農学国際特論 I

28 June 2013

Advanced Global Agr. Sci. Ⅰ /

IPADS Development Studies

Agricultural technologies 1.

https://sites.google.com/site/2013tokuron1/files

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1

Today's outline

1. Development of agricultural technologies
- 1-1 Beginning of agriculture
- 1-2 First age agriculture
- 1-3 Second age agriculture
- 1-4 Third age agriculture

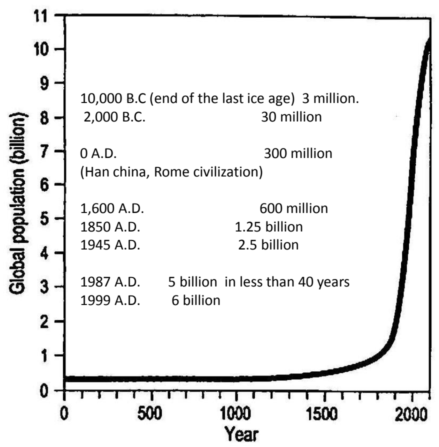
2. Components of agricultural technologies
- 2-1 Farm operation
- 2-2 Cropping system
- 2-3 Seed system
- 2-4 Fertilizers

3. Selected topics related to the third-age agriculture
- 3-1 Conservation agriculture
- 3-2 Plant's ability to acquire nutrients
- 3-3 Microbe's ability to acquire nutrients

4. Future direction

1. Development of agriculture
1-1. Beginning of agriculture

- Agricultural history (Prof. Kurokura)
- Humans first gathered tree fruits etc. and hunt wild animals.
- But then they started cultivation. This is the start of agriculture.
- It took place at various places (domestication center) in the world at different ages, not happened at one place on earth.
- The domestication of crops and animals proceeded.



Global population (billion)

(Figure 1.1, Smil 2000, After McEvedy and Jones (1979) and UN (1998)

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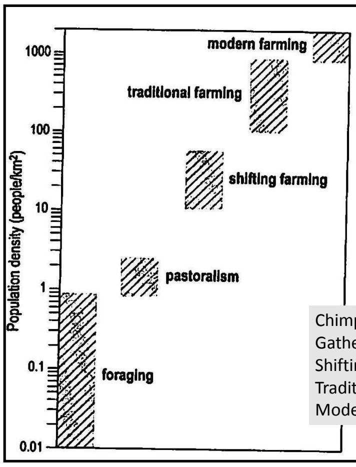


World's **Population Density**

Chimpanzees	2 /km2
Gatherers and hunters	1 /km2
Shifting cultivation	10 /km2
Traditional farming	200-300 /km2
Modern agriculture	1000 /km2

5

Population density

Evolution of the human being

small, scattered, vulnerable, and environmentally inconsequential (=not important) groups of overwhelmingly vegetarian foragers

↓

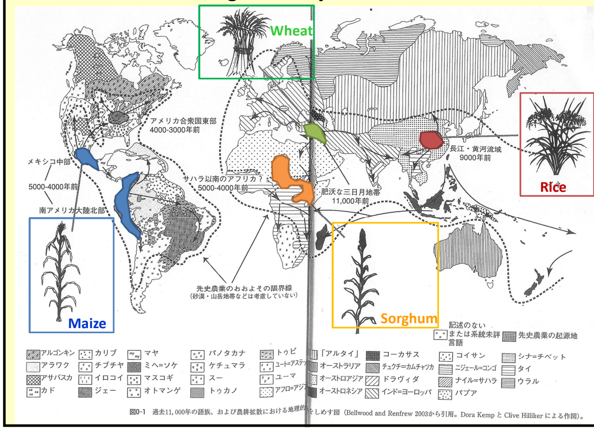
most numerous population of large, substantially carnivorous mammals on the Earth

6

1-2. First age agriculture

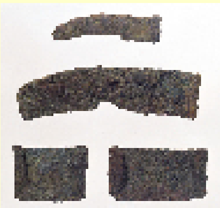
- Sowing and harvest
- Slash and burn system
- Cultivation
- Irrigation
- Weeding
- Crop Rotation
- Application of organic matter
- Selection of useful plants
- Crop-livestock integration

Origin of major cereals

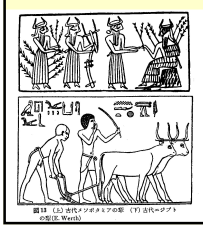


Cultivation


Wooden Hoe


Iron parts of Hoe

In Japan, agricultural tools of both wooden and iron were used during Yayoi era (BC3 to AD3 centuries). Excavated from Yoshinogari relic site.


Use of animal for cultivation

Crop-Livestock Integration in West Africa


Corralling by sticks (Kano, Nigeria)

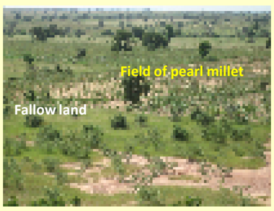

Corralling in a village in Niger (near Niamey)


Millet seedlings under corralled field (Niger)

Manual agricultural technologies from old time


Sowing pearl millet in Sahel


Weeding with hand hoe



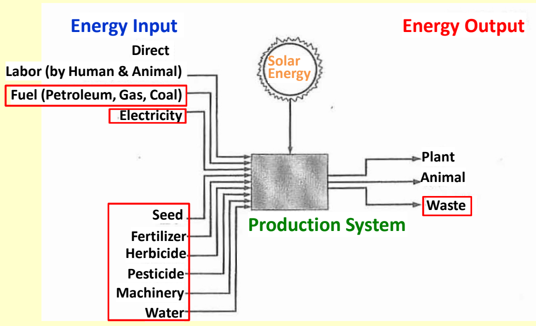
1-3. Second Age (=Industrial) agriculture

- Modern breeding with crossing
- Nitrogen (N) fertilizer
- Phosphorus (P) fertilizer
- Agricultural machinery
- Green revolution

Features

- Increase of input
- Large-scale, mono-cropping type of agriculture

Input and output of energy in agro-ecosystems

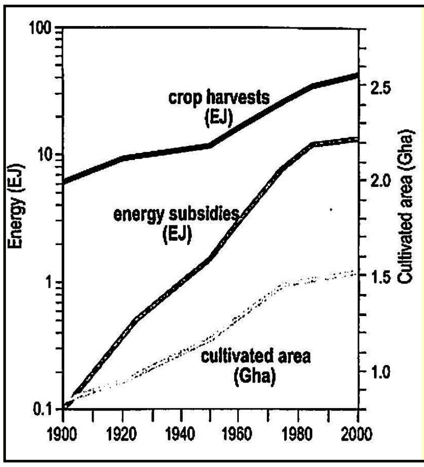


(after Tivy and O'Hare, 1981)

Energy input and output for rice production (1000 kcal/ha)

			Borneo	Japan	California
Input	Direct	Labor	0.63	0.80	0.01
		Hoe and harrow	0.02		
		Machinery		0.19	0.36
		Diesel oil			3.26
		Petroleum		0.91	0.66
		Gas			0.35
	Indirect	Nitrogen fertilizer		2.09	4.12
		Phosphorus fertilizer		0.23	0.20
		Seed	0.39	0.81	1.14
		Irrigation		0.91	1.30
		Pesticides		0.35	0.19
		Herbicides		0.70	1.12
		Drying			1.22
		Electricity		0.01	038
		Transportation		0.05	0.12
Output	Rice yield		7.32	17.60	22.37
Energy efficiency			**7.08**	**2.45**	**1.55**

(after Pimentel, David and Harcia, 1979)



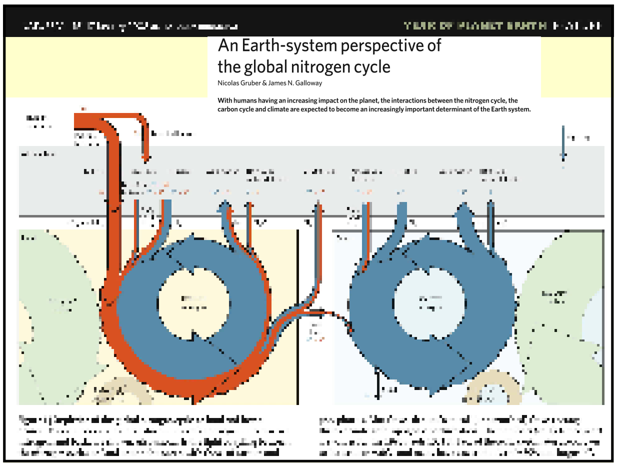
1900-～
Machine (fossil fuels and electricity)

Area increase ×1.3

Yield ×4

Production ×6

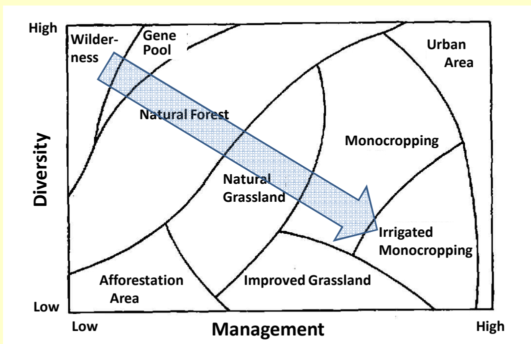
External energy input ×80 (fossil fuels)



Agro-ecosystem vs. Natural Climax ecosystems

- Less species diversity
- Less genetic diversity in each species or genotype
- Simpler spatial structure
- Shorter route of solar energy conversion
- Less complexity (2-3 levels) in food-web
- Larger biomass pool in large herbivore (cow, sheep, goat)
- Smaller energy pool in detritus and soil humus
- Faster nutrient cycle (and loss)
- Lower stability
- Open system

The relative position of agro-ecosystems in term of their intensity of management



(after Smith and Hill, 1975)

1-4. Third Age Agriculture

- IPM
- ISFM
- Conservation agriculture
- Precision agriculture
- Organic farming
- Efficient biological function (plants, microbes)
- In situ plant genetic utilization
- Resource exchange

Features:

- Adjustment, not the increase of scale and input
- Use of ICT technologies
- Use of biological functions
- Human oriented

2. Components of agricultural technologies

2-1. Farm operation (agricultural machinery)

2-2. Cropping system

2-3. Seed system

2-4. Fertilizers

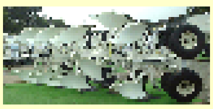
2-1. FARM OPERATION

Chopper : Residue management

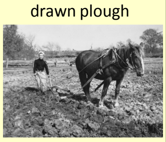
Plough

Rotary plough

Reversible plough



Traditional animal drawn plough



http://www.youtube.com/watch?v=WGzmZCMgXoM

Harrow

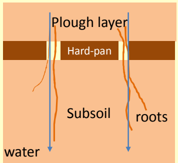
Tooth (Drag) harrow

Disk harrow

Vertical harrow

Rotavator (Rotary, Rotary tiller) to incorporate lime and fertilizers into the soil

Subsoiler : improve drainage

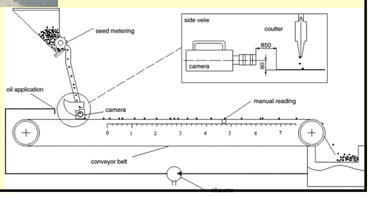


Sowing (播種）

- Drill
- Roll seeder
- Belt-system
- Slide-roll system
- Vacuum seeder
- Pick –planter
- Tape seeder

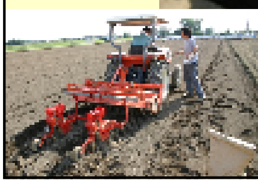
Drill seeder (grain drill, for row planting)

Simple
Efficient (fast)
Best for small seeds (wheat, rice, canola, etc.)



Belt seeder

- Low sowing efficiency
- Adjustable by changing different belts

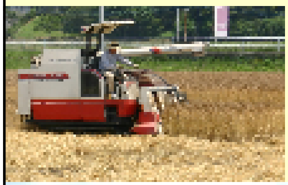


Check the seeds and seeding depth

Herbicide application after the sowing

Inter-row cultivation

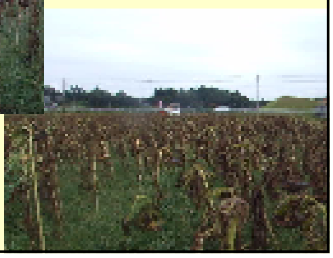

コンバイン(Combine harvester)　自脱型と普通型



Head feeding combine
(自脱型)
(for rice and wheat)

Combine harvester （普通・汎用型）
(for wheat, soybean, backwheat, rice, rapeseed, sunflower)

Namegata-Town, Ibaraki

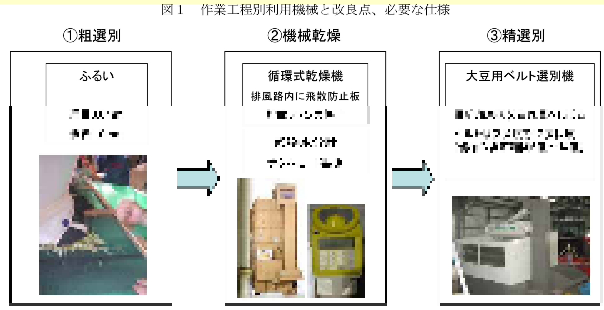
Thresher in combine harvester

Transfer grains from combine to grain tank

Grain drier (Vertical type, horizontal type)

Dry depod

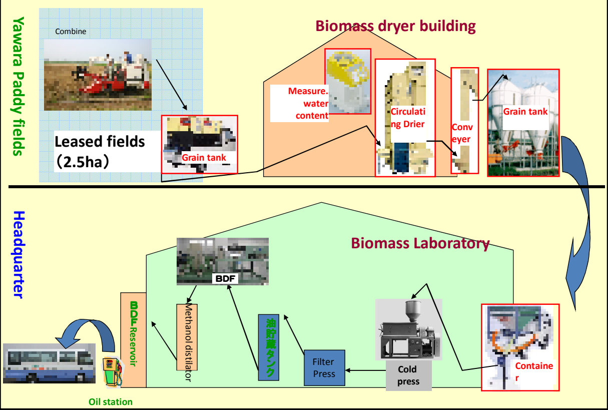
Grain separator



Storage

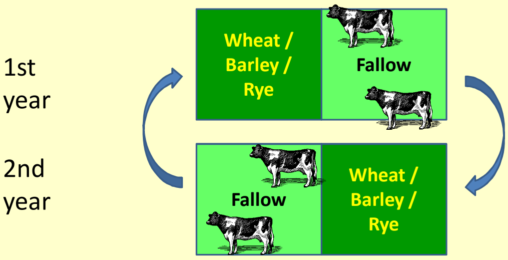
Namegata-Town, Ibaraki

From harvest of rapeseed/sunflower to BDF



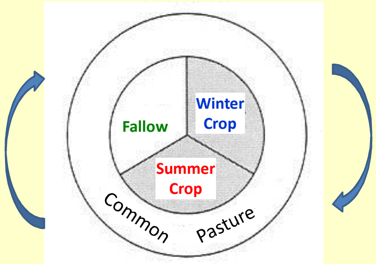
2-2. CROPPING SYSTEMS

Two-field system （二圃式農業）



- Conducted in Europe and middle East in early times.
- In the fallow, the livestock are allowed to graze on the stubble and enrich the soil with droppings.

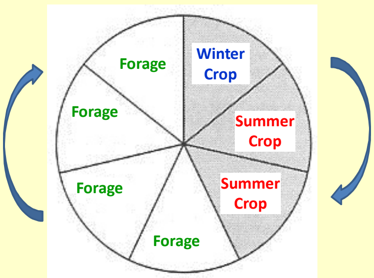
Three-field system（三圃式農業）



When the Roman empire was extended to the middle Europe, the two-field system for winter rain climate was modified to the summer rain climate

- Winter crop : wheat, rye
- Summer crop : barley, oat, faba, pea
- The animal was grazed in permanent pasture and kept in the pen to collect droppings
- Could not ensure the fodder for winter

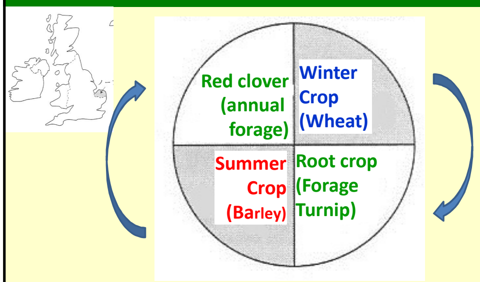
Convertible husbandry（穀草式農法



Several years' crop production followed by several years' forage production

- A part of the common pasture was enclosed and converted to the private **forage field**
- Higher forage production increased animal production.
- It also increased the soil fertility of the **crop land**

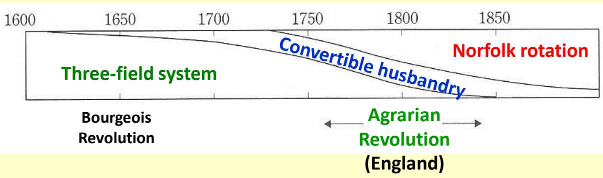
Norfolk rotation（輪栽式農法、ノーフォーク農法）



Mid 18ct, most intensive rotation system was established in **Norfolk** area in England.

- In this system, all the common pasture and fallow was **discontinued**, and forage turnip and red clover (legume) were **introduced**.
- This enabled group raising(多頭飼育) and drylot feeding（舎飼い)

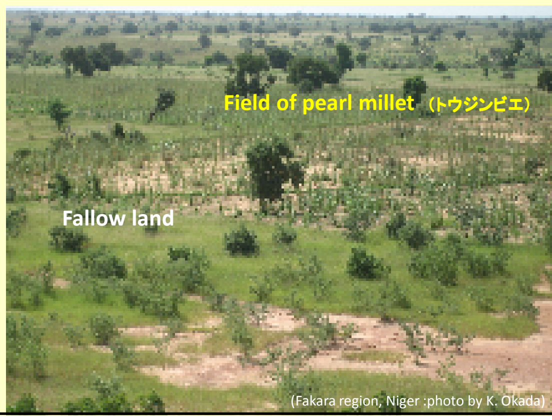
History of the development of cropping systems



The factors which increased the productivity in new cropping systems

1. Livestock manure droppings in fallow (three-field)
2. Forage and manure (convertible)
3. Legumes (Norfolk)
4. Root crops (Norfolk)

Fallow (休閑)

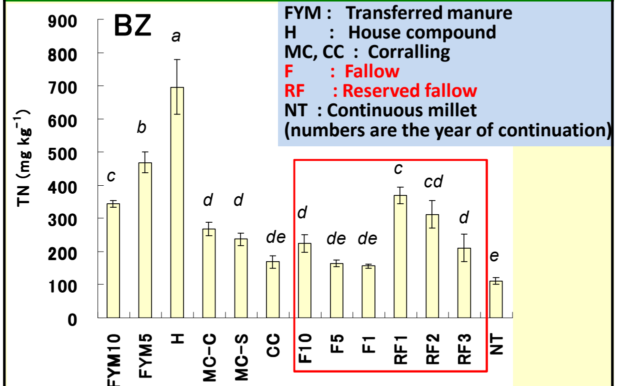


(Fakara region, Niger :photo by K. Okada)

Crop land vs. fallow land

(Niger)

Effect of fallow on total N in the Sahel region



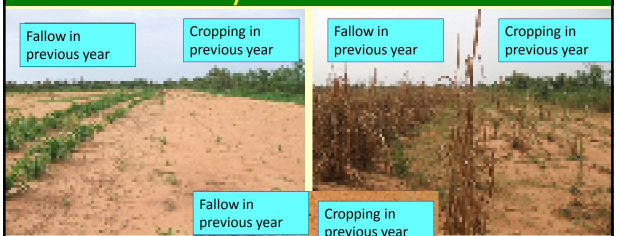
Farmers' fields in Banizumbou village in Niger (Suzuki, et al. 2008)

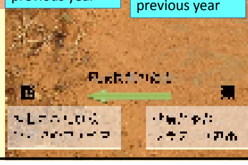
Fallow lands in Burkina Faso

40 years' fallow (Higher standing biomass including tree, but the chemical indices of the soils were low)

Grass fallow in dry season (Standing residue is considered to function as trap for dust mineral)

Effect of "fallow band system" on soil fertility recover in Sahel





(Ikazaki)

Improved fallow

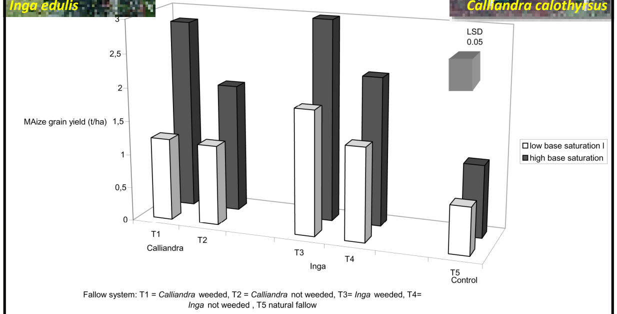


Figure 2. Maize grain yield after *Inga edulis* and *Calliandra calothyrsus* fallow on degraded acid soils in southern Cameroon.

(Kanmegne et al 2003)

CROP ROTATION

- Legume rotation
- Effect of legume rotation other than N
- Legume rotation and soil carbon
- (Effect of mycorrhizae → later)

Legume mixed cropping in the world

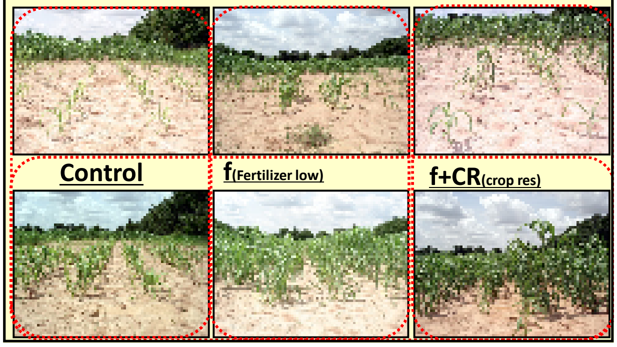
- Maize with Bean (Central and South America)
- Rice with Soybean (Asia)
- Rice with Mungbean (Asia)
- Sorghum with Pigeonpea (India)
- Pearl millet with cowpea (Africa)

Low consumption of legumes compared with cereals
→ Low planting density of legumes compared with cereals

Effect of crop rotation(1)

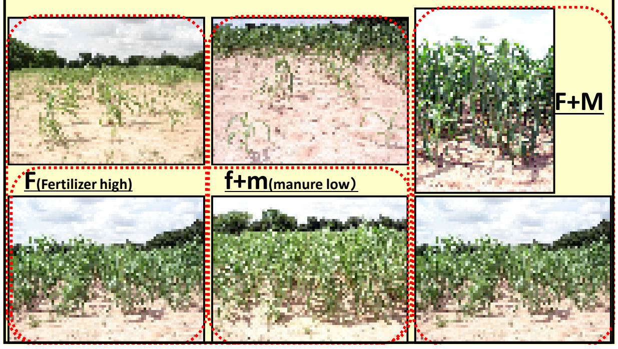
A. Mori

- Long-term exp at Burkina Faso (2006) 46 days after sowing
- Upper-Continuous sorghum, Lower-Sorghum-Cowpea rotation

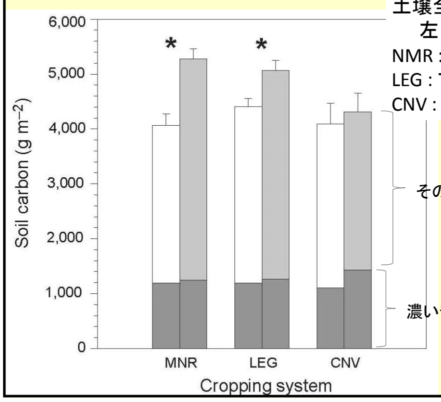


Effect of crop rotation(cont.)

A. Mori



マメ科主体の作付体系で、C3由来の炭素量が増加する



(Drinkwater 1998)

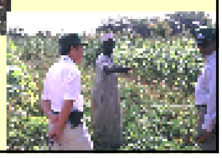
INTERCROPPING, MIXED CROPPING

•Various inter/mixed cropping
•Yield advantages of intercropping

•Risk diversification
•Complementary resource utilization
•Reducing diseases, nematodes, insect pests

Intercropping (Sorghum/cowpea)

Intensive sorghum-cowpea intercropping in northern Nigeria (Kano suburb)

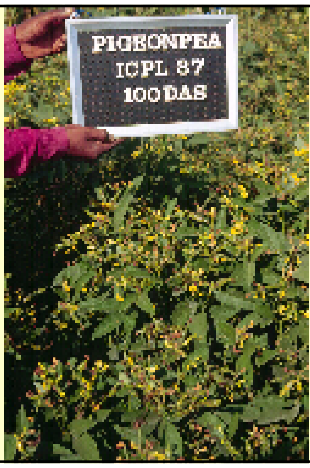


Pearl millet / hibiscus mixed croppping

(Niger)

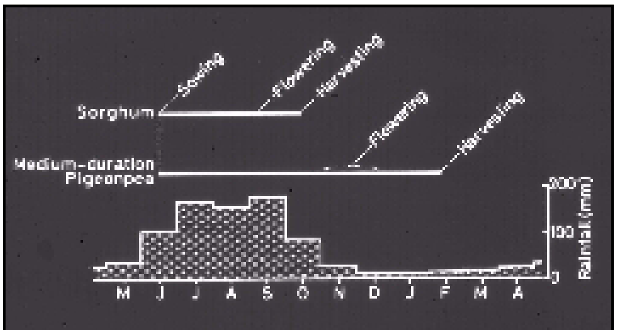
Intercropping (p.59, PG1)

Hybrid sorghum improved at ICRISAT



Short-duration pigeonpea

(cv. ICPL 87)



Intercropping of sorghum and medium-duration pigeonpea in semi-arid tropics

Intercropping of sorghum and pigeonpea in a farmer's field

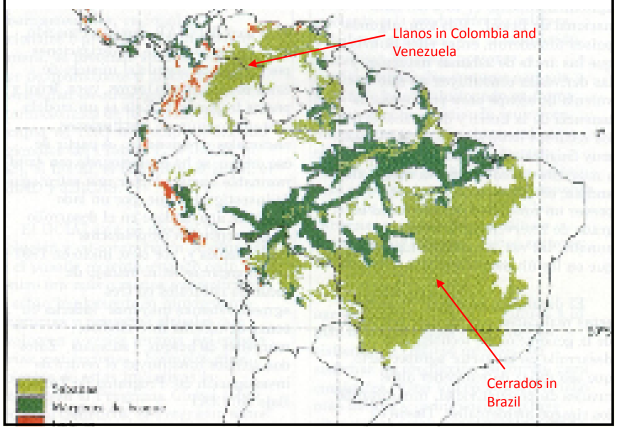
After sorghum harvest (pigeonpea are remaining)

Intercropping of hybrid sorghum and pigeonpea (improved medium-duration variety).

Example of rice-pasture system from Llanos Orientales (Eastern Savanna) in Colombia

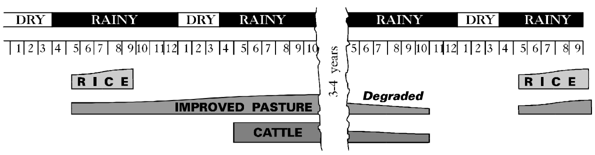
CROP-PASTURE SYSTEM

Sub-humid savannas in South America



Tropical sub-humid savanna (Llanos Orientales, Colombia, S.A.)

Native pasture in Llanos Orientales, Colombia



Rice-Pasture system

Combination of rice and pasture species for Rice-Pasture system in Llanos, Colombia

	Rice cv.	+	Grass	+	Legume
Combination 1	Orizica Sabana 6		*Brachiaria dictioneura*		*Centrocema acutifolium*
(Density)	(60 kg/ha)		(3 kg/ha)		(4 kg/ha)
Combination 2	Oryzica Sabana 6		*Andropogon gayanus*		*Stylosanthes capitata*
(Density)	(60 kg/ha)		(10 kg/ha)		(3 kg/ha)

Upland rice was drill-sown with the 34 cm distance of rows, pasture seeds were broadcasted.

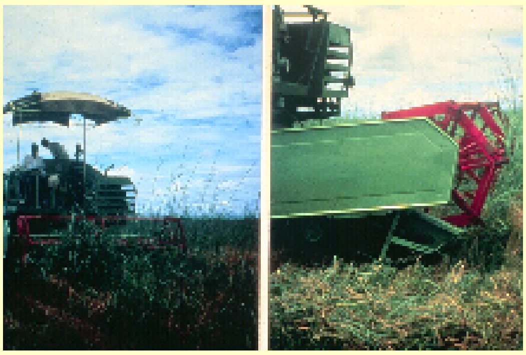
Preparation of field and applying fertilizers

Emergence of upland rice seedlings

At vegetative stage

At maturity
(Rice+*Centrocema*+*Brachiaria*)

Rice-pasture system at maturity of rice
(Rice + *Brachiaria* + *Centrosema*)

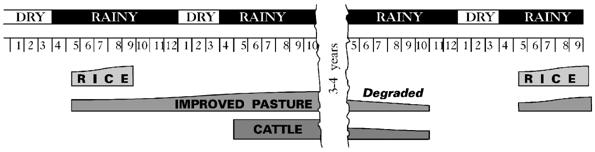


Harvest of rice by large combine
(Rice + *Andropogon*)

Just after the harvest of rice

Rapid growth of pasture after the harvest of rice

Establishing improved pasture at next rainy season



Rice-Pasture system

Average size of farmland with rice-pasture system (2000 ha)

‘Rice-Pasture System’

Economically feasible technique for:

(1) Introducing improved pasture into native pasture

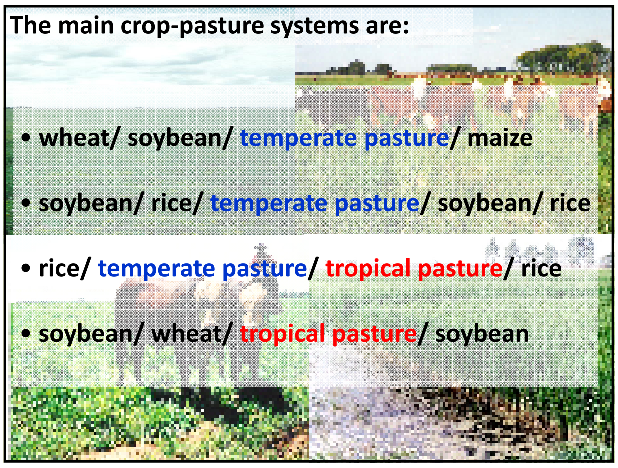
——→ Economic development

(2) Renovation of degraded pasture

——→ Sustainable and Economical development

Requirement

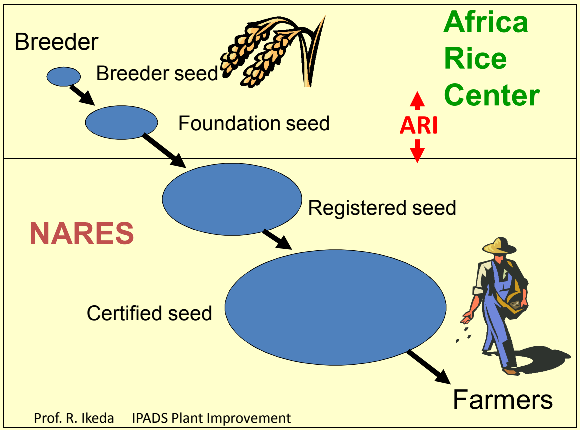
- New Pasture species
- New Rice Variety
- New Agronomy



The main crop-pasture systems are:

- wheat/ soybean/ temperate pasture/ maize
- soybean/ rice/ temperate pasture/ soybean/ rice
- rice/ temperate pasture/ tropical pasture/ rice
- soybean/ wheat/ tropical pasture/ soybean

2-3. SEED SYSTEM



Prof. R. Ikeda IPADS Plant Improvement (5-7 August)

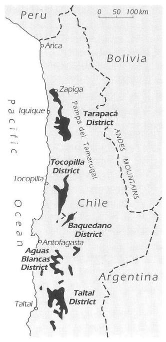
2-4. FERTILIZERS

Nitrogen (N)

Table 4-21 Composition of Some Common Soluble Fertilizer N Sources

N Source	N	P_2O_5	K_2O	CaO	MgO	S	Cl	Physical State
	Nutrient Content (%)							
NH_4^+ or NH_4^+ forming								
Anhydrous ammonia	82	—	—	—	—	—	—	Gas
Aqua ammonia	20–25	—	—	—	—	—	—	Liquid
Ammonium chloride	25–26	—	—	—	—	—	66	Solid
Ammonium nitrate	33–34	—	—	—	—	—	—	Solid
Ammonium sulfate	21	—	—	—	—	24	—	Solid
Monoammonium phosphate	11	48–55	—	2	0.5	1–3	—	Solid
Diammonium phosphate	18–21	46–54	—	—	—	—	—	Solid
Ammonium phosphate-sulfate	13–16	20–39	—	—	—	3–14	—	Solid
Ammonium polyphosphate	10–11	34–37	—	—	—	—	—	Liquid
Ammonium thiosulfate	12	—	—	—	—	26	—	Liquid
Urea	45–46	—	—	—	—	—	—	Solid
Urea-sulfate	30–40	—	—	—	—	6–11	—	Solid
Urea-ammonium nitrate	28–32	—	—	—	—	—	—	Liquid
Urea-ammonium phosphate	21–38	13–42	—	—	—	—	—	Solid
Urea phosphate	17	43–44	—	—	—	—	—	Solid
NO_3^-								
Calcium nitrate	15	—	—	34	—	—	—	Solid
Potassium nitrate niter硝石	13	—	44	0.5	0.5	0.2	1.2	Solid
Sodium nitrate nitratineチリ硝石	16	—	—	—	—	—	0.6	Solid

Chilean nitrates



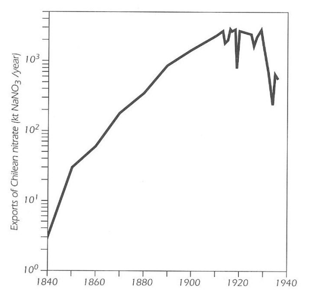
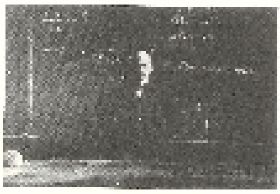


Figure 3.4
Exports of Chilean nitrates, 1840–1940.

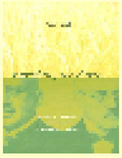
Figure 3.2
Major areas of nitrate deposits (marked in black) in northern Chile.

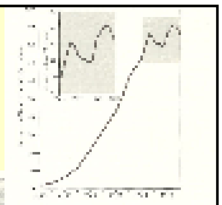
Haber-Bosch process

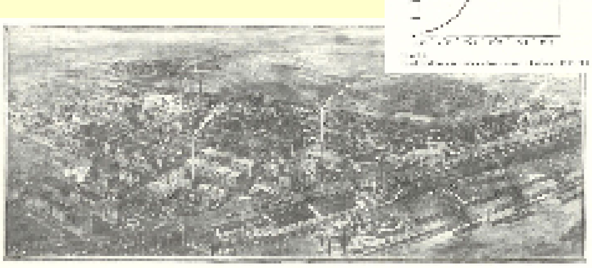


1909 experimental scale
1931 industrial scale

$N_2(g) + 3H_2(g)$ ----- $2NH_3$ (g)







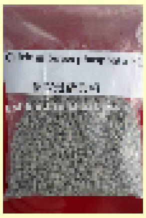
Phosphorus (P)

Raw material for P fertilizer:
Phosphate Rock

Egyptian rock phosphate

- CO_3-F apatite
- 0 in water soluble, but 5-17% citrate soluble
- Available low pH soils (2-3 times)
- Extensive plantation (e.g. rubber, oil palm, cacao on very acid soils)
- Warm climate, moist soils, long growing seasons
- High initial dose (10-30 t/ha) and 5-10 years repetition

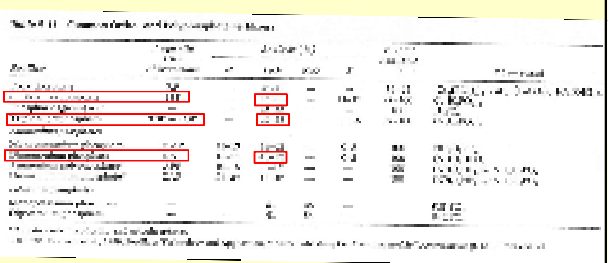
Common phosphorus fertilizers



Triple Super Phosphate (SSP)

Single Super Phosphate (SSP)

Diammonium Phosphate (DAP)



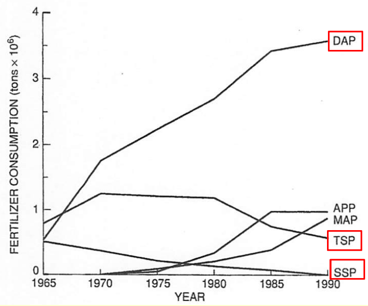
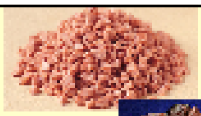


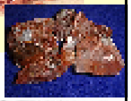
Figure 5-20 Use of common P fertilizers in the United States. DAP, diammonium phosphate; APP, ammonium polyphosphate; MAP, monoammonium polyphosphate; TSP, triple superphosphate; SSP, single superphosphate. *(USDA ERS, 1990.)*

Potassium (K)

Organic = animal manure and sludge

Inorganic = fertilizers





Potash

Table 6-6 Plant Nutrient Content of Common K Fertilizers

Material	N	P_2O_5	K_2O	S	Mg
	%				
Potassium chloride	—	—	60–62	—	—
Potassium sulfate	—	—	50–52	17	—
Potassium magnesium sulfate	—	—	22	22	11
Potassium nitrate	13	—	44	—	—
Potassium hydroxide	—	—	83	—	—
Potassium carbonate	—	—	,68	—	—
Potassium orthophosphates	—	30–60	30–50	—	—
Potassium polyphosphates	—	40–60	22–48	—	—
Potassium thiosulfate	—	—	25	17	—
Potassium polysulfide	—	—	22	23	—

Sulfur

Table 7-4 S-Containing Fertilizer Materials

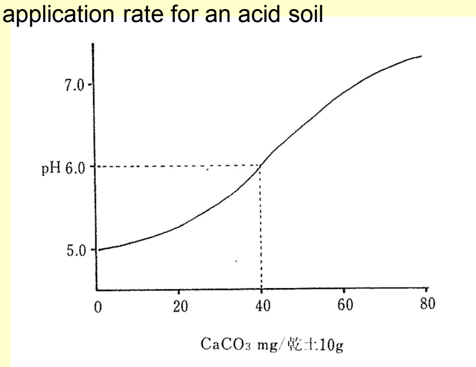
Material	Formula	Plant Nutrient Content (%) N	P_2O_5	K_2O	S	Other
Ammonium polysulfide	NH_4S_x	20	-	-	45	
Ammonium sulfate	$(NH_4)_2SO_4$	21	-	-	24	
Ammonium thiosulfate	$(NH_4)_2S_2O_3$	12	-	-	26	
Calcium polysulfide	CaS_x	-	-	-	22	6 (Ca)
Calcium thiosulfate	CaS_2O_3	-	-	-	10	6 (Ca)
Ferrous sulfate	$FeSO_4 \cdot H_2O$	-	-	-	19	33 (Fe)
Gypsum	$CaSO_4 \cdot 2H_2O$	-	-	-	19	24 (Ca)
Magnesium sulfate	$MgSO_4 \cdot 7H_2O$	-	-	-	13	10 (Mg)
Potassium-magnesium sulfate	$K_2SO_4 \cdot MgSO_4$	-	-	22	22	11 (Mg)
Potassium polysulfide	KS_x	-	-	22	23	
Potassium sulfate	K_2SO_4	-	-	50	18	
Potassium thiosulfate	$K_2S_2O_3$	-	-	25	17	
Sulfur	S^0	-	-	-	100	
Sulfur (granular w/additives)	S^0	0–7	-	-	68–95	
Sulfuric acid (100%)	H_2SO_4	-	-	-	33	
Superphosphate, single	$Ca(H_2PO_4)_2 \cdot CaSO_4 \cdot 2H_2O$	-	20	-	14	
Superphosphate, triple	$Ca(H_2PO_4)_2 \cdot CaSO_4 \cdot 2H_2O$	-	46	-	1.5	
Urea-sulfur	$CO(NH_2)_2 + S$	38	-	-	10–20	
Urea-sulfuric acid	$CO(NH_2)^2 + H_2SO_4$	10–28	-	-	9–18	
Zinc sulfate	$ZnSO_4 \cdot H_2O$	-	-	-	18	36 (Zn)

SOURCE: Bixby and Beaton, 1970, *Tech. Bull. 17*, Washington, D.C.: The Sulphur Institute.

Calcium (Ca) or Lime

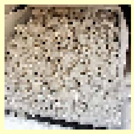
For acidic soils

An example to calculate necessary lime application rate for an acid soil

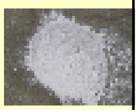


Ca sources

- $CaCO_3$ (calcitic lime, calcite)



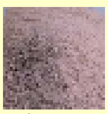
- $CaMg(CO_3)_2$ (dolomitic lime)



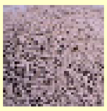
- Gypsum ($CaSO_4$-$2H_2O$) Does not change pH.
- TSP, SSP, Calcium nitrate, Rock phosphate, manure

Various Liming Materials

Limestone

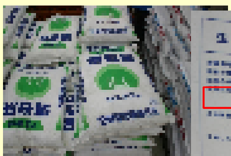


Powered Limestone

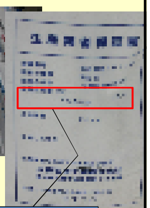


Granulated Limestone

Dolomite



Powered Limestone



Guaranteed alkalinity=72.0

Different Liming Materials and their Calcium Carbonate Equivalence (CCE)

Table 1. Relative (CCE) values for different liming materials.

Material	Composition	CCE
Calcitic limestone	$CaCO_3$	98-100
Dolomitic limestone	$CaMg(CO_3)_2$	100-109
Calcium oxide	CaO	179
Magnesium oxide	MgO	250
Hydroxides	$Ca(OH)_2$ or $Mg(OH)_2$	120-136
Marl	$CaCO_3 \cdot X^*$	60-90
Slags	$CaSiO_3 \cdot X^*$	50-90
Sludges	$CaCO_3 \cdot X^*$	30-80
Wood ashes	X^*	30-50

*X indicates impurities of an unknown nature.

(Mahler, R. L.)

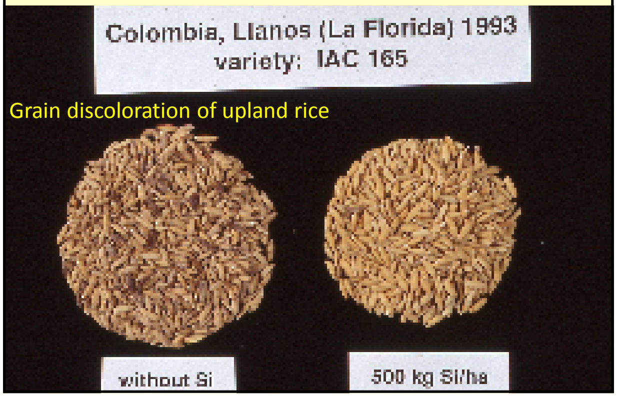
Particle size and the effectiveness of liming materials

Table 2. The influence of lime particle size on soil pH change 1 year after application. Two tons of lime were applied to all treatments except the control.

Lime particle size (mesh)	Soil pH		Relative effectiveness	
	Calcitic limestone	Dolomitic limestone	Calcitic limestone	Dolmitic limestone
No lime (check)	5.0	5.0	0	0
4-8	5.0	5.0	5	8
20-30	5.6	5.5	54	39
40-50	5.9	5.8	74	65
60-80	6.3	6.2	96	84
100	6.5	6.6	100	100

Larger the particle size (smaller the mesh), smaller the pH correcting ability and effectiveness.

Silicon (Si) Important element for rice



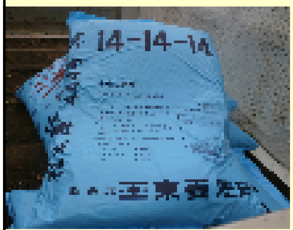
Si sources

- Calcium silicate slag ($CaAl_2Si_2O_8$) 18 to 21% Si
- Calcium metasilicate ($CaSiO_3$) 31% Si
- Sodium metasilicate ($NaSiO_3$) 23% Si

Rice straw, rice husk

Compound fertilizer

Examples of compound fertilizers

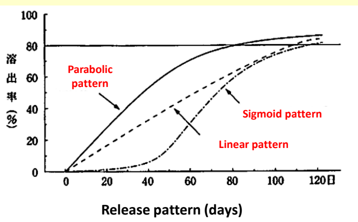


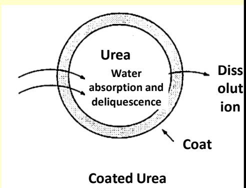
General, horizontal
14-14-14 = N : P_2O_5 : K_2O (%)

For legumes

Controlled-release fertilizer

Controlled-release fertilizer (肥効調節型肥料)





deliquescence

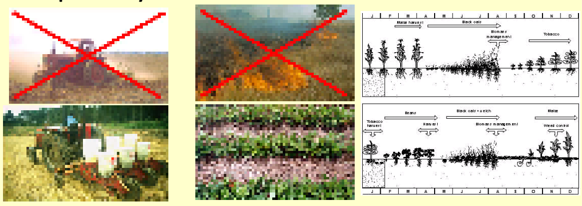
1. Coated fertilizers
2. Synthetic slow-release fertilizer
3. Compound fertilizers containing nitrification inhibition

3. SELECTED TOPICS
3-1. CONSERVATION AGRICULTURE (CA)

Conservation agriculture (CA)

The three principles of conservation agriculture:

1. **Direct planting of crop seeds**
2. **Permanent soil cover, especially by crop residues and cover crops**
3. **Crop diversity**



FAO site for CA
http://www.fao.org/ag/ca/index.html

No-till (Conservation agr.)

(= **zero tillage**, **direct planting**)

- Definition : Growing crops from year to year without disturbing the soil through tillage.

Technological components :

1. Residue management
2. Direct seeding with no-till planter
3. Herbicide use for weed management

No-till planter (1)
http://www.youtube.com/watch?v=pX5tud-2tgc&feature=related
3:00 Row Cleaner, 4:03 Spike wheel, 5:25 Coulter

Direct-drilling wheat at 14 mph
http://www.youtube.com/watch?v=6vspPAtT_og 4:25 Emergence

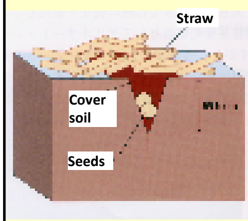
Non-till planter

Mechanical sowing (1)

Non-till planter

May 17, 2005 **Sowing sunflower by non-till planter**

No-till planter with herbicide sprayer



Seed position by no-till planter and germination

Advantages of no-till seeding

- No need for ploughing
- High efficiency（4 to 5 m/second）
- Best-timing operation（shortly after rain）
- One-time operation（sowing, fertilization and herbicide application）

Disadvantages

- Highly risk of **excess moisture**
- Less weed suppression

Water in thesowing path at germination（Ibaraki, Tamatsukuri）

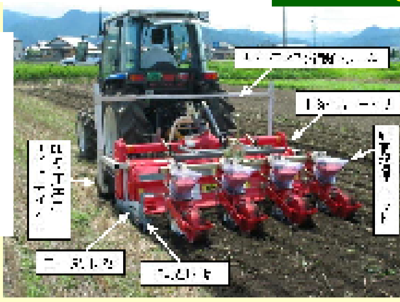
Effect of drainage on the growth of sunflower in farmers' fields

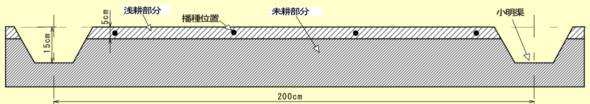
Mechanical sowing

Shallow-tillage

"Shallow rotary tillage seeder with side disk ditcher"

(originally developed for soybean)





Good early growth of rapeseed by shallow planter with small ditcher（16 Jan, 2006 (Sown at 6 Oct. 2005)）

Good growth of sunflower sown by shallow planter with small ditches

Strip-till

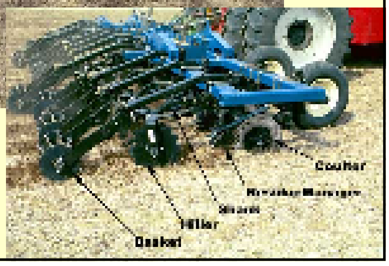
First, a parial width of the row (20-25cm) is cultivated with special equipment. Fertilizers and chemicals are usually applied at the same time.

In the second run, the seeds were sown on the strip.

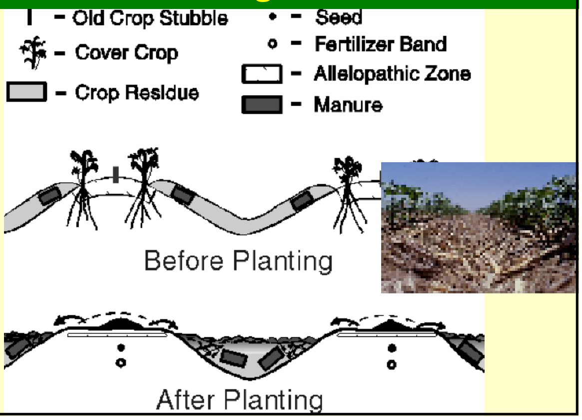
Benefit: The higher soil temperature compared with non-till , less erosion, etc.

http://www.youtube.com/watch?v=J1OZWZ2yAaY

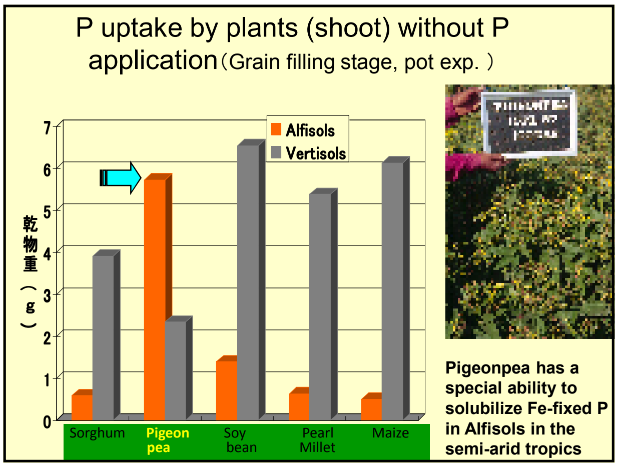
Strip-till

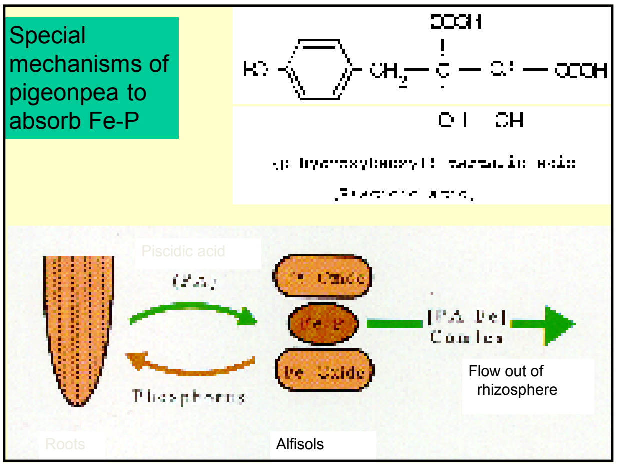


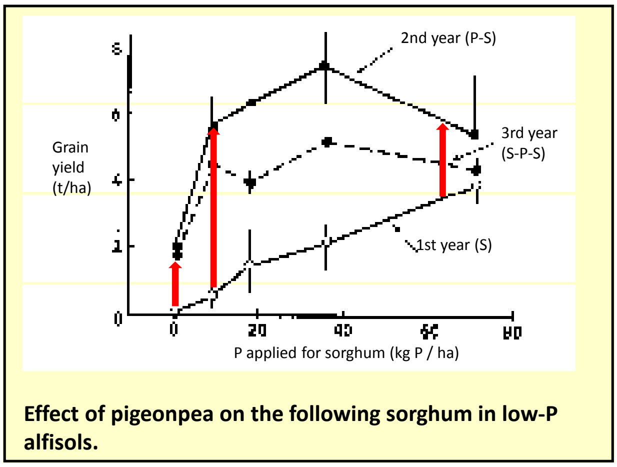
Ridge-till

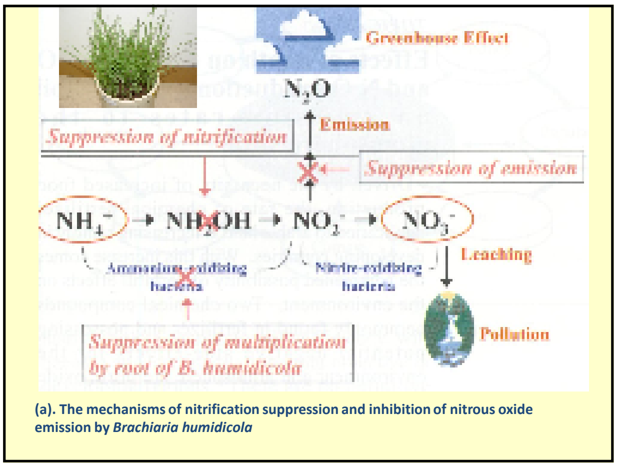


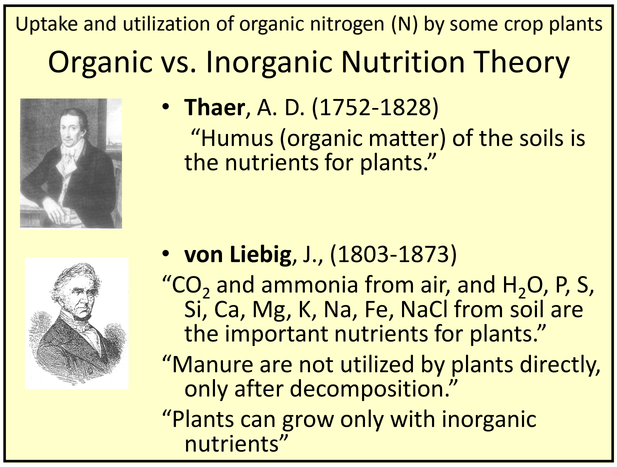
3-2. UTILIZING PLANT'S ABILITY TO ACQUIRE NUTRIENTS FROM SOILS

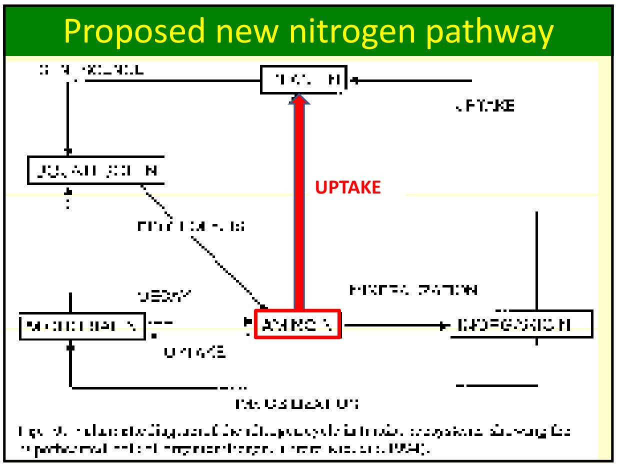

P uptake by plants (shoot) without P application (Grain filling stage, pot exp.)
Alfisols
Vertisols
乾物重（g）
0
1
2
3
4
5
6
7
Sorghum
Pigeon pea
Soy bean
Pearl Millet
Maize
Pigeonpea has a special ability to solubilize Fe-fixed P in Alfisols in the semi-arid tropics


Special mechanisms of pigeonpea to absorb Fe-P
COOH
COOH
Piscidic acid
Phosphorus
Flow out of rhizosphere
Roots
Alfisols


Grain yield (t/ha)
2nd year (P-S)
3rd year (S-P-S)
1st year (S)
0
20
40
80
P applied for sorghum (kg P / ha)
Effect of pigeonpea on the following sorghum in low-P alfisols.

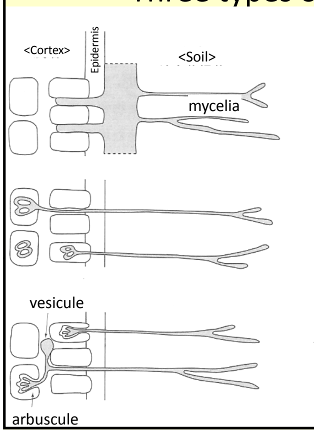

Greenhouse Effect
N_2O
Emission
Suppression of nitrification
Suppression of emission
NH_4^+
NH_2OH
NO_2^-
NO_3^-
Ammonium-oxidizing bacteria
Nitrite-oxidizing bacteria
Leaching
Pollution
Suppression of multiplication by root of B. humidicola
(a). The mechanisms of nitrification suppression and inhibition of nitrous oxide emission by Brachiaria humidicola


Uptake and utilization of organic nitrogen (N) by some crop plants
Organic vs. Inorganic Nutrition Theory
• Thaer, A. D. (1752-1828)
"Humus (organic matter) of the soils is the nutrients for plants."
• von Liebig, J., (1803-1873)
"CO_2 and ammonia from air, and H_2O, P, S, Si, Ca, Mg, K, Na, Fe, NaCl from soil are the important nutrients for plants."
"Manure are not utilized by plants directly, only after decomposition."
"Plants can grow only with inorganic nutrients"

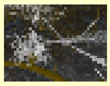

Proposed new nitrogen pathway
UPTAKE
UPTAKE
MINERALIZATION
INORGANIC N
DECOMPOSITION

3-3. UTILIZING MICROBIAL ABILITY TO ACQUIRE NUTRIENTS FROM SOILS

Three types of mycorrhiza



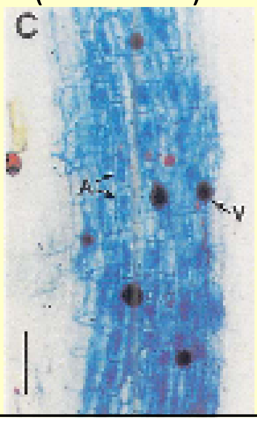
Ectomycorrhizal fungi
for trees, Basidiomycetes

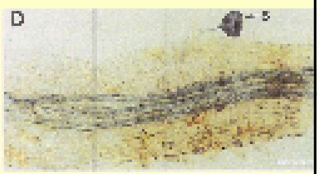


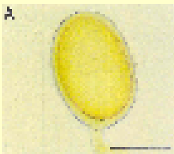
Ericoid mycorrhizal fungi
for orchids, Ericaceae

Arbuscular mycorrhizal fungi (AMF, VAM)
Important for many plant species

(Vesicular-) Arbuscular Mycorrhiza



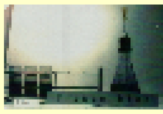




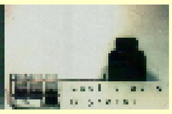
Spore
Bar = 0.1 mm

(Ueda et al 1992)

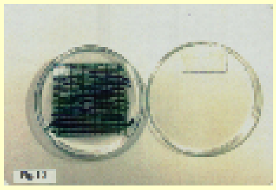
AM measurement (1) % root infection

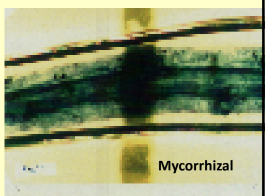


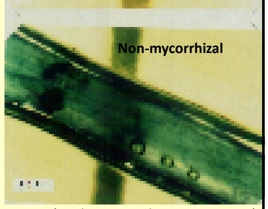
Dying with trypan blue



Fixation





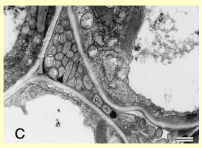


(Usuki, personal communication)

Effect of the previous crops on the growth of maize in Hokkaido, Japan

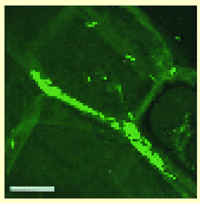
Endophyte

- endo (within)+ phyte (plant)
- Definition : An endophyte is an symbiotic microbes in plant tissue, often a bacterium or fungus, that lives within a plant for at least part of its life <u>without causing apparent disease</u>. Endophytes are ubiquitous and have been found in all the species of plants studied to date.

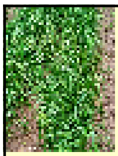


Bacteria colonized in 3rd leaf of rice

(Elbeltagy et al 2001)



Fluorescence micrographs of GFP-tagges *Herbaspirillum* sp. strain



(Lolium temulentum)

Endophyte history

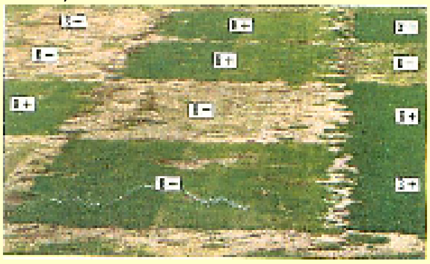
- Darnel (毒麦) (*Lilium temulentum*) was known from old age (mentioned in New Testament), but it was rather recent that the toxins were produced by fungus which colonizes in the plants.
- Since 1970's these were found to be the cause of the animals' intoxication. In 1975 the cause of the fesucue toxicosis was found to be the endophytic fungi in tall fescue (*Festuca arundinacea*) in North America, and in 1979 ryegrass staggard was found to be caused by enophyte in perennial ryegrass (*Lolium perenne*).

(Tall fescue)

-E +E

(rye)

- But Prestidge (1982) reported that endophytic perennial ryegrass is more tolerant to a kind of weevil (Argentine stem weevil).



Perrenial ryegrass affected by *Crambus spp.*)
E+ Variety infected by endophyte : E- Variety not infected by endophyte

Power of endophyte (NHK video)
http://cgi4.nhk.or.jp/gendai/kiroku/detail.cgi?content_id=2958

Endophytic N_2 fixation in Sugarcane

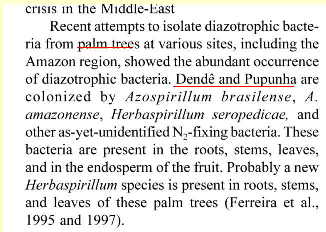
Table 3. Total nitrogen accumulation of sugar cane and *Brachiaria arrecta* and estimates of nitrogen derived from BNF using N balance and ^{15}N isotope dilution techniques ($g N m^{-1}$). means of 4 replicates. After Urquiaga et al. (1991)

Variety/ Species	Final N content of soil	N accum. whole plant 3 years	Estimates of BNF contribution: All three years, N balance[1]	All three years, ^{15}N[2]	Annual mean, N balance	Annual mean, ^{15}N
CB 47-89	835	61.4bc	39.7	34.8c	13.2	11.6
CB 45-3	864	84.3ab	62.6	52.6b	20.9	17.5
NA 56-79	884	57.8c	36.1	32.6c	12.0	10.9
IAC 52-150	924	59.6bc	37.9	33.8c	12.6	11.3
SP 70-1143	852	77.5bc	55.8	51.9b	18.6	17.3
SP 71-799	860	56.9c	35.2	33.3c	11.7	11.1
SP 79-2312	845	63.6c	41.9	35.4c	14.0	11.8
Chunee	826	33.0d	11.3	16.9d	3.8	5.6
Caiana	857	11.6d	−10.1	6.7d	− 3.4	2.2
Krakatau	857	102.8a	81.1	71.8a	27.0	23.9
B. arrecta	830	24.9d	3.2	—	1.1	—
CV (%)	5.1ns	25.0***	—	29.2***	—	29.2

(Boddey et al. 1991)

Plants associated with N_2-fixing endophytes

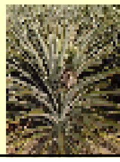
- sugarcane
- rice
- palm (date, oil, etc.)
- sweet potato
- pineapple
- tea
- coffee
- and more?



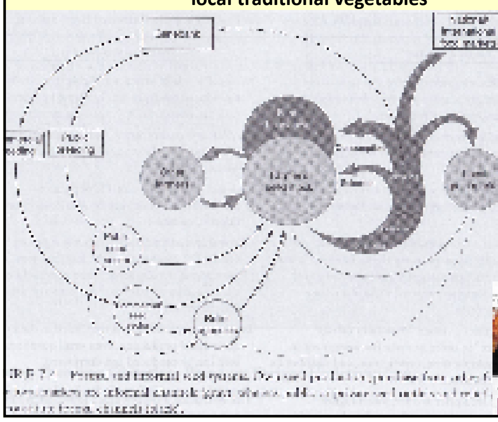
crisis in the Middle-East

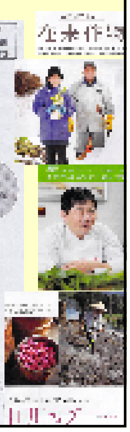
Recent attempts to isolate diazotrophic bacteria from palm trees at various sites, including the Amazon region, showed the abundant occurrence of diazotrophic bacteria. Dendê and Pupunha are colonized by *Azospirillum brasilense*, *A. amazonense*, *Herbaspirillum seropedicae*, and other as-yet-unidentified N_2-fixing bacteria. These bacteria are present in the roots, stems, leaves, and in the endosperm of the fruit. Probably a new *Herbaspirillum* species is present in roots, stems, and leaves of these palm trees (Ferreira et al., 1995 and 1997).

(Reis et al 2000)



Informal seed system, *in situ* genetic conservation, local traditional vegetables





6. Future Direction

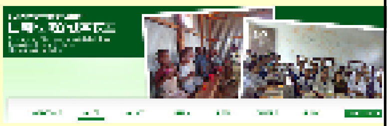
Present issues for agriculture and food for consumers

- Safety of the food
  - Additives, Remaining antibiotics, BSE,
  - Virus, Radioactivity
- High price
- Unbalanced nutrients
  - Convenient food

Present issues for agriculture and food for producers

- Low benefit, fluctuation
- Unbalanced labor / price
- Working conditions
- Two extremes
  - Quest of the high value-added products, which will not lead to the benefit of the consumers

Comparison with the health care



- “Health” : A value, to e maintained, to be pursued, if it is threatened, measures should be taken
- “Agricultural welfare (well-being)”

  Agriculture not only as industry, but value

  For those agriculture is the major means of the income, it should be the reasonable income source and quality of life. For the consumers, it si the means to provide the safe and sound food and green related environment.

Necessary endeavors for the further quest of the 3rd generation agricultural technologies

Critical thinking

Quantitative assessment for the impact

Transforming new findings to real technologies.

レポート課題/Report

- 特殊な肥料または機械を必要とする作物（なるべく作物、しかし難しければ野菜・果物でも可）を調べて見つけ出し、その作物の特殊性と肥料・機械について述べよ。（400～600字）
- Find a crop (or vegetable/fruit) to which special fertilizer or machinery is needed, and discuss the special characteristics of the crop and why the special technology is necessary (200-300 words)