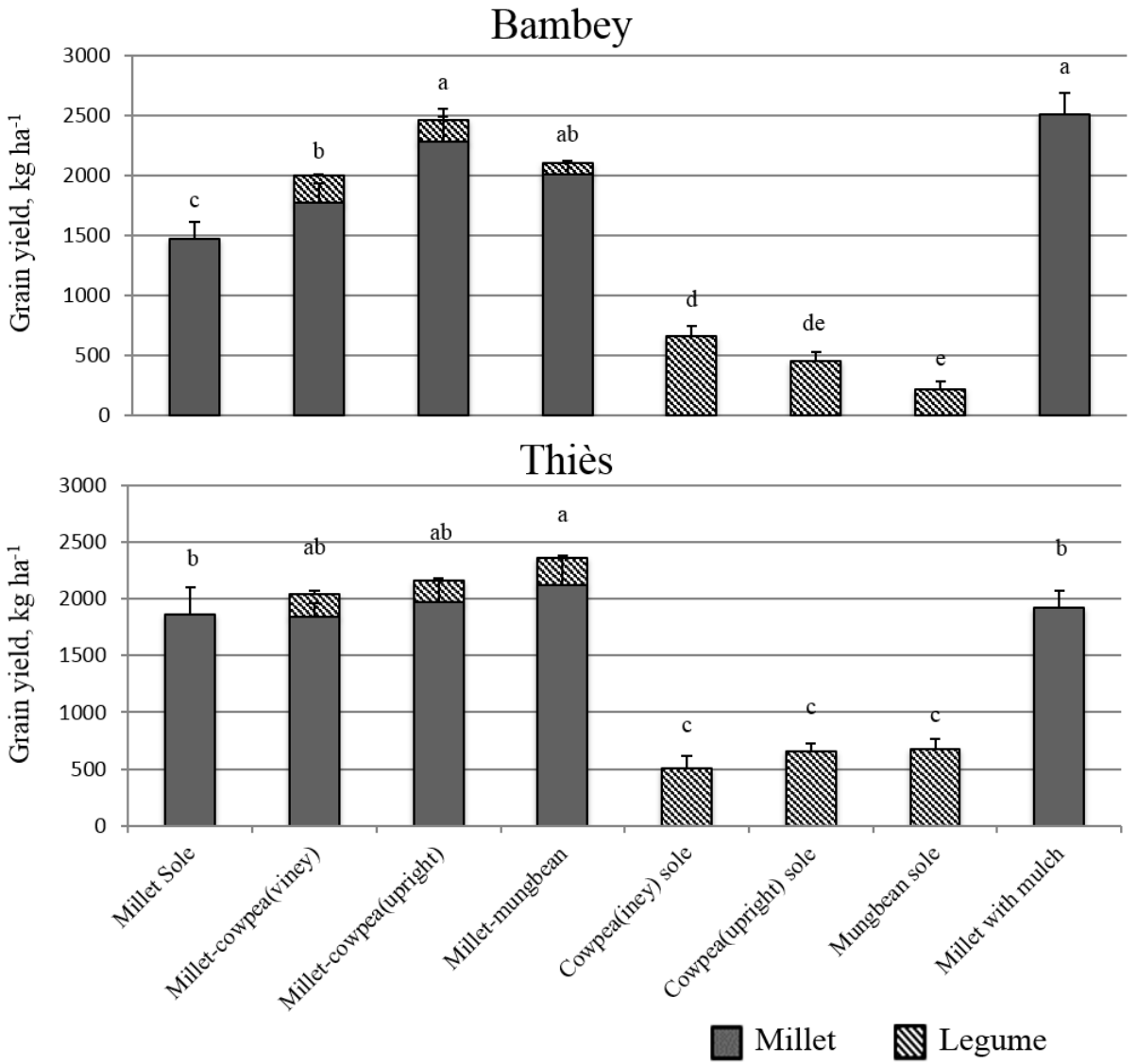
3 3 10 3 3 10 = 32

2 8 2 8 2 8 2 8 = 40

2 12 2 12 2 12 2 12 = 56


Millet grown alone
Legume grown alone
Millet-legume intercrop
1m between rows
1m within rows
50cm between rows
50cm within rows
Millet:
1m between rows
1m within rows
Legume:
1m between rows
50cm within rows





https://dl.sciencesocieties.org/publications/aj/abstracts/108/4/1742

There are no ‘Silver Bullet’ solutions – GM/CC’s have their respective **challenges**

- Timing of the planting
- Seed Availability
- Managing GM/CC’s before planting the subsequent/primary crop
- Have relied on herbicides and chemicals in the past
- Even the most drought tolerant options still need water
- Acceptance/adoption locally
- Using a Cove Crop and as additional crop… it happens all too often!

Important Points to Consider *before* Introducing a GMCC into your Cropping Systems

- Short duration vs. Long duration?
- Drought resistant or moisture loving?
- Will it compete with other crops for light, nutrients, water, etc…?
- Can I broadcast seeds, or do I need to direct plant?
- Will the GMCC interfere with application of sprays or nutrients of primary crop?
- How will I manage it once I want to get rid of it?
- Will the GMCC remain true, or will I remove the GMCC for fodder, mulch, feed, etc..?

TROPICAL COVER CROP SELECTION TABLE

Drought Tolerant ⟷ Adapted to Humidity

Grass | Broadleaf | Grass

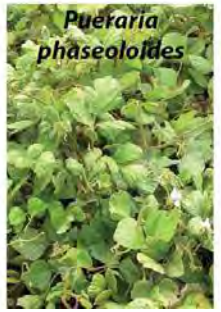
Growth Habits:
- Erect
- Semi-erect
- Spreading
- Climbing

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

Leguminous

Sorghum *Sorghum bicolor* A								Fruit Trees (star fruit, papaya) P	Job's Tears *Coix lacryma-jobi* A/P
Teff *Eragrostis tef* A	Amaranth *Amaranthus cruentus, Amaranthus hypochondriacus* A								
Fonio *Digitaria exilis* A	Lagos spinach *Celosia argentea* A								
Guinea grass *Panicums maximum* P	Spiderplant *Cleome gynandra* A						Perennial peanut *Arachis pintoi* P	Coconut *Cocos nucifera* P	Sugarcane *Saccharum officinarum* P
Finger Millet *Eleusine coracana* A	Moringa *Moringa oleifera* P	Fish Bean *Tephrosia vogelii* P	Stylo *Stylosanthes guianensis* P	Sunnhemp *Crotalaria juncea* A	Sunnhemp *Crotalaria ochroleuca* A	Hariy Indigo *Baptisia arachnifera* A	Velvet Bean *Mucuna pruriens* A	Oil palm *Elaeis guineensis* P	Rice *Oryza sativa* A
Pearl Millet *Pennisetum glaucum* A	Buckwheat *Fagopyrum esculentum* A	Pigeon Pea *Cajanus cajan* A/P	Peanut *Arachis hypogaea* A	Cowpea *Vigna unguiculata* A	Jack Bean *Canavalia ensiformis* A	Tropical Kudzu *Pueraria phaseoloides* P	Siratro *Macroptilium atropurpureum* P	Coffee *Coffea arabica* P	Corn *Zea mays* A
Signalgrass *Brachiaria sp.* P	Sunflower *Helianthus annuus* A	Hyacinth Bean *Lablab purpureus* A	Marama Bean *Tylosema esculentum* P	Horse Gram *Macrotyloma uniflorum* A	Rice Bean *Vigna umbellata* A	Mung Bean *Vigna radiata* A	Soybean *Glycine max* A	Cassava *Manihot esculenta* P	Napier Grass *Pennisetum purpureum* P



Which crops (if any) are used as Cover Crops in your area?

Are they grown in rotation or with cereal crops or integrated?

Additional Resources

GM/CC Technical Resources on echocommunity.org
https://www.echocommunity.org/resources/aa593147-43e3-42c1-aa81-3b764b4eaa4c

More information on GMCC Cover Crops from Northern Thailand
https://c.ymcdn.com/sites/echocommunity.site-ym.com/resource/collection/f6ffa3bf-02ef-4fe3-b180-f391c063e31a/Green_Manure_Cover_Crops.pdf?hhSearchTerms=%22gmcc%22

GM/CC Seed offered through our Seedbanks in Florida and Thailand
https://www.echocommunity.org/plants/category/Green%20Manures%20and%20Cover%20Crops

Coming Soon:

1). A new Cover Crop Selection tool through ECHOcommunity.org

2). Research Update from ECHO Asia GMCC Field Trials

Cover Crop Options for the Tropics

Beach Bean *Canavalia maritima syn. rosea*

Beach Bean is a leguminous, drought and salt tolerant vine adapted to growing under very dry and hot conditions. History says that it was an important food crop for Captain James Cook and his crew on their voyage around the world from 1768-1771. Vines are widely distributed on beaches and dunes...

Butterfly Pea *Clitoria ternatea*

Butterfly pea most likely originated in tropical Asia, although its true origin probably is obscured by its extensive cultivation and naturalization around the globe.

Cowpea *Vigna unguiculata subsp. unguiculata*

A wild pea that is very similar to this cultivated variety is native to central Africa and is now grown around the world where temperatures are moderate.

Desmanthus *Desmanthus virgatus*

Native to the American tropics and subtropics.

Fish Bean *Tephrosia vogelii*

Fish Bean is native to West Africa, but is now found in India, Asia, and other tropical regions.

Flemingia *Flemingia macrophylla*

Flemingia is a woody, leguminous, deep-rooted shrub native to Asia but now found in Sub-Saharan Africa and Malaysia.

Hairy Indigo *Indigofera hirsuta*

Hairy Indigo, a leguminous plant, is native to tropical Africa, southern Asia and northern Australia. Hairy Indigo is an erect-growing, reseeding, summer annual legume that may grow 1-2 m (4-7 ft) tall if not grazed. It produces heavy foliage on fine stems that become course in latter stages of...

Jack Bean *Canavalia ensiformis*

Jack Bean is native to the West Indies and Central America. It closely resembles Sword Bean, *Canavalia gladiata*, and the predominantly African wild species, *Canavalia virosa.* Jack Bean now is widely distributed in the tropics and subtropics although it is regarded as a minor vegetable rather than...

Lablab *Lablab purpureus (syn. Dolichos lablab, Lablab niger)*

Lablab Bean is capable of growing in a wide range of climatic conditions and soil types, depending upon the variety chosen. It is widely cultivated throughout the tropics and subtropics and occurs wild in tropical Africa (including Madagascar) and India. The palatability of lablab surpasses that...

Siratro *Macroptilium atropurpureum*

The exact origin of this crop is not known but it is commonly grown from southern Texas south to Peru. It was named “Siratro” and first hybridized in the early 1960’s.

Cover Crop Options for the Tropics

Sunn Hemp/Slender Leaf Rattlebox *Crotalaria ochroleuca*

Sunn Hemp originated in tropical Africa.

Sunn Hemp *Crotalaria juncea*

Sunn Hemp has been cultivated in India since ancient times. This species is widely distributed throughout the tropics, being most numerous in eastern and southern Tropical Africa.

Sword Bean *Canavalia gladiata*

Sword Bean is a perennial or annual, fast-growing, heavily producing, climbing vegetable. It is widely cultivated in the humid tropics of South and Southeast Asia but world-wide it remains a minor vegetable due to its toxicity when eaten uncooked.

Tarwi *Lupinus mutabilis*

This legume crop grows best in cool highlands and plateaus. Tarwi seeds have been found in tombs of the pre-Incan era of the central Andean region of South America. A mass of foliage is produced with brilliant purplish blue blossoms; the plant grows to a height of 1 meter.

Tropical Kudzu *Pueraria phaseoloides*

Tropical Kudzu is native to Malaysia, although it is widely distributed throughout the world in the wet tropics.

Vining Velvet Bean *Mucuna pruriens (syn. M. deeringiana)*

Velvet Bean originally came from China and eastern India, where it was once commonly grown as a green vegetable crop

White Lupine *Lupinus albus*

It is believed that lupines have been cultivated for 2,000 years, beginning in Egypt. Until recently, nearly all of the 300 lupinus species were considered bitter (high-alkaloid).

Sesbania *Sesbania rostrata*

There are about 20 species of Sesbania in the tropics broadly classified into annual types and perennial (tree) types. The African Sesbania rostrata is an annual (matures in 180 - 270 days), aquatic legume that has the unique ability of producing nitrogen-fixing nodules on its stems and...

American Joint Vetch *Aeschynomene americana*

The American Joint Vetch is native to the Caribbean and nearby regions of the Americas. It is found in South America south to Argentina and northward into southern Florida. It has been introduced in Southeast Asia into countries such as Vietnam, Thailand and the Philippines.