A Primer on Organic-Based Rice Farming

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Contents

Foreword

Fertilizer has become a major input in rice production around the world. As its use has grown, traditionally used organic materials such as farmyard manure and green manure crops have been increasingly neglected.

Farmers have become more and more dependent on off-farm supplies, which require cash and may not always be available on time.

The harmful effects on the environment of heavy and improper use of chemicals are becoming more evident. Further, the fossil fuels used in the production of nitrogen fertilizers are becoming scarcer. At the same time, the demand for rice is going up as populations increase, particularly in Asia.

Thus, interest in sustainable farming—using renewable resources easily and cheaply available on the farm—is growing. Such a system maintains soil fertility as far as possible by the traditional biological means—rotating cereal crops with legumes, recycling manure and other organic wastes, using green manures—and combining these with moderate amounts of chemical fertilizers. Research has shown such combinations to be more effective than any single nutrient source in improving soil quality and nutrient use efficiency, and thus yields.

Such a system is also more environmentally sound than one that relies solely on chemical fertilizers.

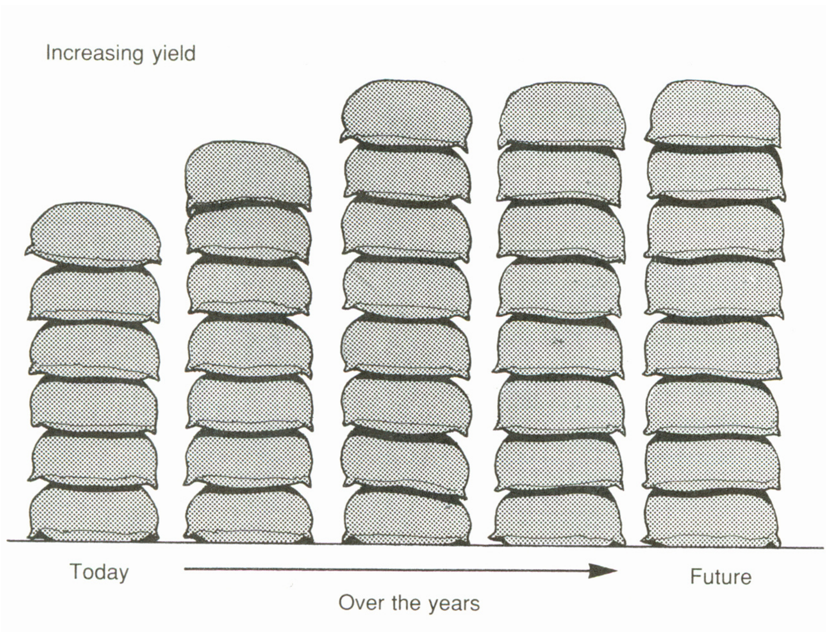
This book outlines the whys and hows of integrating organic and chemical fertilizer use, emphasizing the growing of green manure crops.

About 50 legumes suited to a wide range of rice-growing environments are described so that farmers may choose the ones best for their own needs. Most are multipurpose crops that not only will replenish soil nutrients but will also provide food, fodder, fuel, and extra income for the rice farmer.

The book was edited by Vrinda Kumble, Editorial Consultant Services, New Delhi, India, with special illustration by John Figarola, IRRI Communication and Publications Department. The book is designed to facilitate translation and copublication.

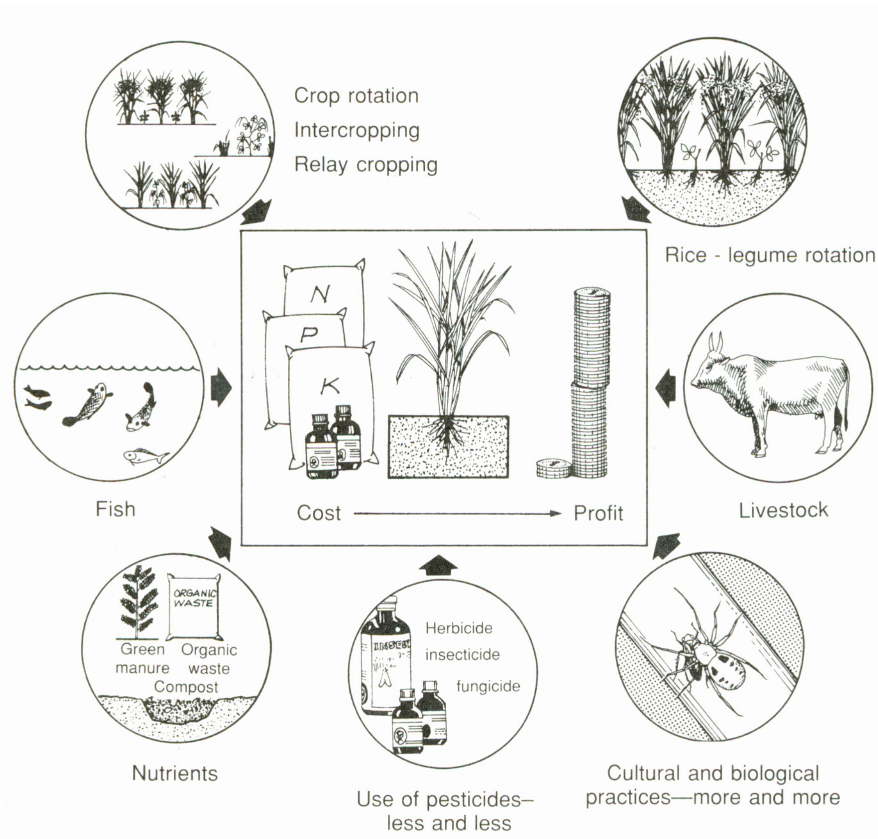
Klaus Lampe
Director General

Sustainable rice farming



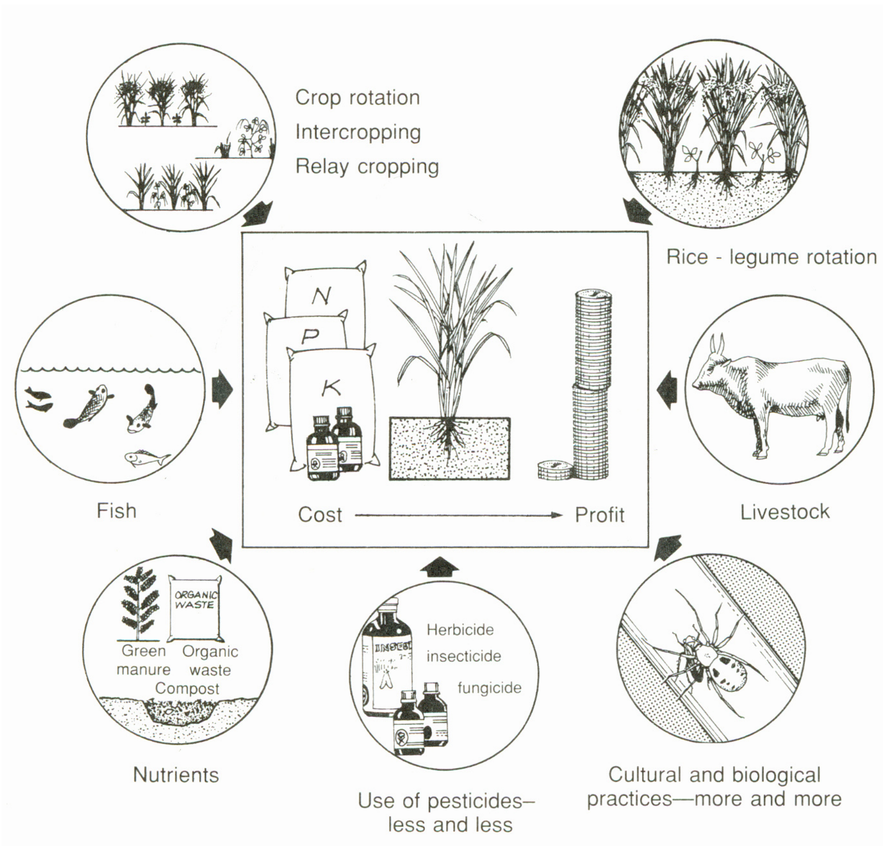
■ Today's rice farmers must not only get high yields in the short term but also consider how to sustain those yields over the years, without raising the cost of production.

Sustainable rice farming



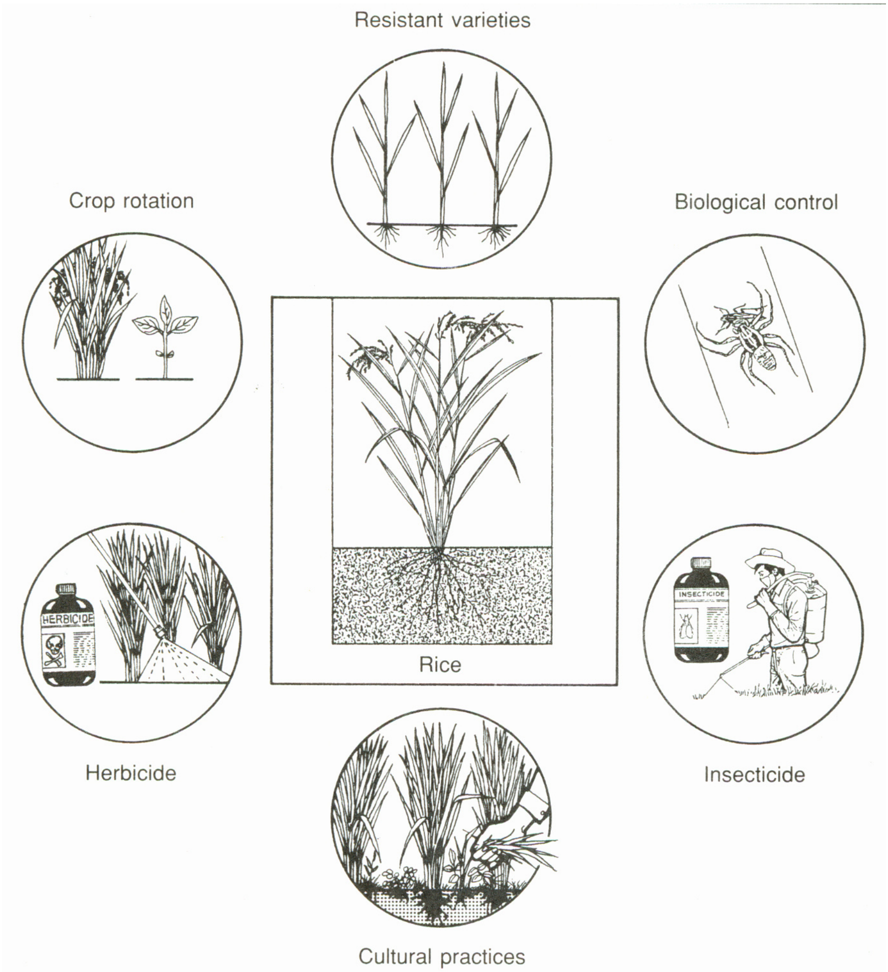
- "Integrated" farming tries to make the fullest use of the farm's own resources, combining these with chemical inputs as needed.
- Crops and cropping systems are arranged to
  - — make the best use of sunlight and rainwater,
  - — control pests, and
  - — renew soil fertility.

Sustainable rice farming



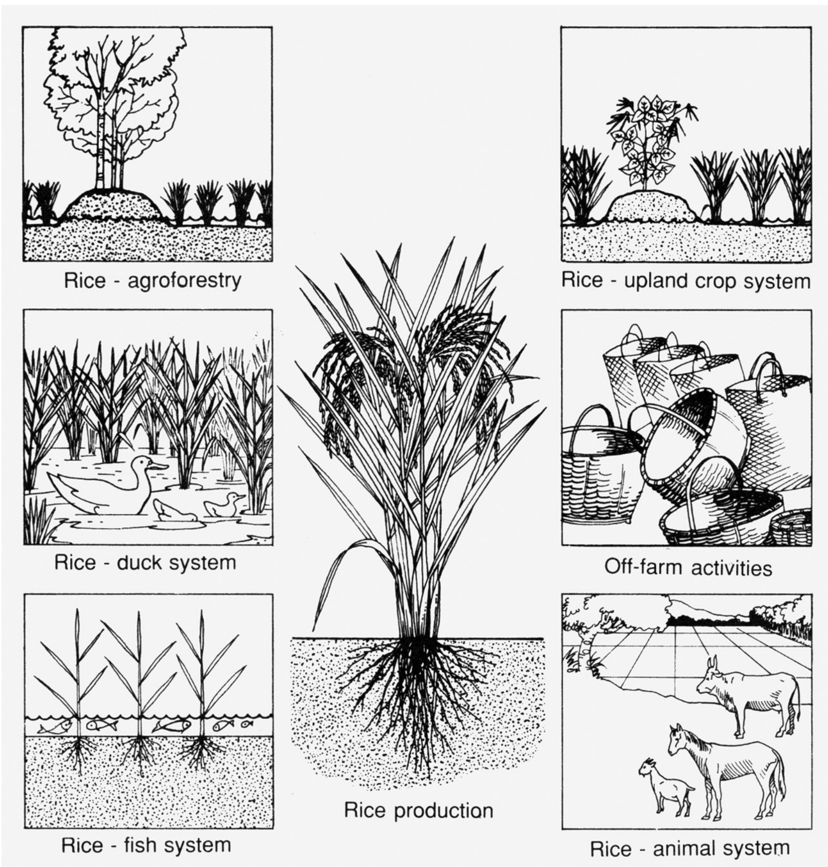
- This system maintains soil fertility as far as possible by biological means, such as rotating crops, growing leguminous green manures, and recycling manure and other organic wastes, which are cheap and easily available on the farm.
- These are combined with moderate amounts of inorganic fertilizer to achieve optimum yields.

Sustainable rice farming



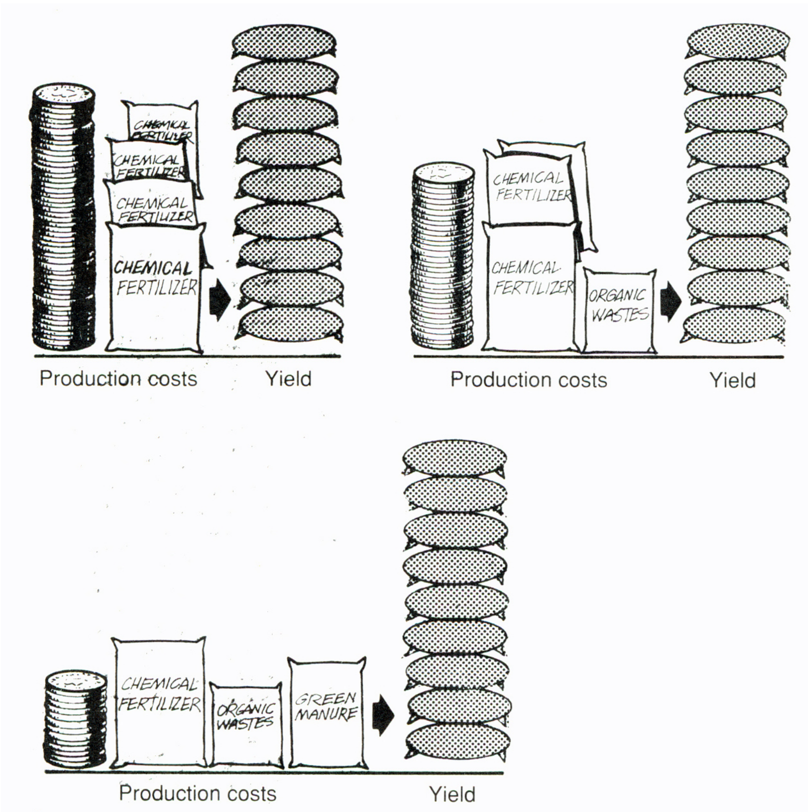
■ Control of pests and diseases in an integrated farming system is chiefly through cultural practices and biological control—backed, where necessary, by pesticides and herbicides.

Sustainable rice farming



- Rice production is the central activity in integrated rice farming. Other farm activities complement rice growing to give the farmer added income during the off-season.

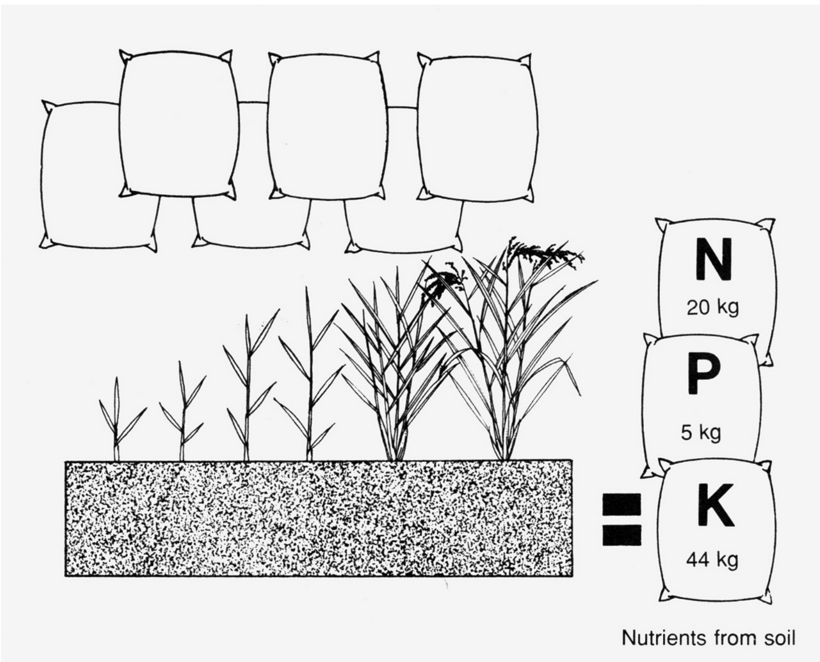
Reducing farming costs



- An integrated farming system enables farmers to reduce production costs by reducing purchased inputs.
- Although fertilizers, pesticides, and other purchased inputs are used as needed, farmers do not have to rely solely on them.
- The system is self-renewing, to a large extent. It allows farmers to be self-sufficient and make their own decisions about managing the farm.

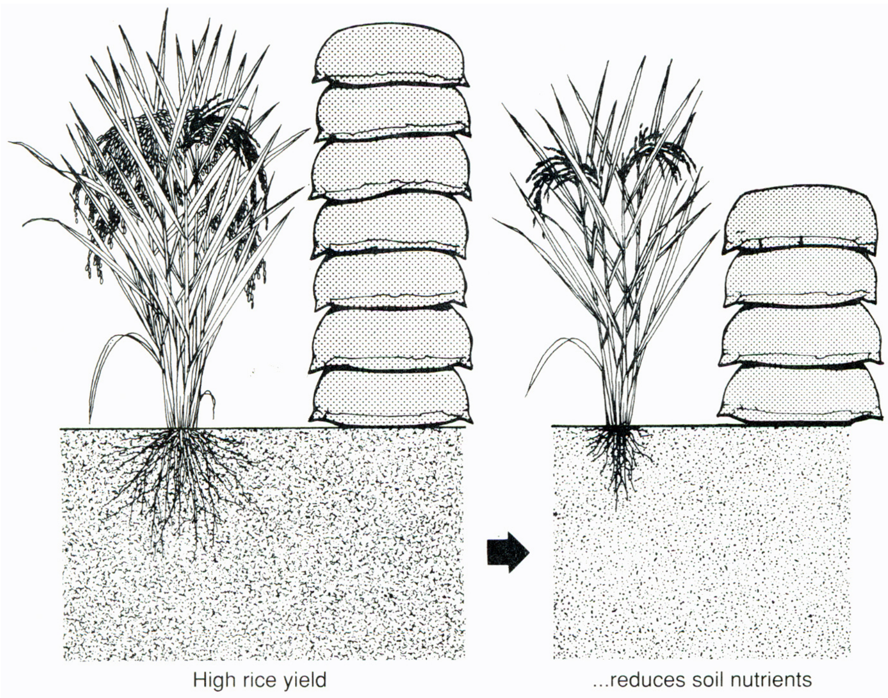
Keeping the soil fertile

Why use nutrients?



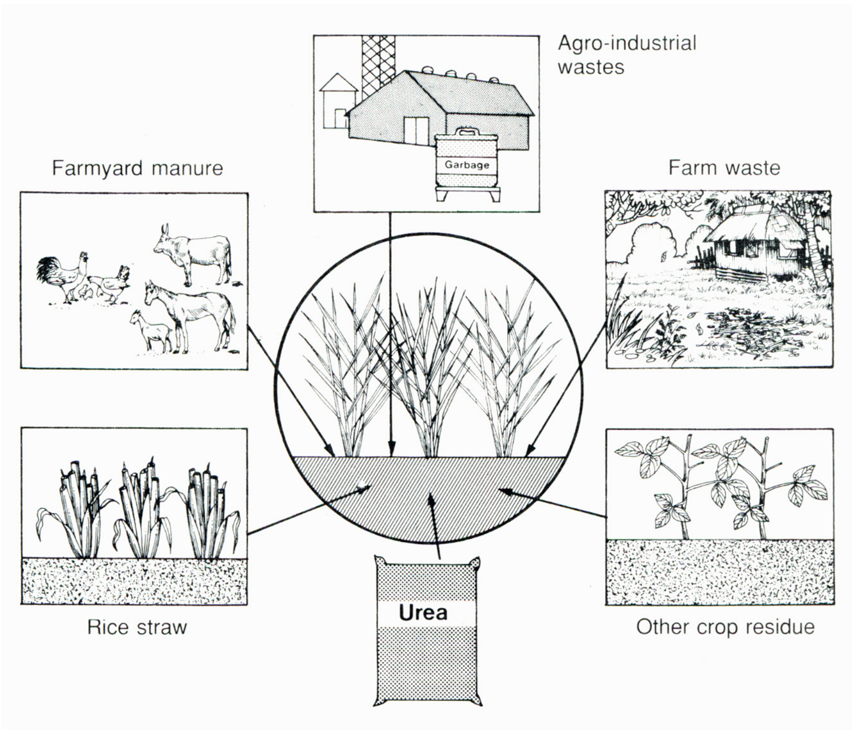
- As the rice crop grows, it uses up the nutrients present in the soil.
- For each ton of rice grain produced, the crop removes from the soil about 20 kg nitrogen, 5 kg phosphorus, and 44 kg potassium.

Why use nutrients?



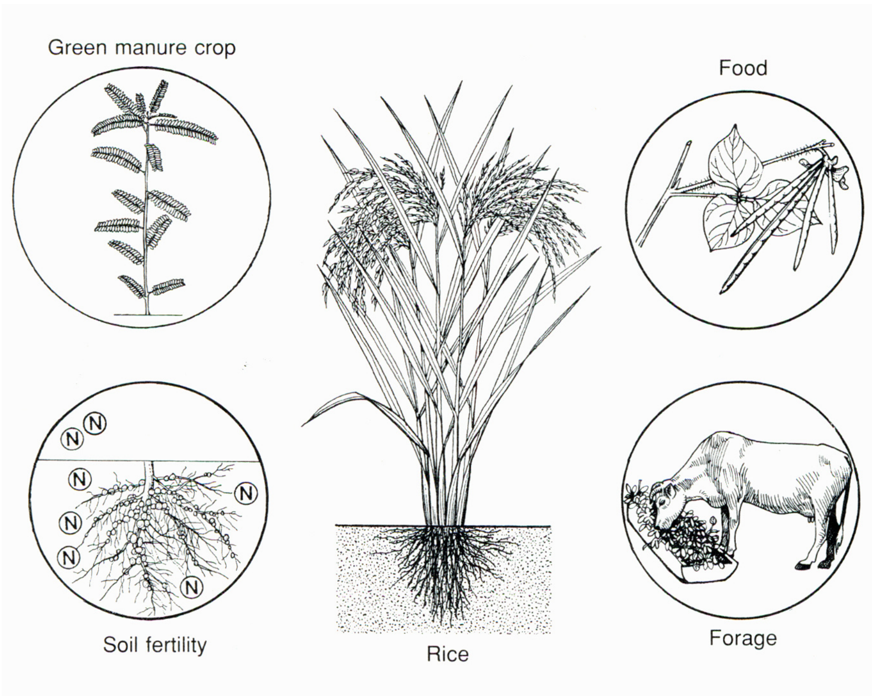
- The higher the grain yield, the more nutrients the crop removes.
- These must be put back into the soil regularly. Otherwise yields will get lower and lower as soil nutrients are used up.

Sources of nutrients



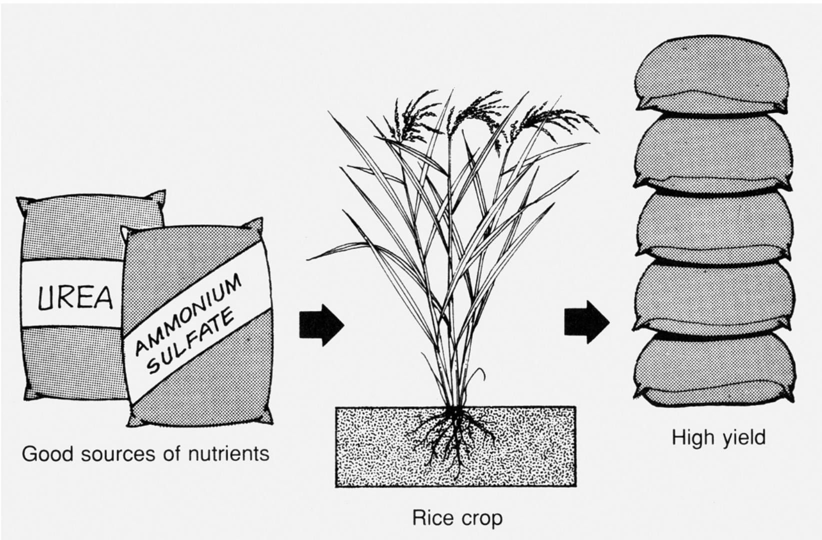
- Soil nutrients can be replenished from many sources.
- Inorganic fertilizers, sold in the market, are one source.
- Organic materials—crop residues, manure from farm animals, kitchen wastes—are another source. They contain all plant nutrients, even minor elements that are needed only in very small amounts.

Sources of nutrients



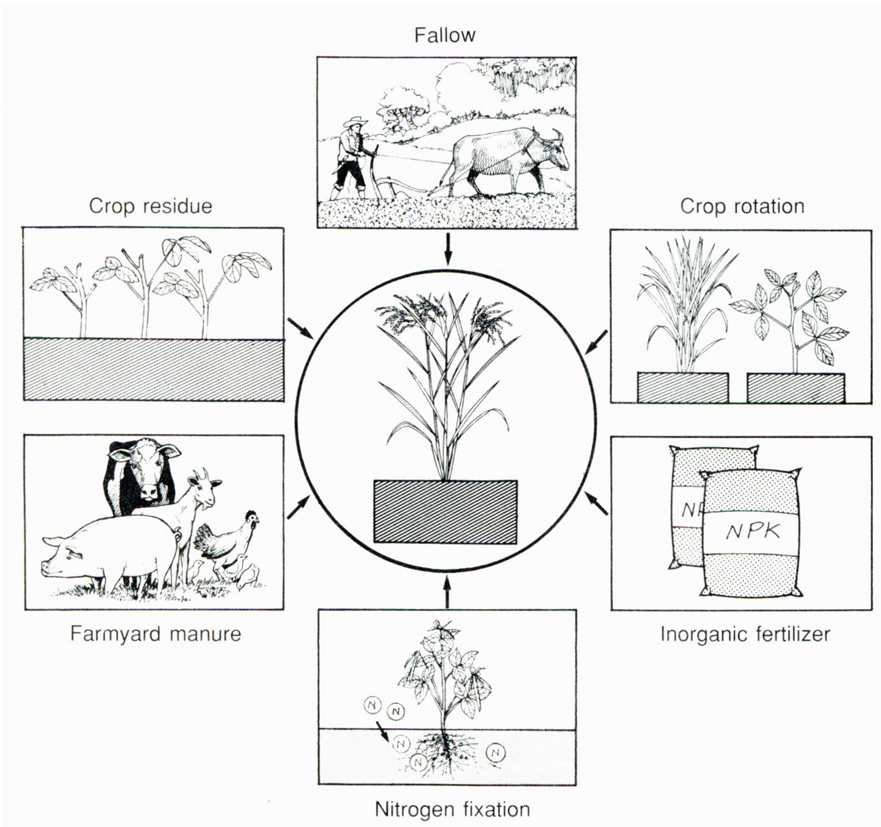
- Green manure crops are a special kind of organic fertilizer: they are grown chiefly to supply nitrogen to the main crop in a cropping system.
- They can also draw up other nutrients from deeper layers of the soil.
- In addition, legume green manure crops, such as cowpea and clover, can supply food or fodder.

Putting back soil nutrients



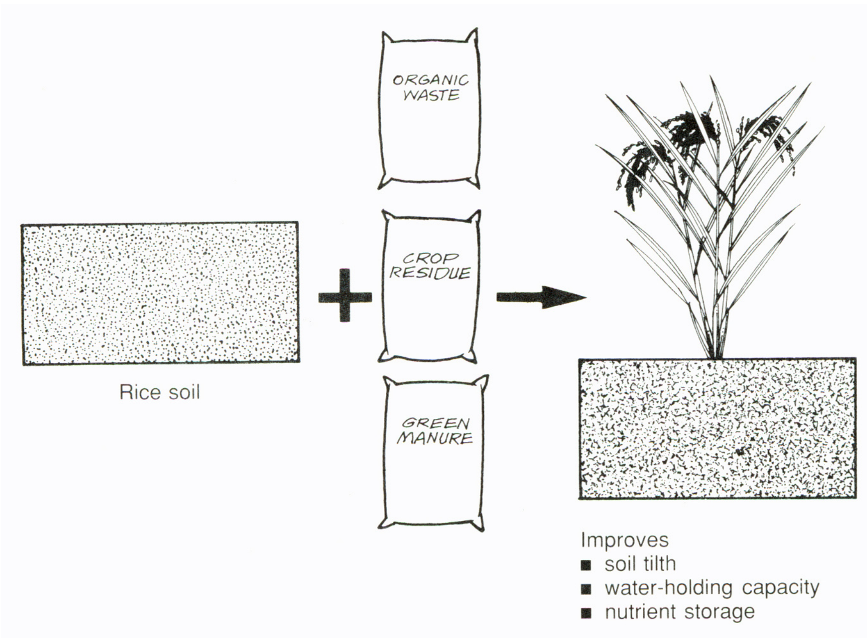
■ Soil nutrient reserves can be built up by adding inorganic fertilizers. Nitrogen fertilizers such as urea or ammonium sulfate are most commonly used on rice. They are easy to use, but
— the farmers need cash to buy them;
— they may not always be available at the right time;
— they may even harm the soil and water, if overused or improperly used.

Putting back soil nutrients



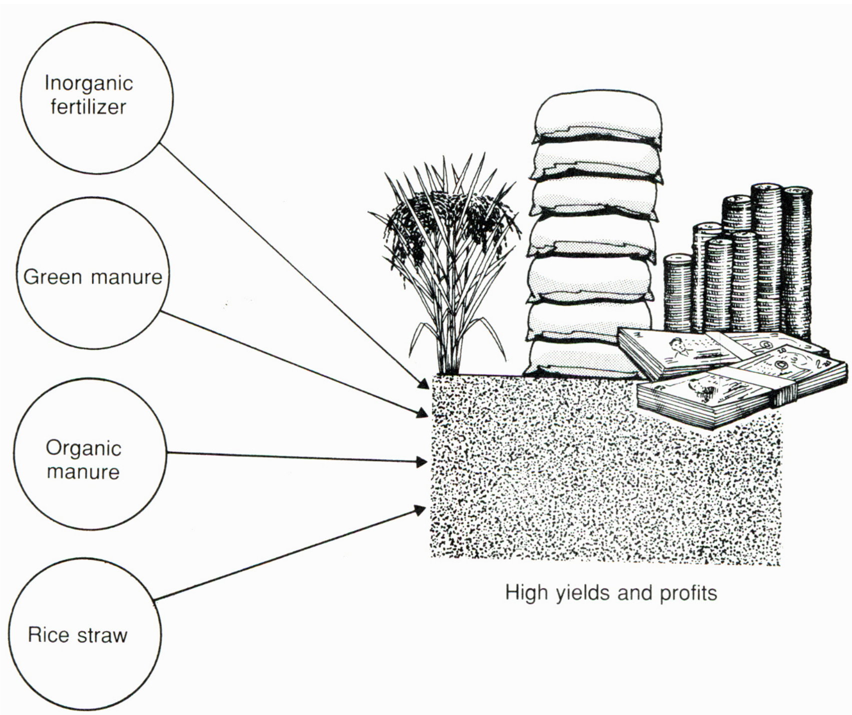
■ Soil nutrient reserves can also be built up by
— adding compost and organic wastes, and
— growing green manure crops that can be plowed into the soil before the main crop is planted.

Improving soil health



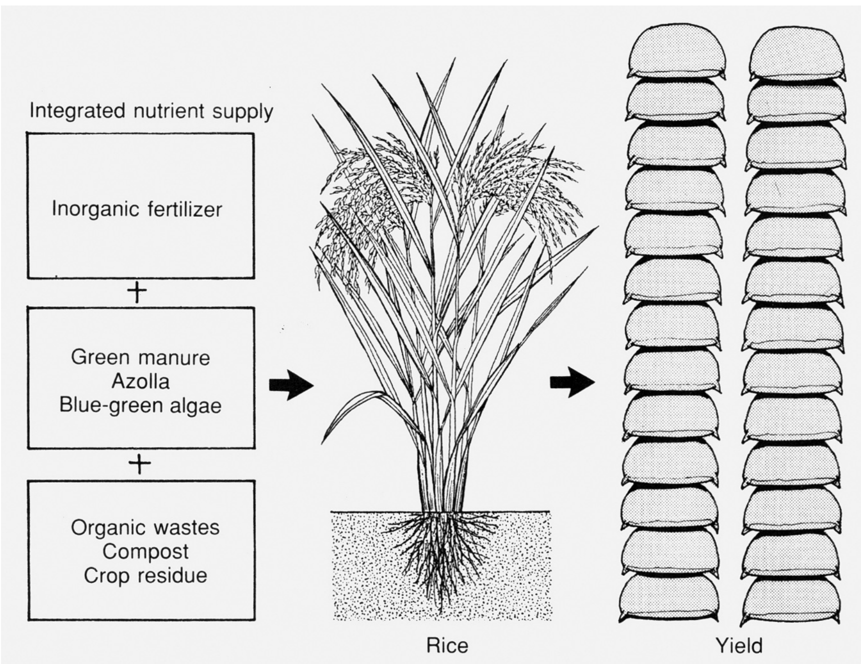
- Adding organic matter to the soil improves all soil properties.
- Clayey soils become more porous, letting water go down into the lower soil layers.
- Sandy soils hold water better, keeping crop roots from drying and preventing nutrients from leaching out.
- But organic fertilizers must be used in very large amounts to be effective. Their nutrient content also varies widely.

Improving soil health



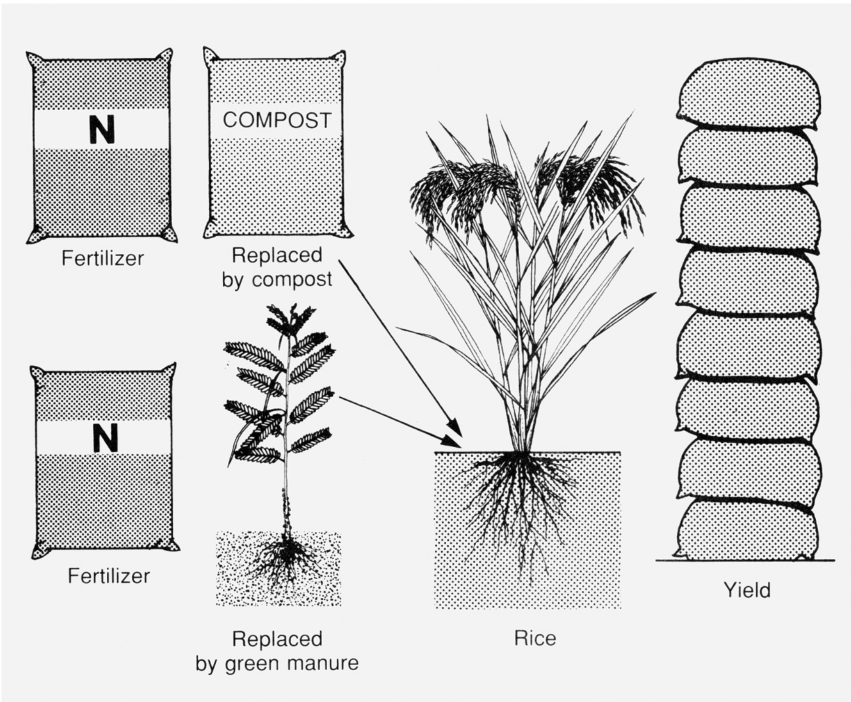
- The best way to keep the soil fertile is to combine all three types of nutrient sources, adding organic matter, green manure, and commercial inorganic fertilizers.
- Such a combination improves soil health, keeps yields high, and reduces fertilizer costs.

Keeping yields high



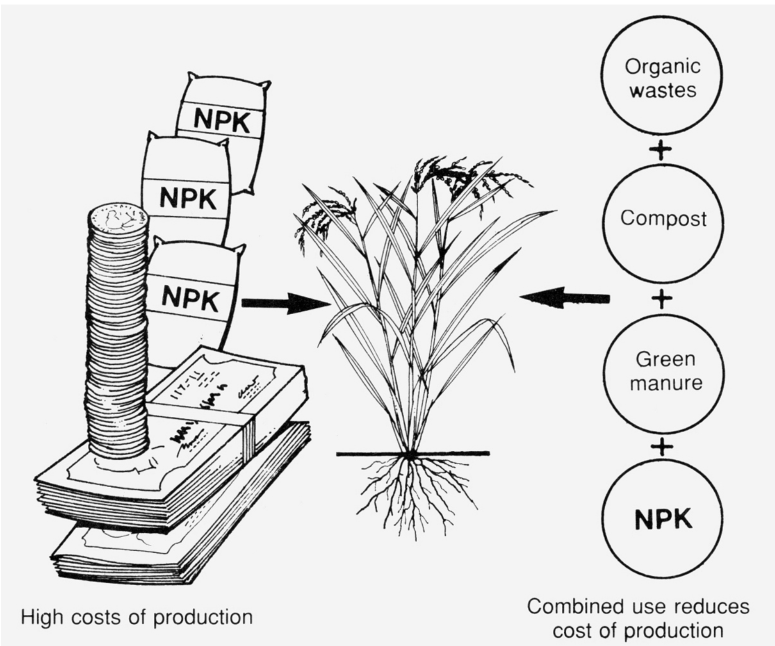
- Such a combination gives higher yields than does any single type of fertilizer, because
  - — the nutrients from the combination are more efficiently available to the crop;
  - — humus releases nutrients slowly, acting as a store of food for the crop throughout the growing season.

Reducing fertilizer costs



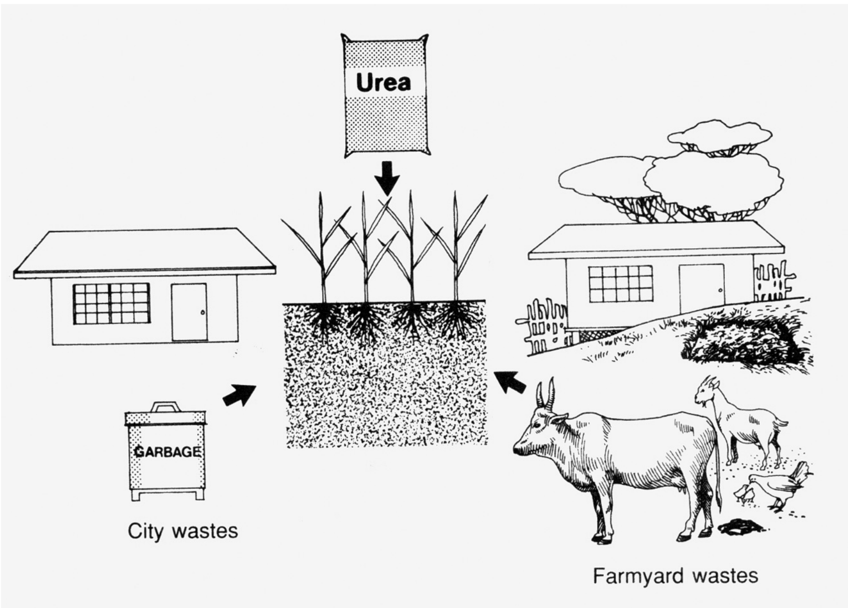
- To reduce costs:
  - — a part of the fertilizer can be replaced by compost and organic wastes, which are usually available free on the farm;
  - — a part of the fertilizer can be replaced by green manure grown before, after, or with the rice crop.

Reducing fertilizer costs



- How much of each material should be used depends on the nutrient content of the organic matter and green manure. The rest is made up by applying inorganic fertilizer.
- Because the crop takes up more of the nutrients from such a combination than from inorganic fertilizer alone, less nutrients are wasted. This reduces overall fertilizer cost.

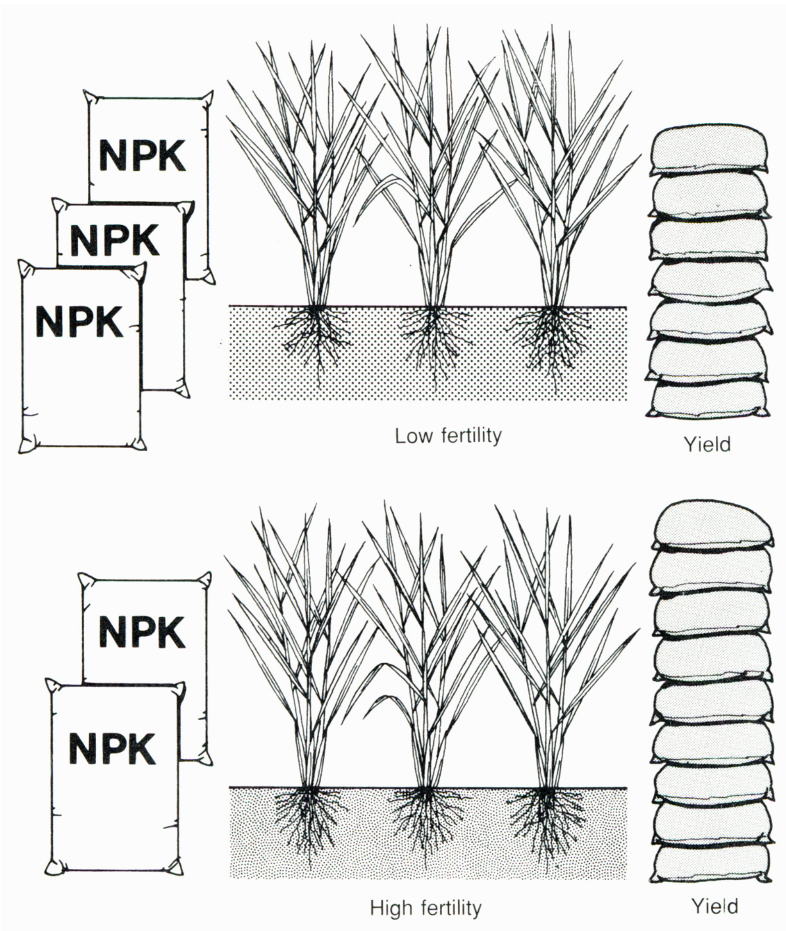
Added benefits



■ At the same time, using farmyard and household wastes to enrich the soil
— keeps the living area clean,
— keeps the surroundings healthy, and
— keeps the air free from smoke and odors.

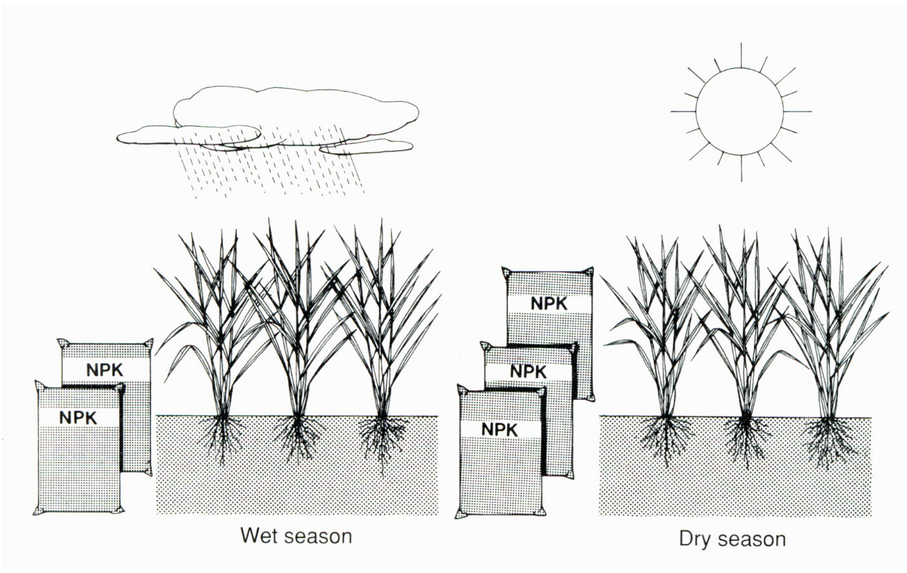
Factors affecting nutrient needs

Initial soil fertility



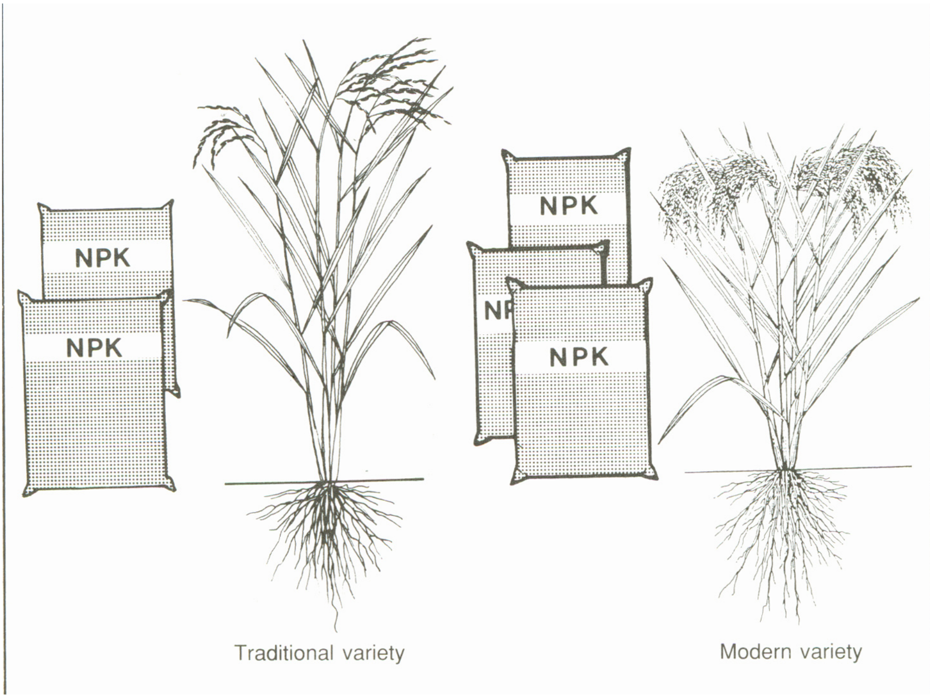
- If initial soil fertility is high, less fertilizer is needed.
- On poor soils, more fertilizer is needed.

Growing season



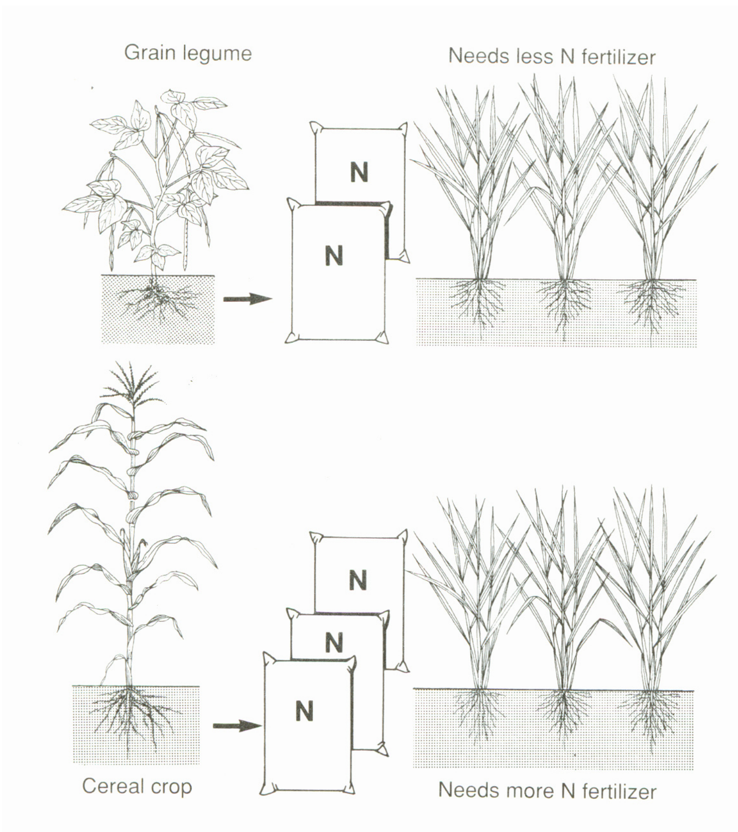
- The rice-growing season affects the nutrients needed by the crop.
- More fertilizer should be used in the dry season than in the wet season.

Variety



- Rice variety and season determine the amount of fertilizer to be added.
- Modern high-yielding varieties of rice are more responsive to fertilizer than traditional tall ones; that is, the yield increase with applied fertilizer is higher in modern varieties when water supply is well controlled.

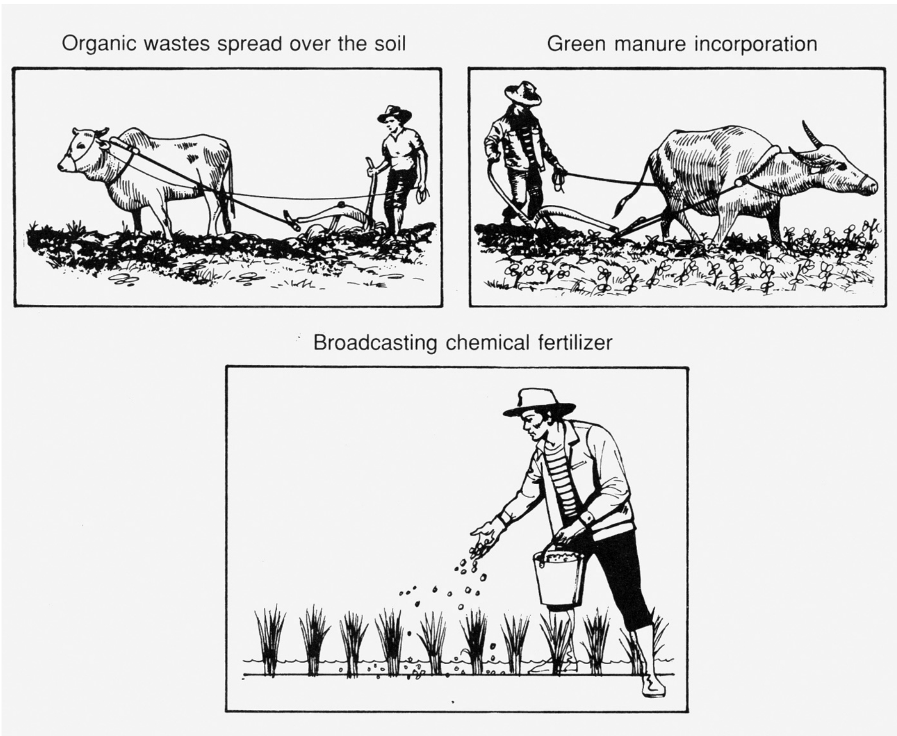
Cropping system



- The cropping system determines the nutrient needs of each crop.
- Rice grown after a legume crop will need less added nitrogen than rice grown after a cereal crop.

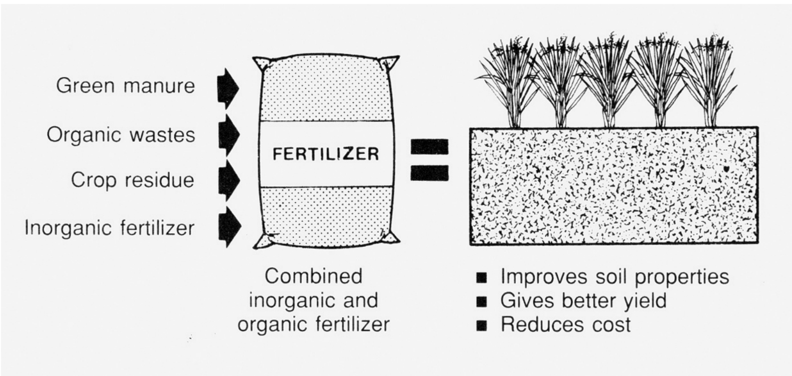
Using organic wastes for fertilizer

Organic wastes for improving soil



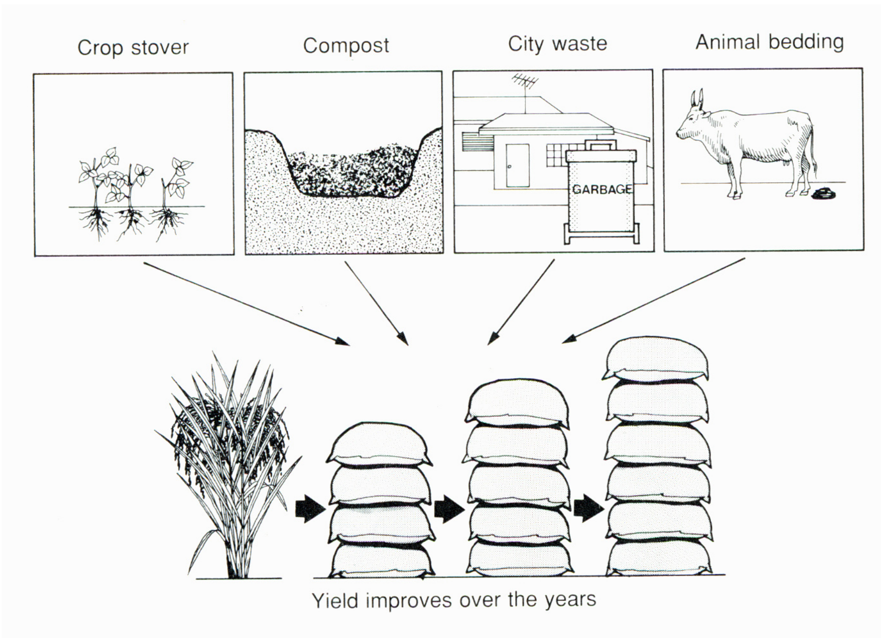
- Through the centuries, farmers have used organic materials available on the farm to fertilize their crops.
- Where inorganic fertilizers are not easily available, these organic materials are still the chief source of plant nutrients.

Advantages of using organic materials



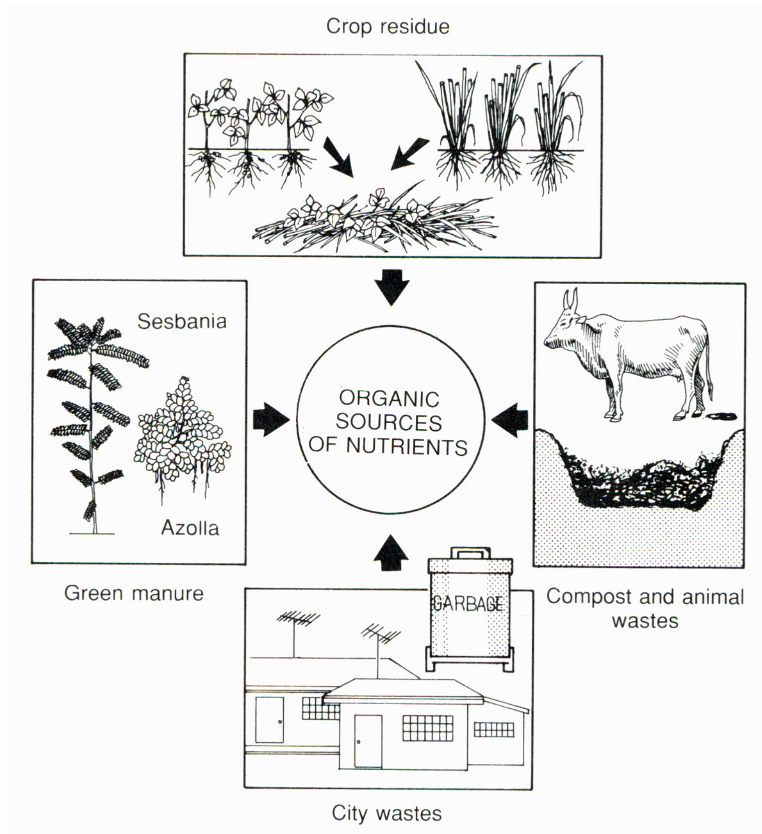
- Inorganic fertilizers perform better when combined with organic materials, producing better crop growth and more stable yields.
- Over the years, addition of organic matter improves all soil properties.

Advantages of using organic materials



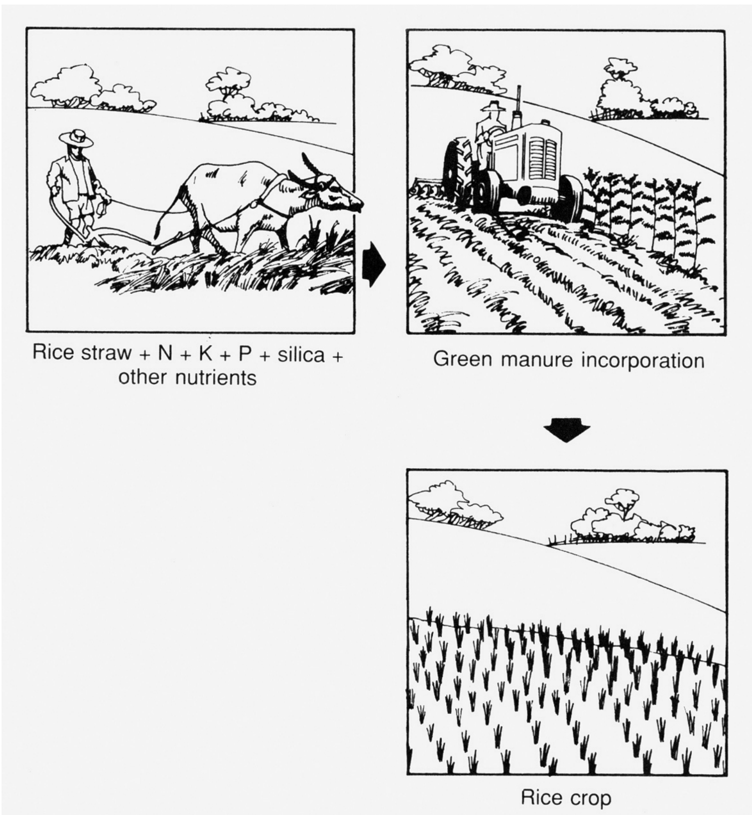
- At the same time, because many of these waste materials cost the farmer little or nothing, their use can also reduce the high cost of fertilizing crops.
- Because they are also readily available, their use can help the farmer become less dependent on outside sources of fertilizer.

Sources of organic materials



■ Organic wastes that can profitably be used to supply crop nutrients include
— crop residues such as straw, stalks, and husks;
— household and farmyard waste;
— agroindustrial wastes; and
— sludge or slurry from biogas plants.

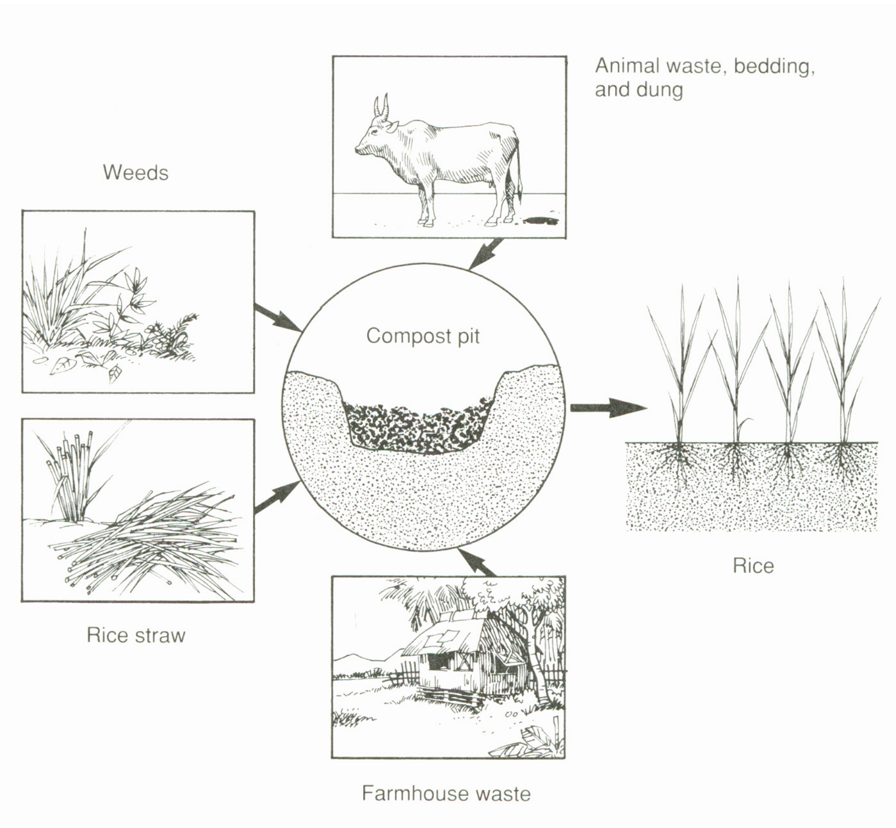
Crop residues



■ Crop residues such as rice stubble and straw can contribute not only nitrogen but also phosphorus, potassium, and minor nutrients. Rice straw, the most readily available material in rice-growing areas, is a good source of silica.

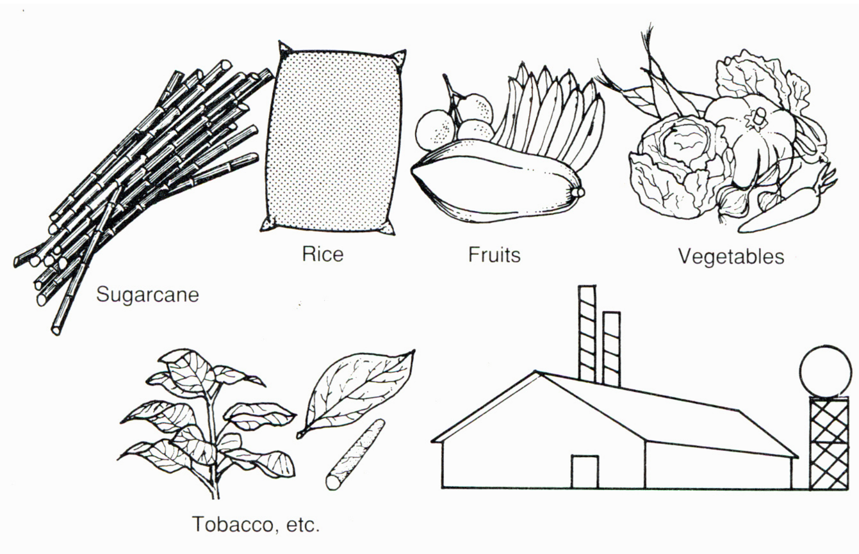
■ However, the rice crop residue should not contain insect pests or disease organisms that can survive to attack the next rice crop.

Compost



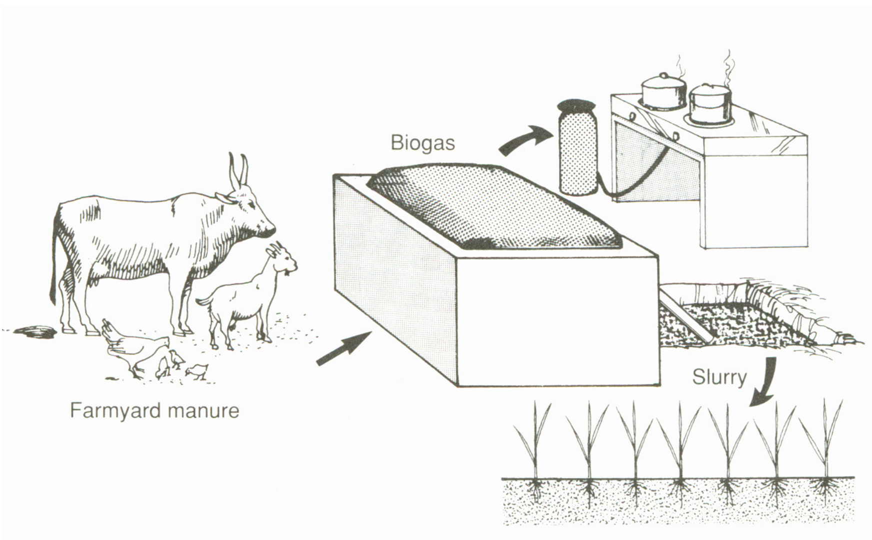
- Organic wastes, such as cow dung and farm and household garbage, should be composted before they are used in the field.
- Collect all wastes—leaves, grass, weeds, animal bedding, garbage from cattle sheds, chicken manure, and kitchen wastes—into a compost pit. They will decay slowly and are ready to use in the field in 12 to 15 weeks.

Agroindustrial wastes



- Wastes from factories and mills that process sugarcane, rice, fruit, vegetables, tea, tobacco, and wood can make valuable organic fertilizer.
- Oil cake—the residue left after pressing oil from oilseeds such as safflower, sunflower, groundnut, or soybean—is another good source of nutrients.

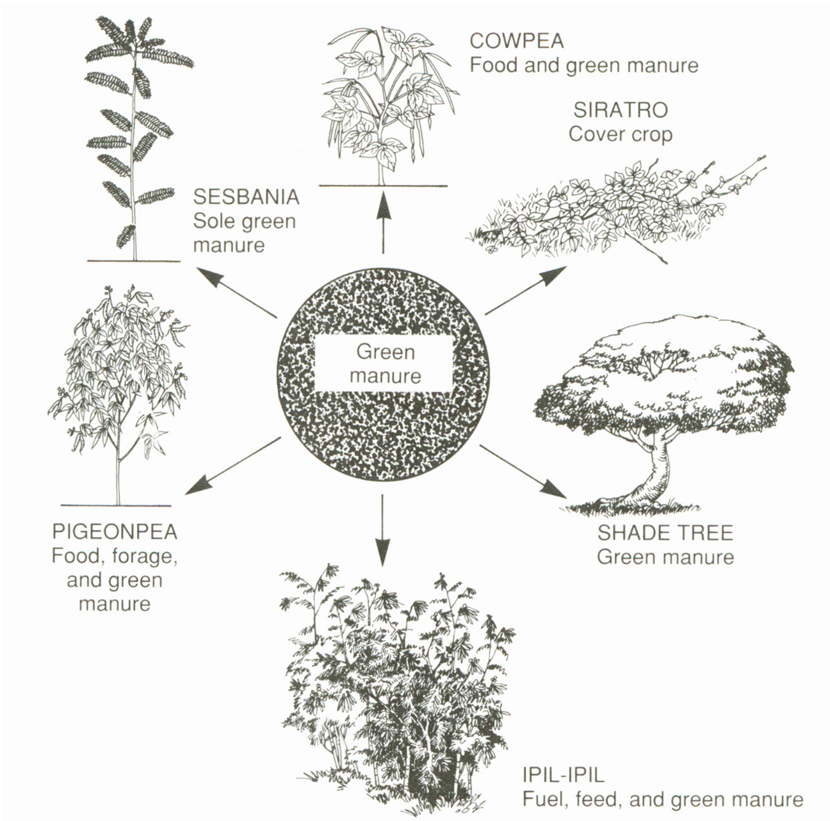
Biogas sludge and slurry



- The residue from biogas plants makes good fertilizer, rich in all crop nutrients.
- It is already composted and can be used directly in the field.

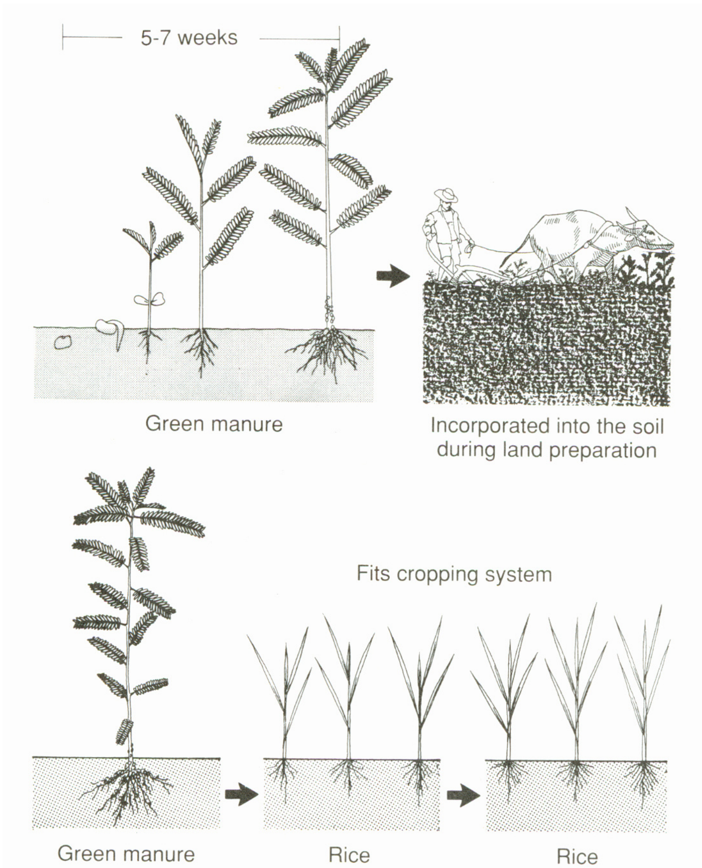
Using green manure crops for fertilizer

What is a green manure crop?



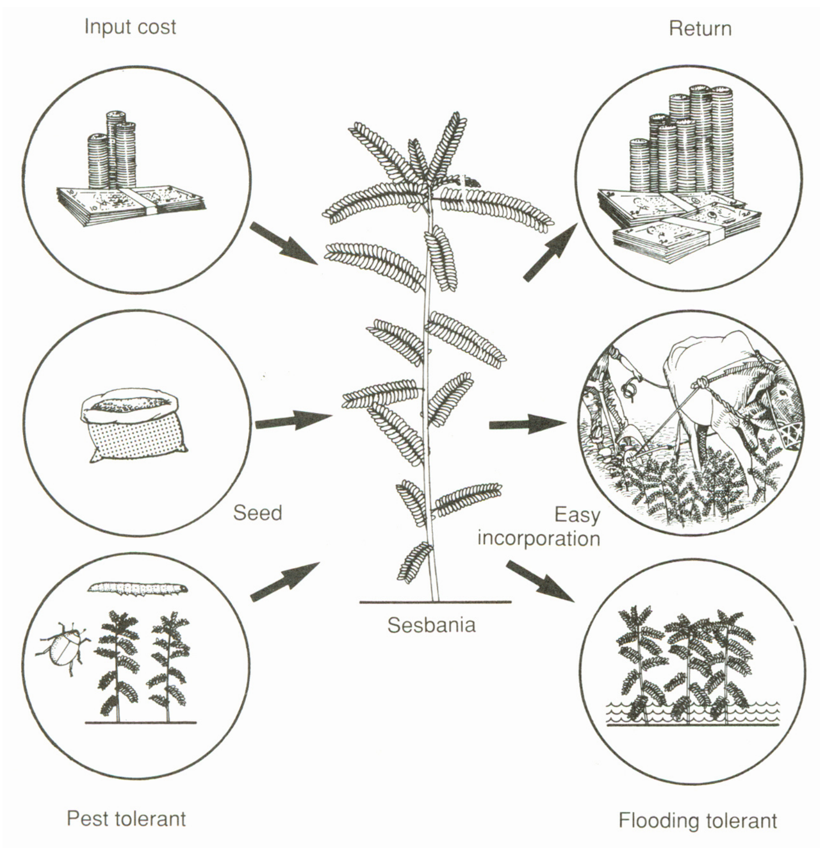
- A green manure is a plant that is grown chiefly to supply nitrogen to the main crop.
- It is grown as a secondary crop, before or after the main crop, during periods when the land is vacant. After 40 or 50 days of growth, the green manure crop is plowed into the soil during land preparation for the main crop.
- Leaf green manure from shrubs or trees can be used.

The ideal green manure crop



- A crop grown for green manure should
  — fit into the cropping system without delaying the planting of the main crop, and
  — grow fast and build up a large biomass and nitrogen content in 5 to 7 weeks.

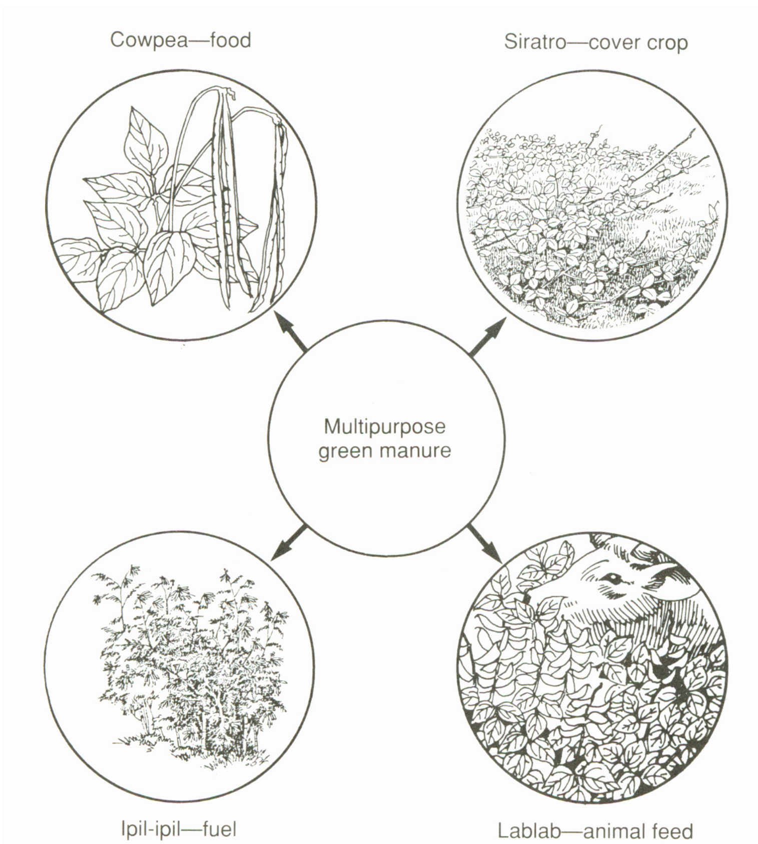
The ideal green manure crop



■ A crop grown for green manure should be a low-cost crop, requiring no costly purchased inputs. It should be

— easy to plant, with easily available seed that germinates well;
— able to stand flooding and drought;
— able to resist pests and diseases; and
— easy to incorporate into the soil.

Multipurpose green manure crops

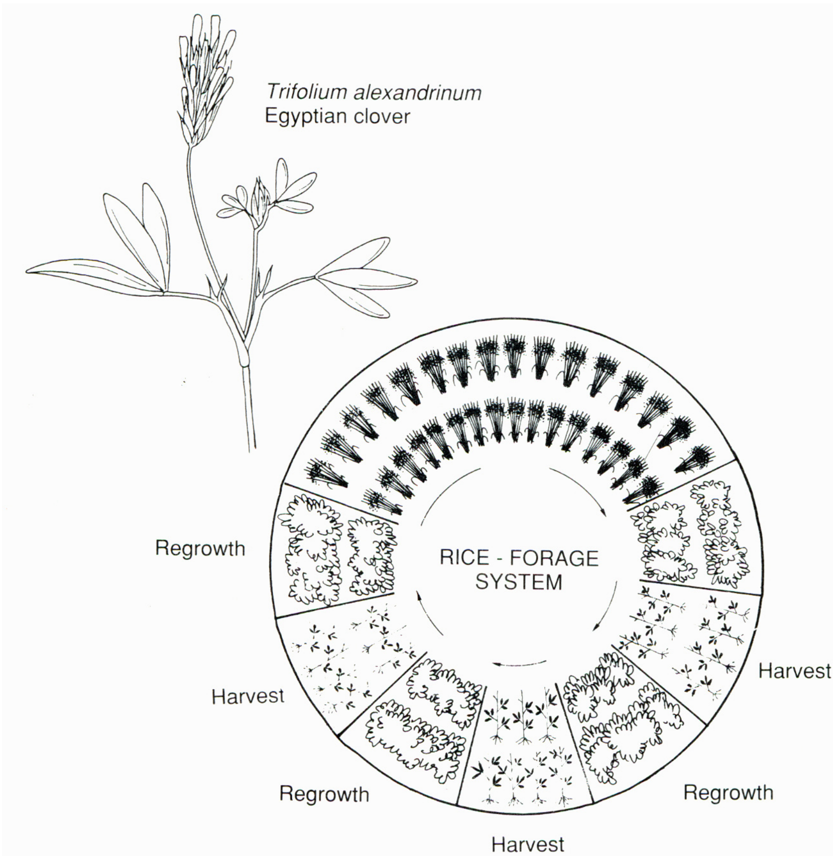


- Many green manure crops can give added profit by supplying food, or feed, or fuel, in addition to nitrogen.
- To make the best use of cropland, plant a multipurpose green manure crop.

Food and green manure

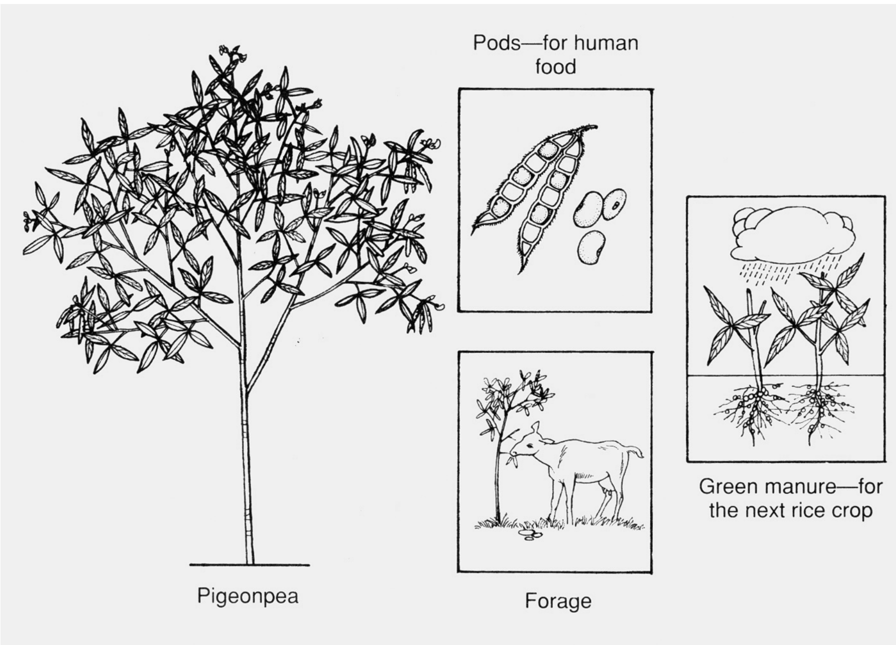
- Crops such as cowpea, soybean, mungbean, and jackbean can be grown for nutritious human food as well as green manure.
- After harvest of pods and seed, the stover can be used as green manure for the following rice crop.

Forage and green manure



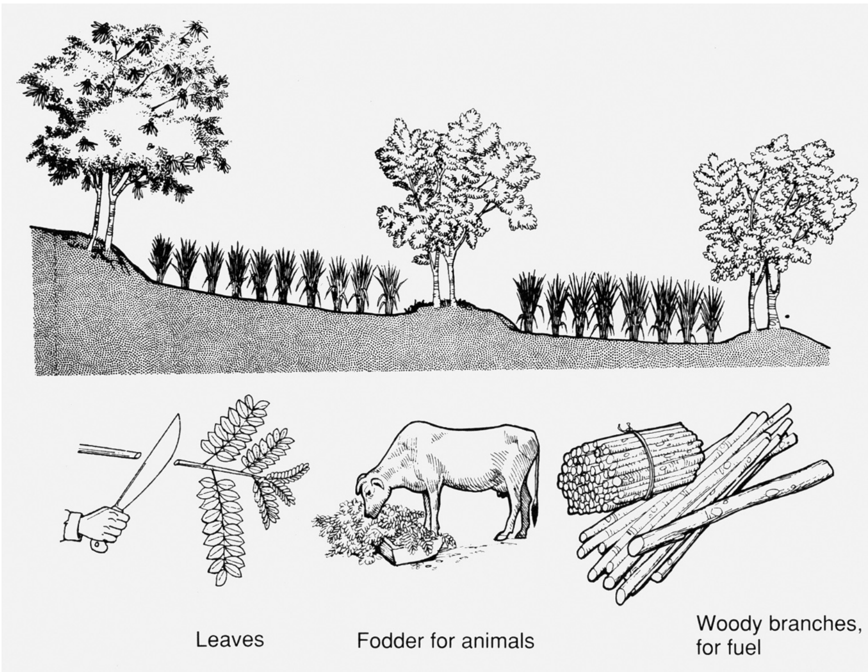
- Sweet clover or berseem (Egyptian clover) can be grown for animal feed, after the harvest of rice.
- After forage is cut two or three times, the crop can be plowed under for green manure.
- Three to four tons of clover biomass can supply about 80 to 100 kg of nitrogen for the following rice crop.

Food, forage, and green manure



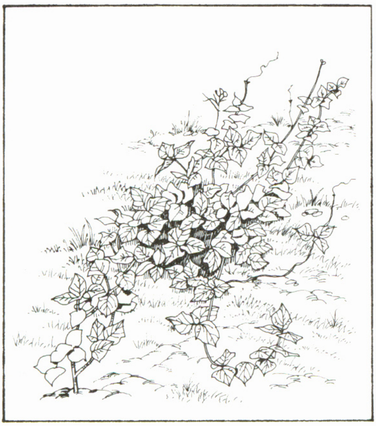
- A crop such as pigeonpea can be grown for human food, animal feed, and green manure.
- After the harvest of pods for seed, cut back the plants just before the rains begin. Use the stover for animal feed.
- With the rains, the pigeonpea plants will put out dense new growth that can give large amounts of green manure for the next rice crop.

Fuel, forage, and green manure



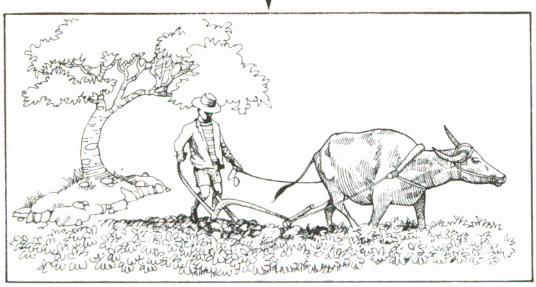
- Trees such as gliricidia and leucaena can be planted on field bunds. Green leaves can be cut for green manure for rice as well as fodder for animals.
- Woody stems or branches can also be cut for fuel or wood for household use.

Cover crops and green manure



Siratro green manure

Planted before rice

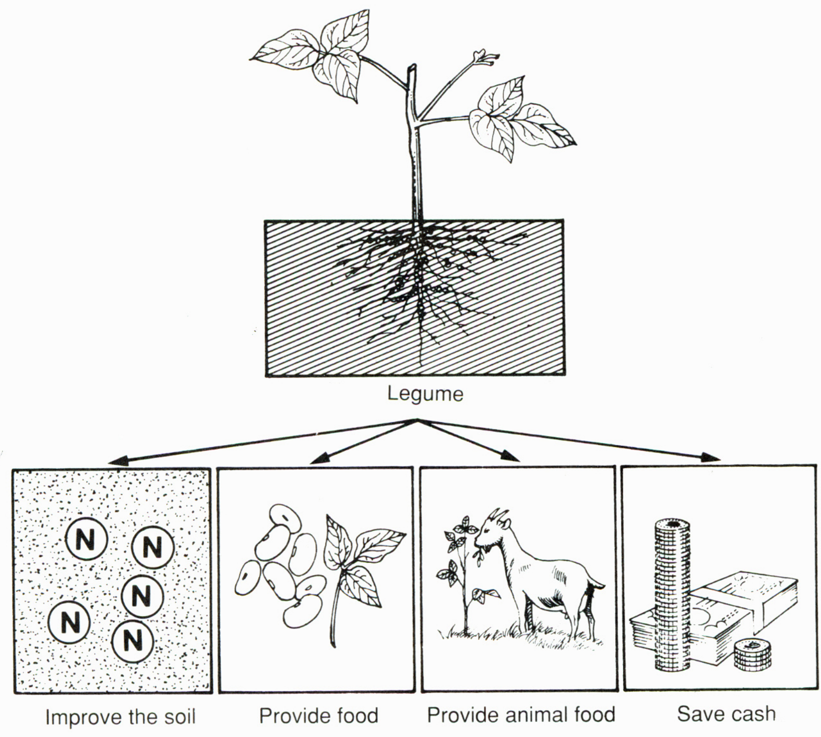


Incorporated into the soil during land preparation

- Dense-growing creeping plants such as siratro can be used in upland areas as ground cover to check soil erosion and improve productivity.
- They can be plowed into the soil for green manure during land preparation for the main crop.

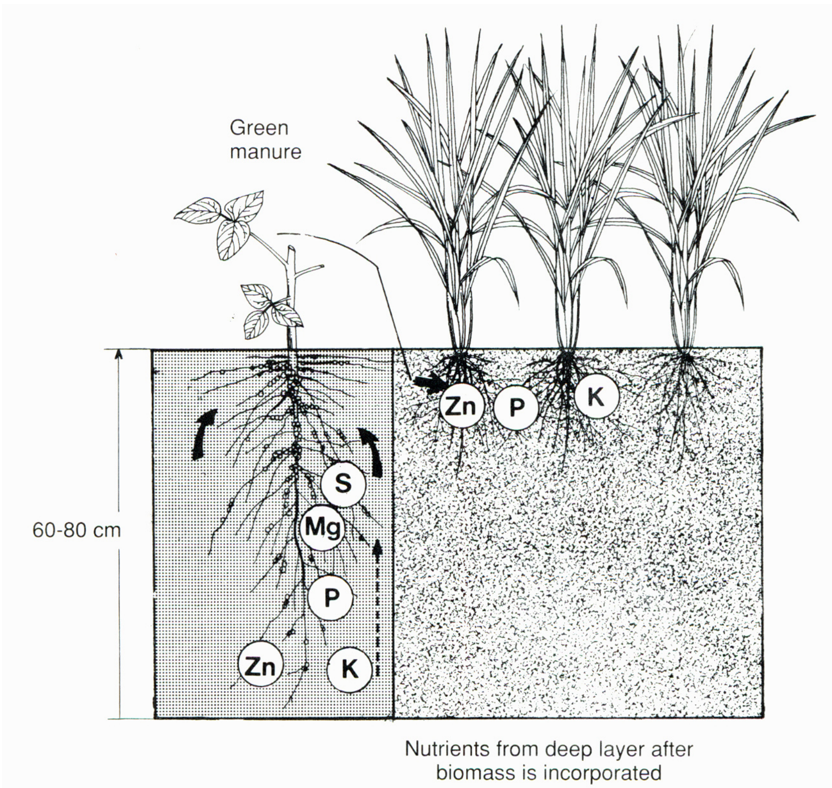
Legumes as green manure

Legumes as green manure



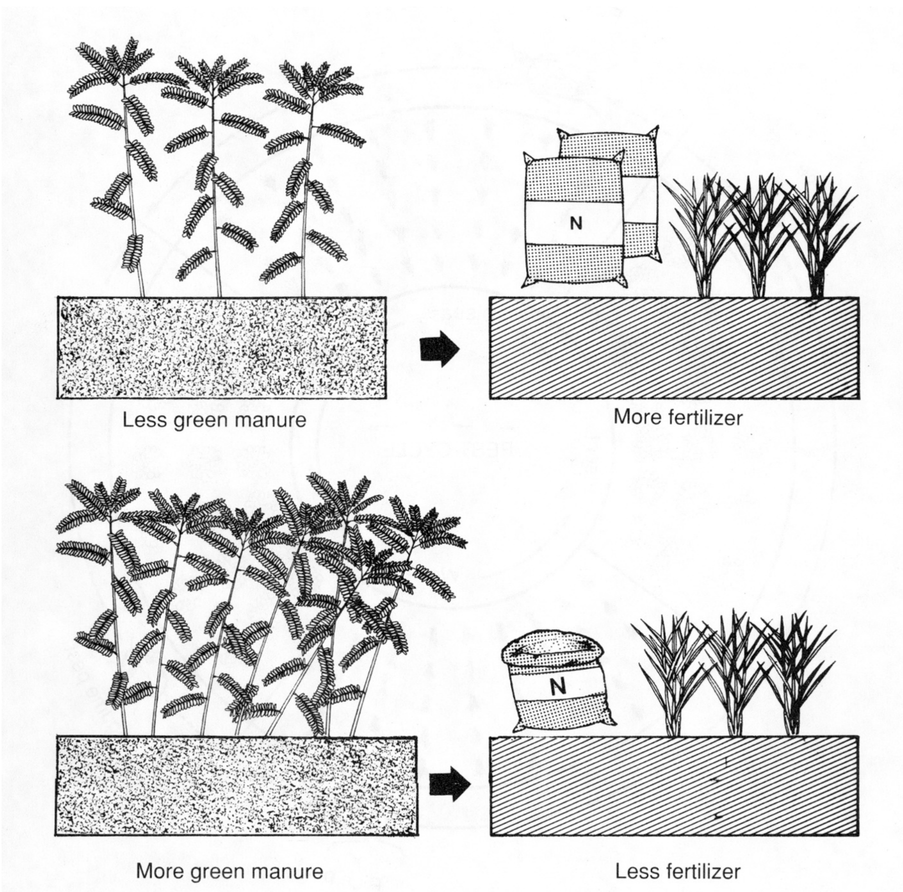
- Leguminous crops are among the most profitable of green manure crops to grow. Rotating legumes with rice offers many advantages.
- Legumes not only give green manure but also
  - — improve the soil,
  - — provide human food and animal feed, and
  - — save cash and add to income.

Legumes improve the soil



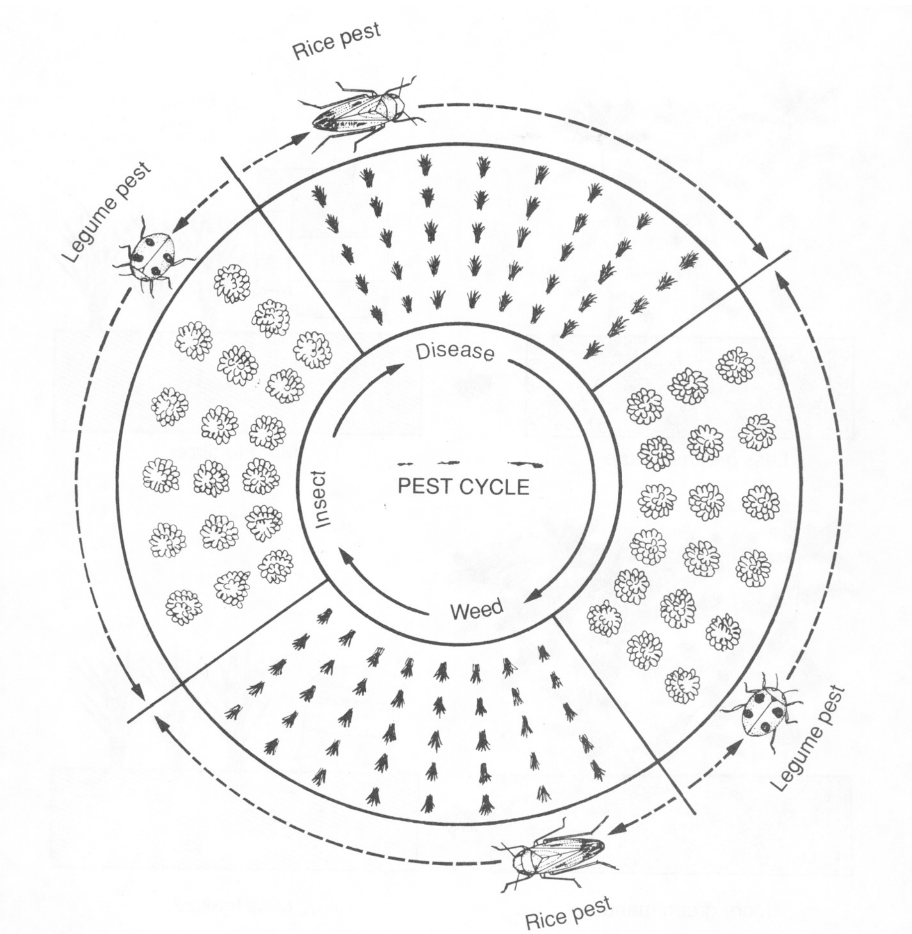
- Legumes can "fix" nitrogen from the air for their own use. In normal soils they need no added nitrogen.
- Because their roots grow deep, many legume crops can also draw up nutrients from the lower soil layers.
- These nutrients then become available in the upper soil layers when the legume is incorporated as green manure.

Legumes reduce fertilizer costs



■ What's more, legumes help save on fertilizer costs. A rice crop grown after a legume will need 40 to 60 kg less nitrogen fertilizer than a rice crop grown after another cereal.

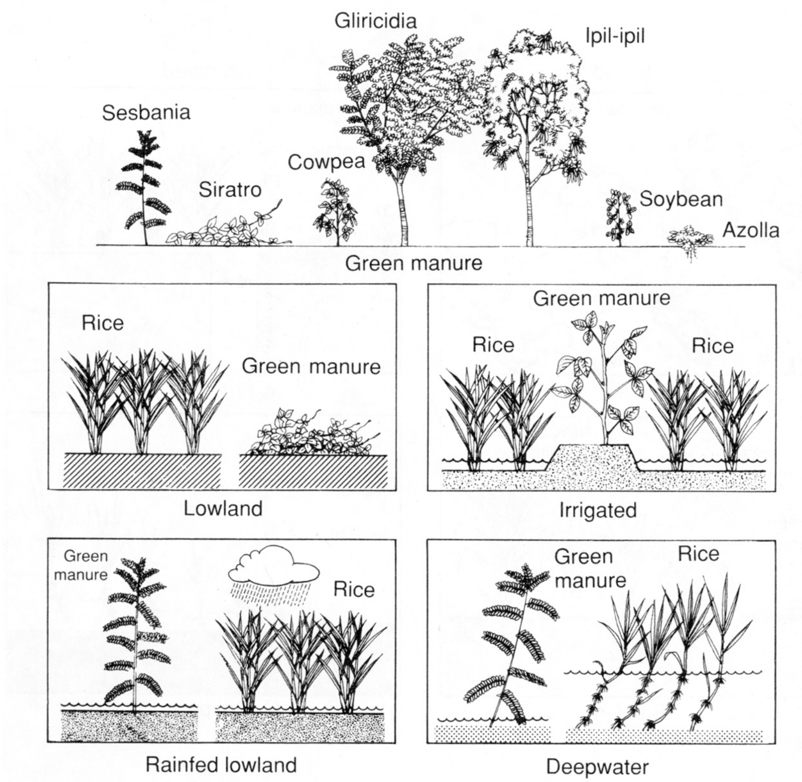
Legumes break the pest and disease cycle



- Most rice pests do not transfer to legumes. Most legume pests do not transfer to rice.
- Therefore growing legumes between rice crops helps break the rice pest cycle.

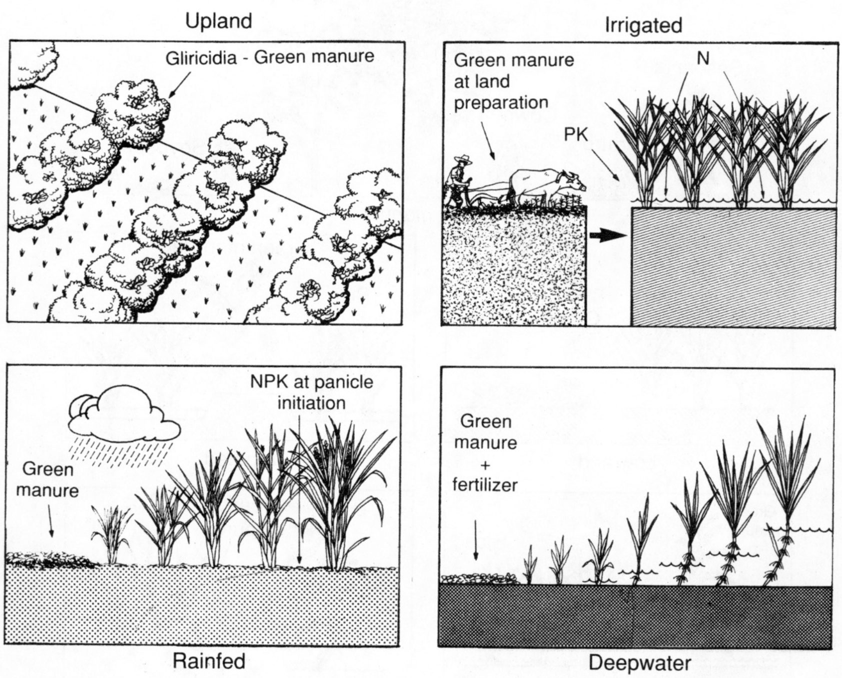
Choosing the right green manure crop

Choosing the right green manure crop



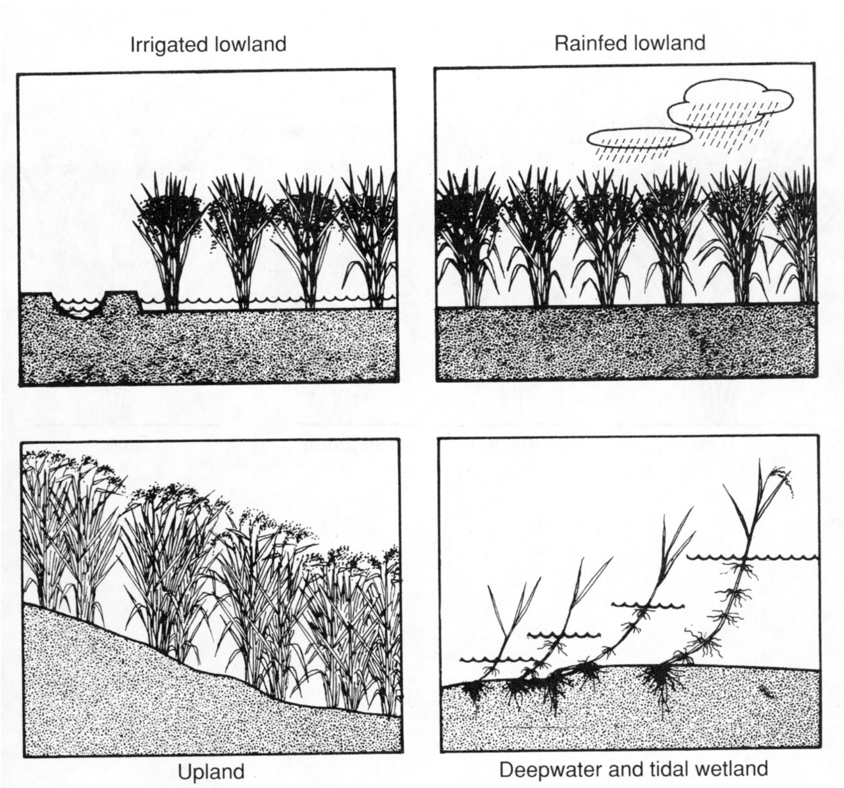
- For green manuring to be profitable, the crop grown must fit the growing environment:
  - Its growth duration must fit the time available between major crops in the cropping system.
  - Its water requirements must match the amount and distribution of rainfall.
  - Its roots must nodulate well with the local *Rhizobium* strains.
  - It should resist or tolerate pests and soil stresses in the area.

Choosing the right green manure crop



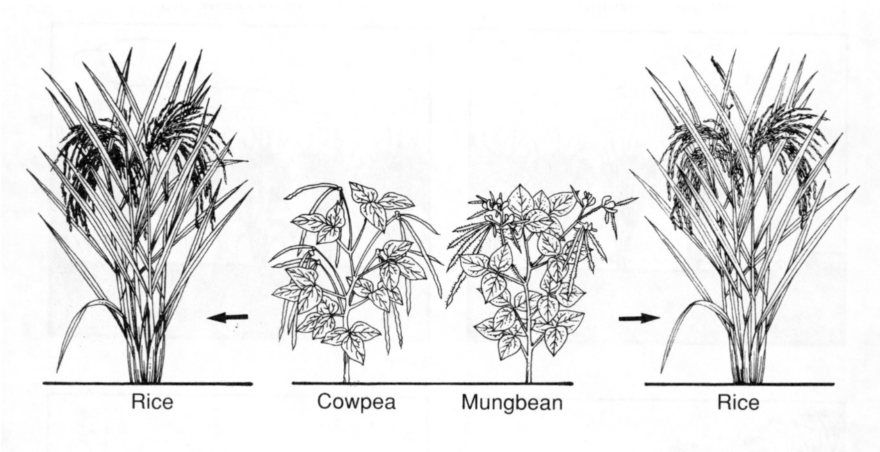
■ Many green manure crops are described later in this book. Choose the one best suited to the environment and available time, based on soil, crop growth duration, water requirement, daylength, temperature, rainfall, and other growing conditions in your area.

Rice-growing environments



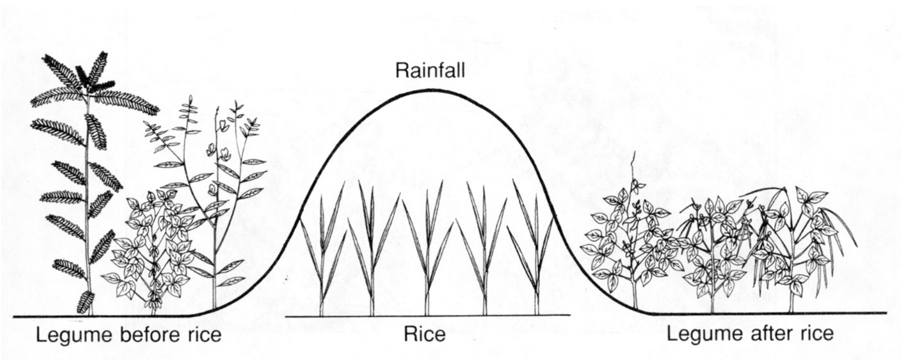
- The main rice-growing environments are
  - — irrigated lowland,
  - — rainfed lowland,
  - — upland, and
  - — deepwater and tidal wetland.
- The green manure crops listed later in this book are grouped according to these environments.

Irrigated lowland areas



- Irrigated areas are usually intensively cropped, with two or three crops a year. Cropland is vacant for only 60 to 65 days between crops.
- Fast-growing food legumes such as mungbean or cowpea can fit into this period.

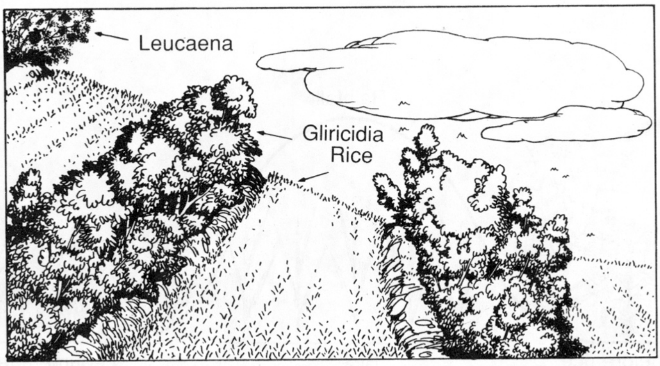
Rainfed lowland areas



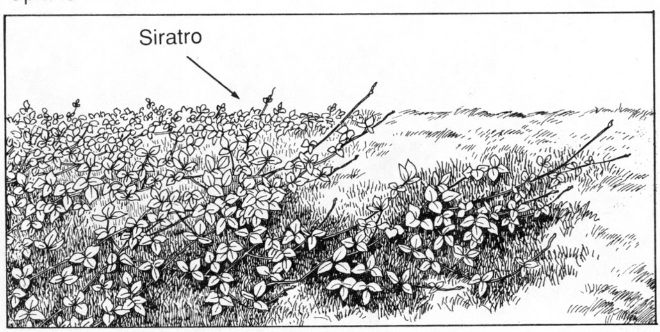
- In rainfed lowland areas, water supply is uncertain. Therefore green manure crops for such areas should be able to stand both drought and flooding.
- A green manure crop can be grown either before or after rice in such conditions.

Upland areas

Rolling

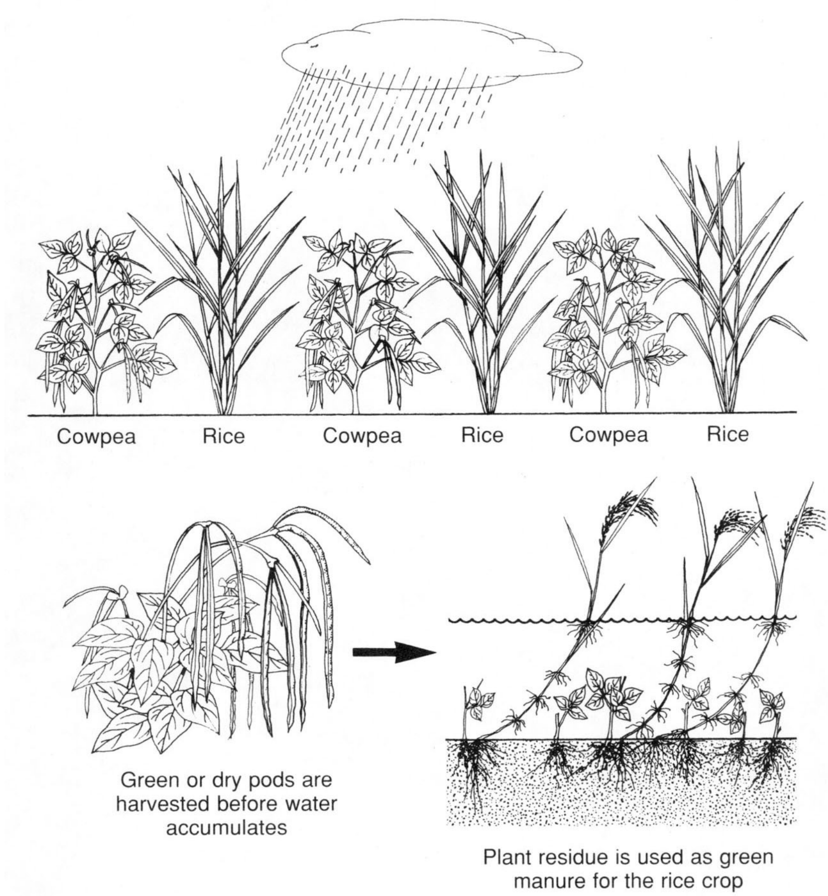


Upland



- Many upland soils are acid (pH 4.0 to 5.5). Green manure crops for such areas should be acid-tolerant.
- Upland soils are also easily eroded. Cover crops such as siratro protect as well as enrich the soil.
- Perennials such as gliricidia and leucaena are well suited to contour planting. Hedgerows of these small trees serve as windbreaks and again protect the soil.

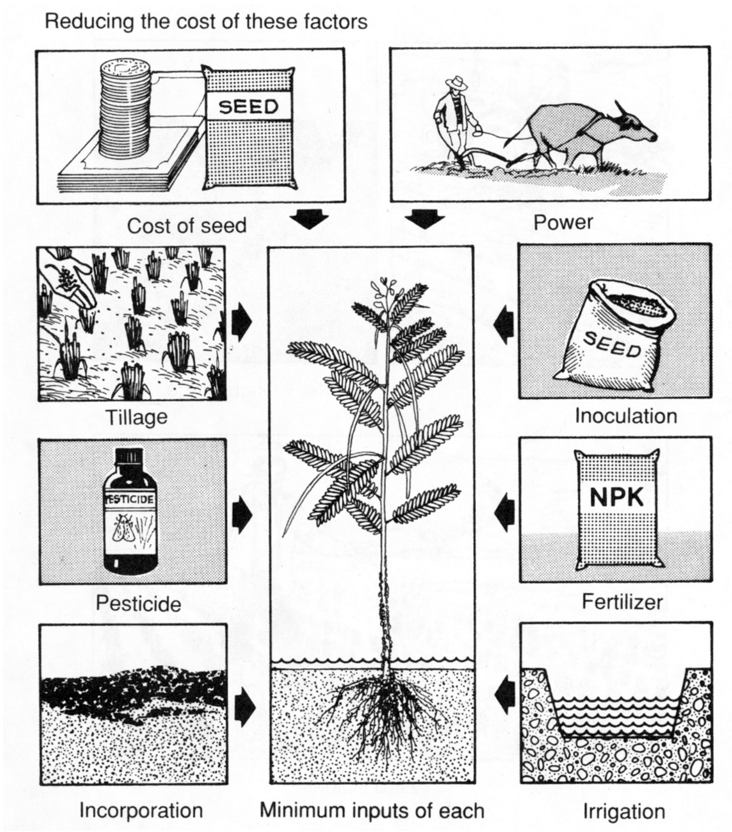
Deepwater and tidal wetland areas



■ In deepwater and tidal wetland areas, fast-growing green manure crops must be intercropped with rice and harvested before deep water accumulates.

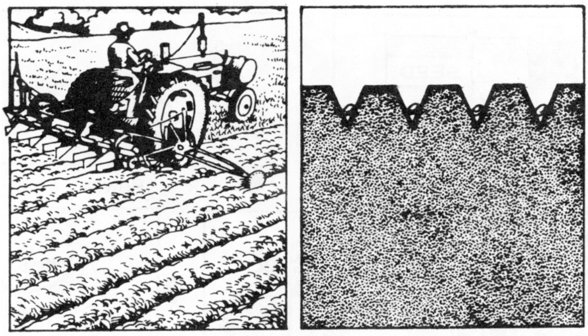
Growing a green manure crop

Growing a green manure crop



- To make a green manure crop worth growing, it should need a minimum of inputs and labor. Here *Sesbania rostrata,* grown before rainfed lowland rice, is used as an example.
- The same criterion must be considered when fitting any green manure crop into a cropping system.

Land preparation and planting

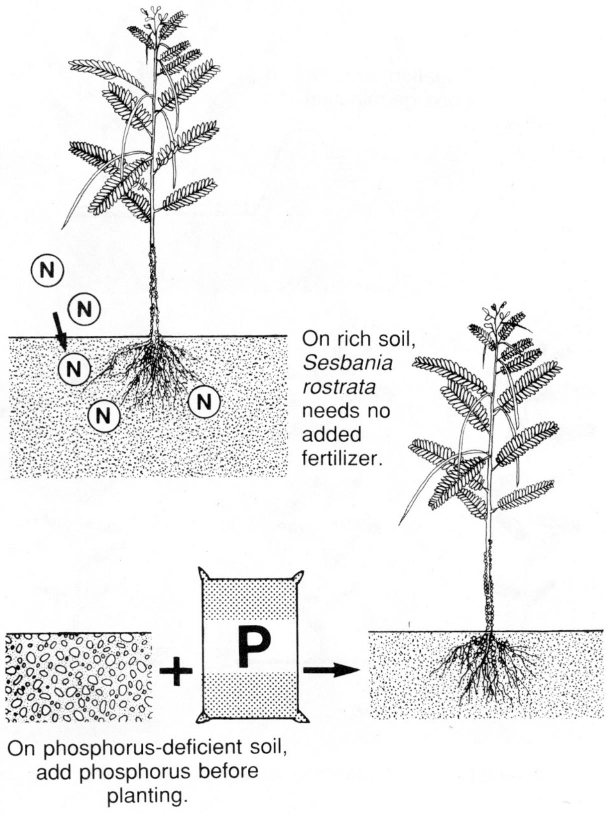


High tillage

Zero tillage

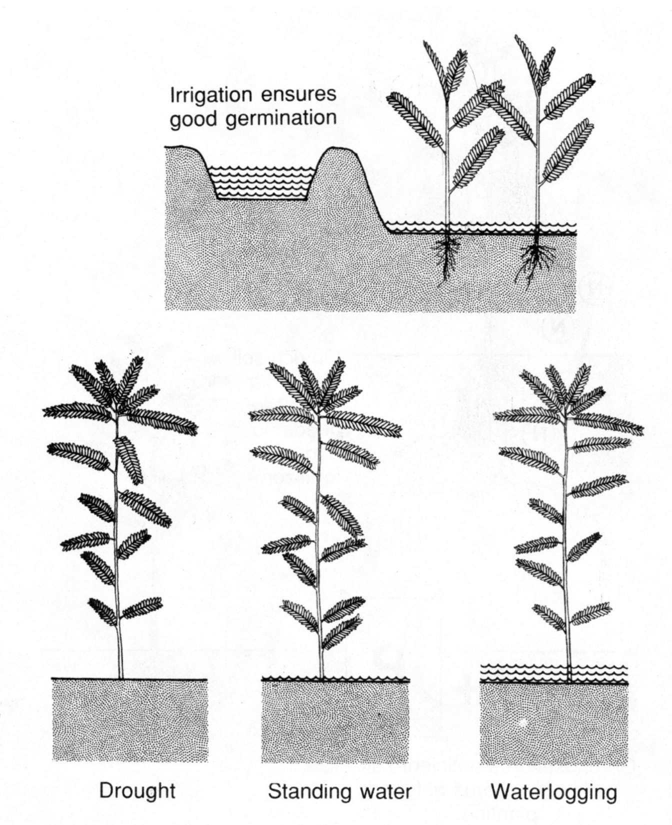
- Zero tillage should be used as far as possible for green manure, because high tillage is costly.
- Broadcast seed (25 kg seed per hectare) in the field at the onset of rain.

Fertilizer



- *Sesbania rostrata* needs no added fertilizer. Like other legumes, this crop fixes nitrogen from the air through its nodules.
- On very poor soils, however, mix in compost before planting the legume. If soil lacks phosphorus, a basal dose should be mixed in, also before planting.

Irrigation



- If rainfall is uncertain, irrigating once after sowing will ensure good germination.
- Once the sesbania plants are established, they can stand periods of drought. Sesbania can also grow well in standing water and in soils prone to waterlogging.

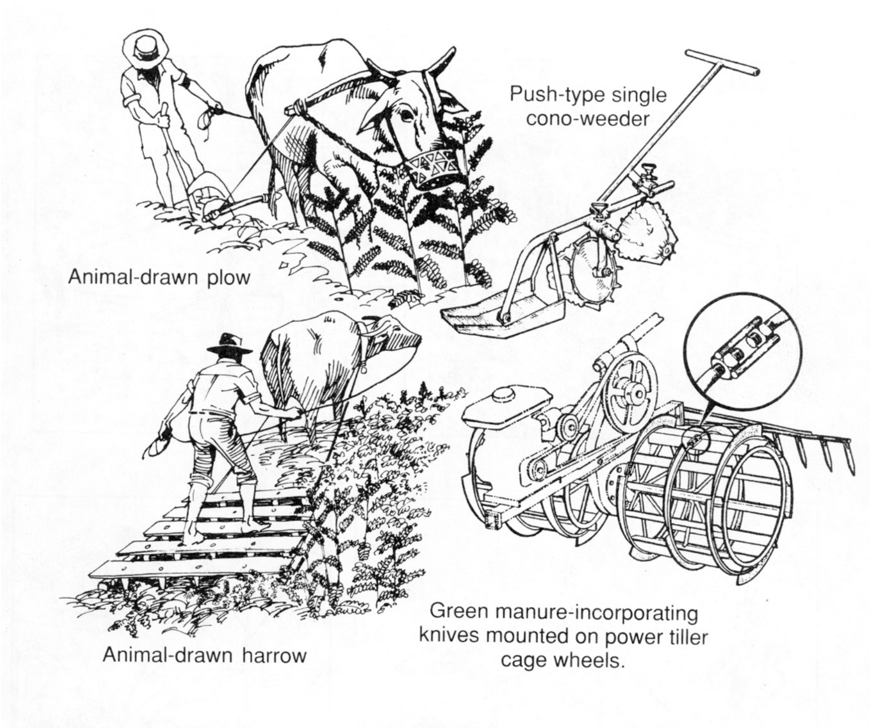
Pesticide

- Use no pesticide, as this is too costly an input for a green manure crop.
- Grow pest-resistant or tolerant varieties of the crop if available, or substitute a different crop for a susceptible one.

Harvesting and incorporating into soil

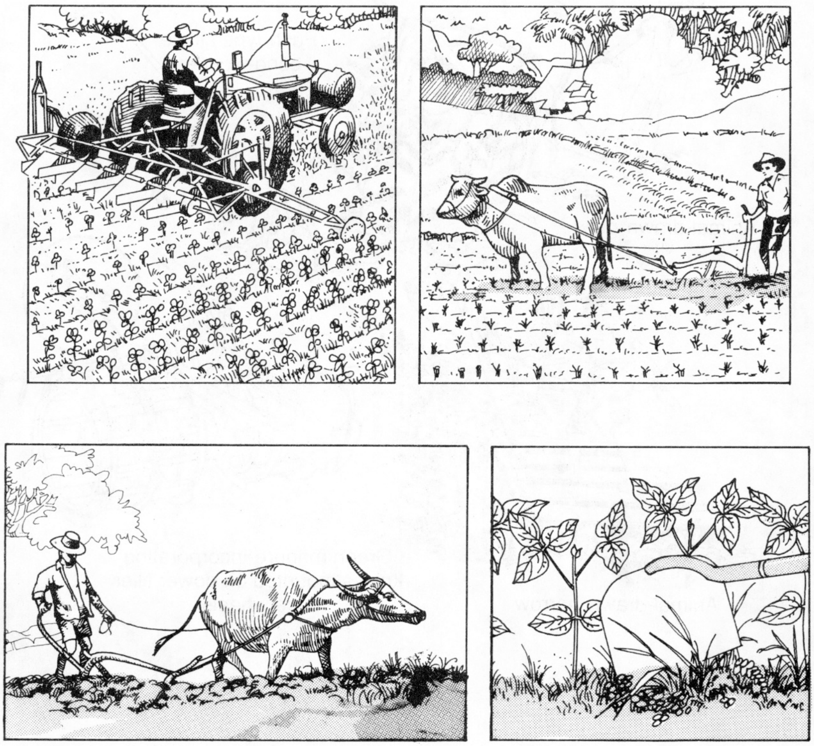
- Allow the sesbania to grow for 40 to 50 days. Plants should be short and easy to chop.
- For efficient nitrogen release, the green manure must be chopped and thoroughly mixed into the soil during land preparation for the main crop.

Tools for incorporating green manure



- Hand tools, animal-drawn machinery, or tractors can be used to chop and incorporate the green manure.
- Tractor-drawn tools are the most efficient, but may also be the most expensive.

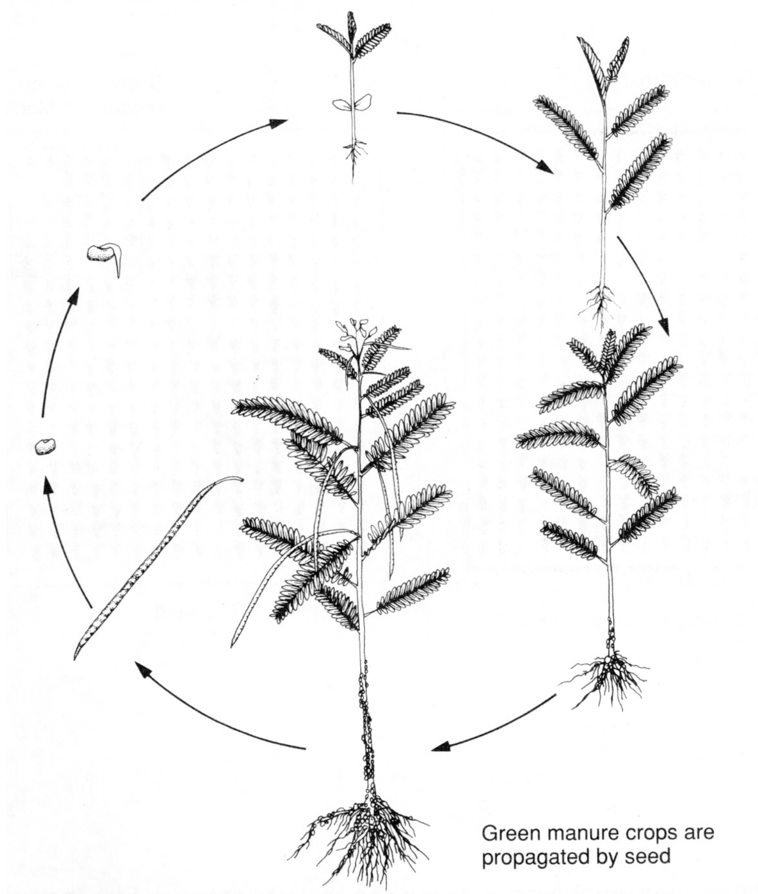
Tools for incorporating green manure



- Power tiller-drawn tools are the most efficient for thoroughly incorporating large plants with woody portions into the soil.
- Animal-drawn moldboard plows or country plows can also be used.
- Cone weeders are good for incorporating leaf green manure in ricefields.

Propagating plants for green manure

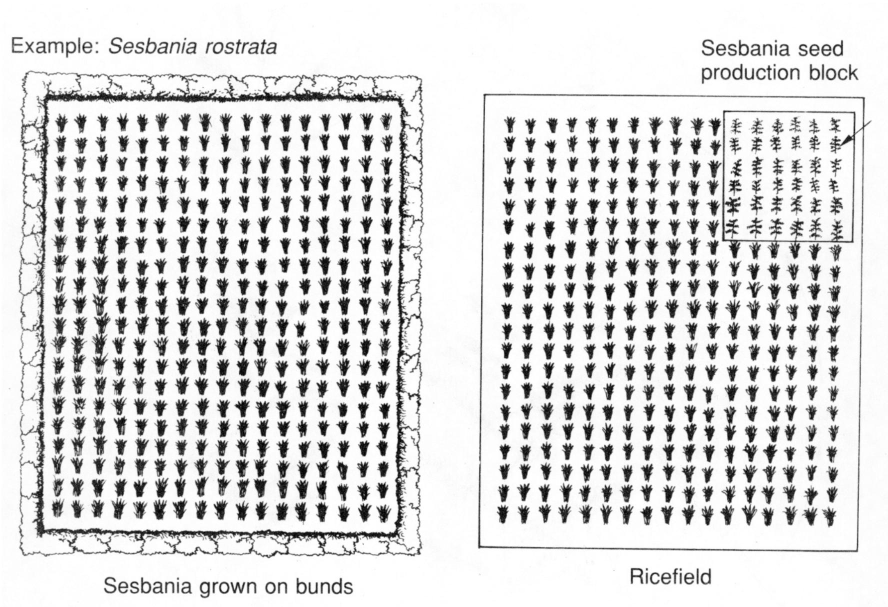
Propagating from seed



Green manure crops are propagated by seed

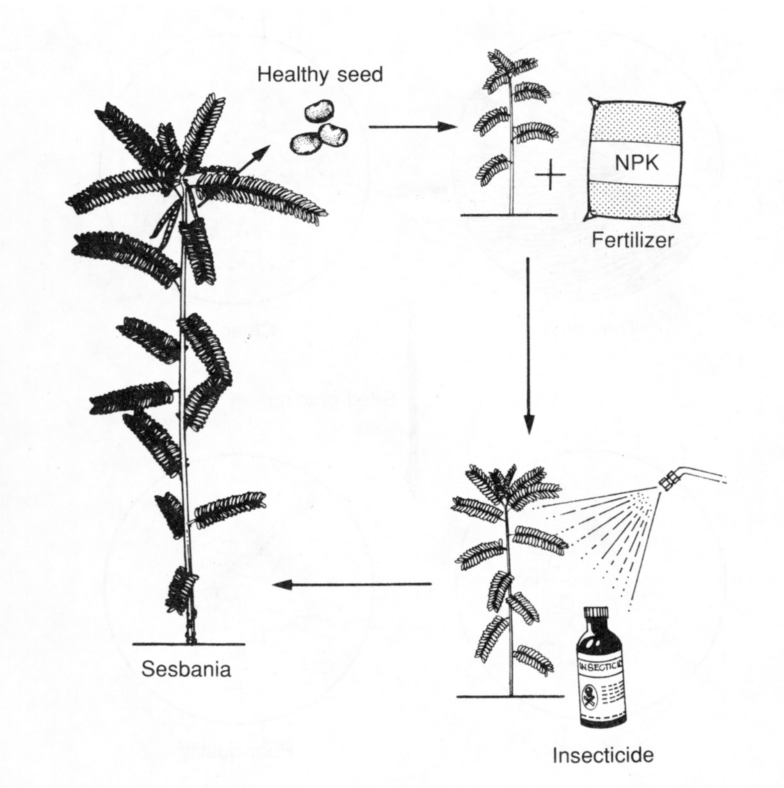
- Both annual and perennial species can be grown from seed. Seed can be stored in a small space and transported easily for planting in the field.
- Buying seed for green manure crops each year can become costly. But farmers can grow their own seed. They can also exchange seed with other farmers in the area.

Seed production



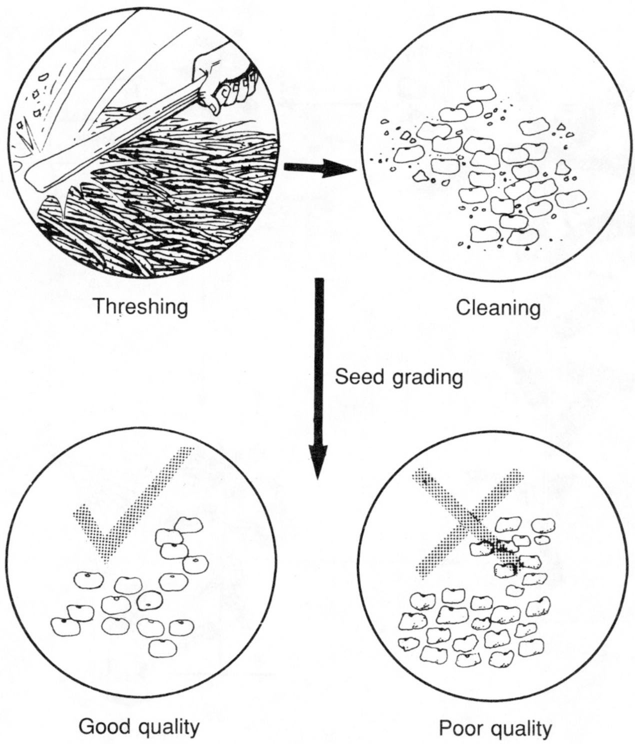
- Although seed production plots may be costly to set up at first, they will pay off in the long run by saving on the cost of buying seed.
- Mark off a part of the field for seed production plots. Unused land or field bunds can also be used for seed plots.
- Let the plants in the seed production plots grow to maturity. Collect and store seed from these plants for the next season.

Seed production



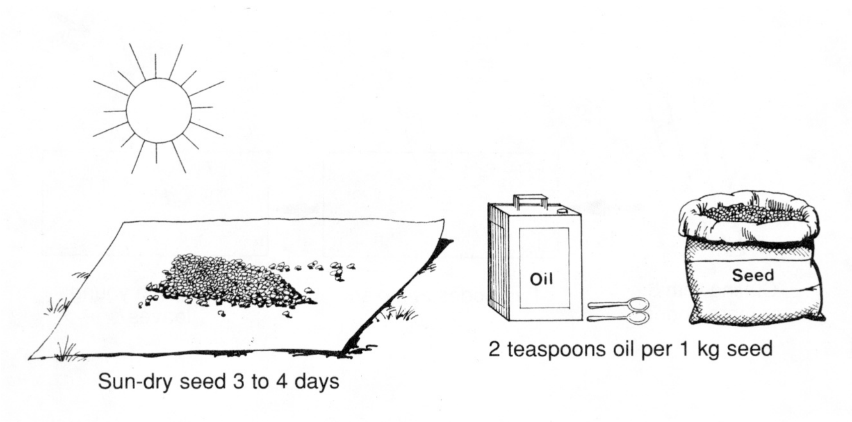
- Plants grown for seed should be healthy. If possible, use fertilizer in seed plots for good plant growth.
- Protect seed plots from insects and diseases. Insect pests are a major problem in producing seed in the tropics.
- Grow resistant varieties of the crop where available. You may need to use insecticide to control flower- and pod-damaging insects.

Processing seed



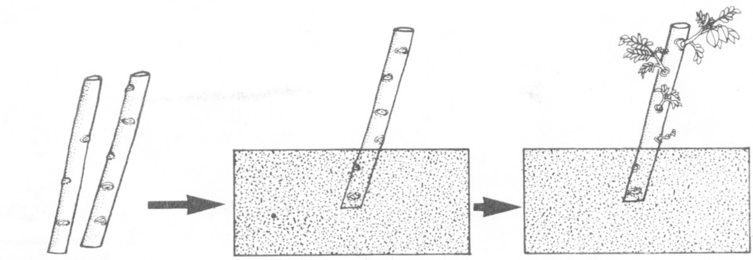
- Select seed that will store well. Seed for storage should be
  — plump and well filled,
  — free from insects and molds, and
  — well-dried (moisture less than 12%).
- Discard cracked, discolored, or empty seeds. These will not germinate well.

Processing seed



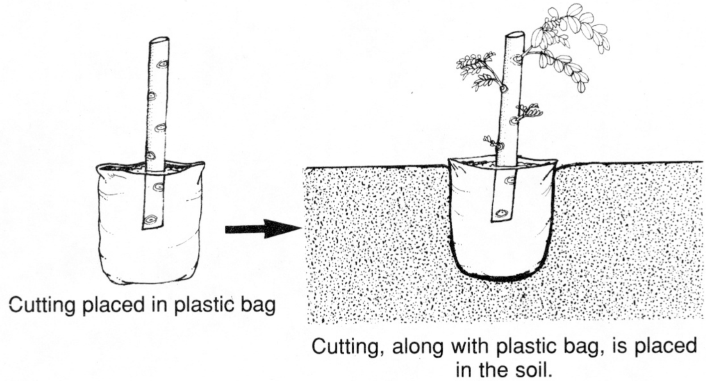
- Sun-dry seed 3 to 4days. A thin coating of vegetable oil can protect seed from some storage insects.
- Using 2 teaspoons oil per kilogram of seed, toss the seed with the oil until thoroughly coated.
- Store the treated seed in airtight containers in a cool, dry place, raised from the ground and away from walls.

Propagating from cuttings



- Perennial species such as gliricidia can be multiplied by stem cuttings.
- Make cuttings from stems that are 1 to 2 cm thick. Each cutting should have at least three or four nodes.

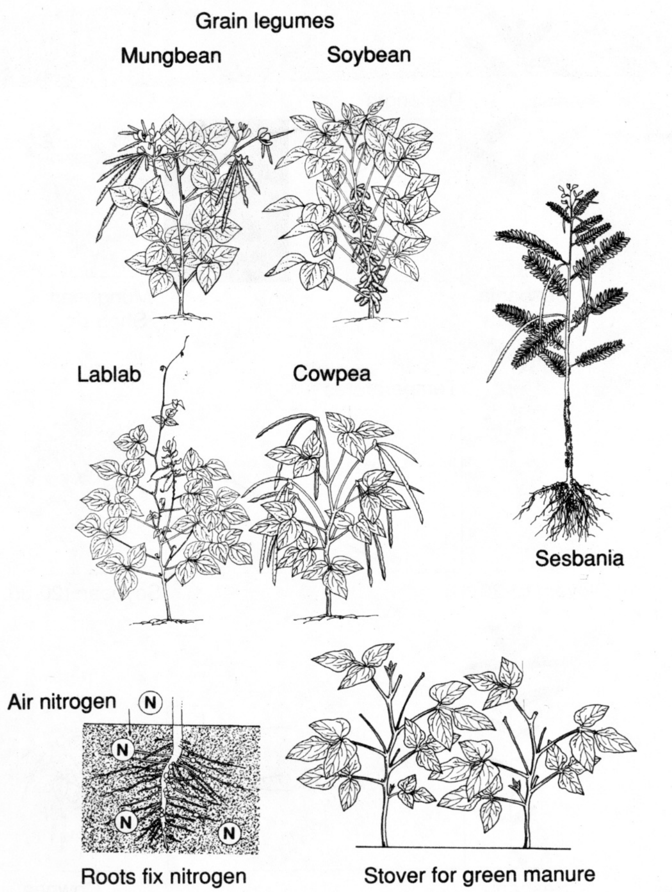
Propagating from cuttings



- Plant 10 to 15 cm deep (or two nodes deep) in beds, in pots, or in individual plastic bags filled with soil. Water to keep the soil moist but not wet. Cuttings will root in about 15 days and can be transplanted in the field in about 60 days.
- Cuttings rooted in plastic bags can be planted along with the bag.

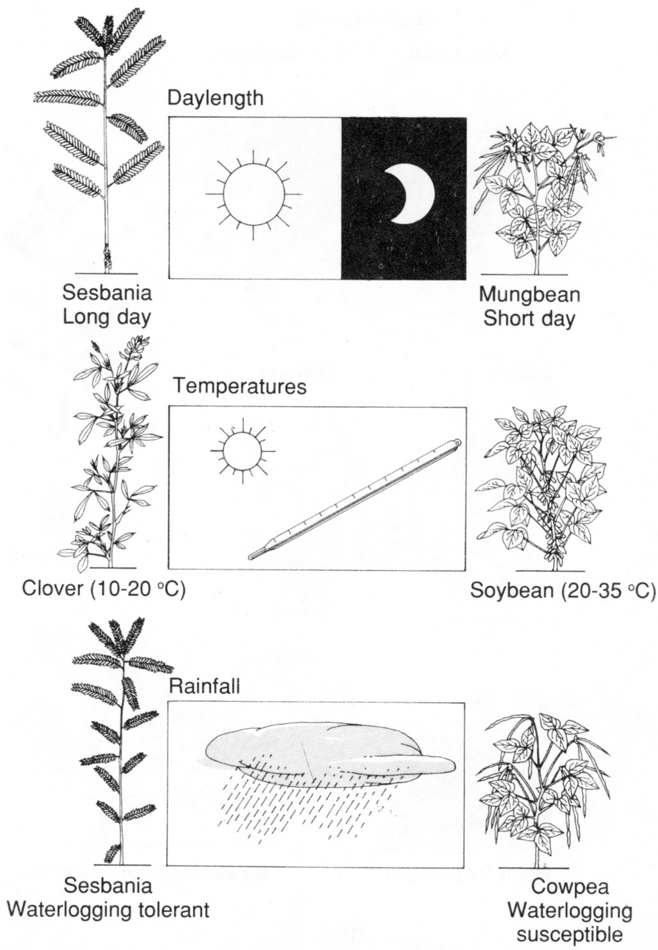
Factors affecting green manure biomass and nitrogen yield

Crop species and nitrogen fixation



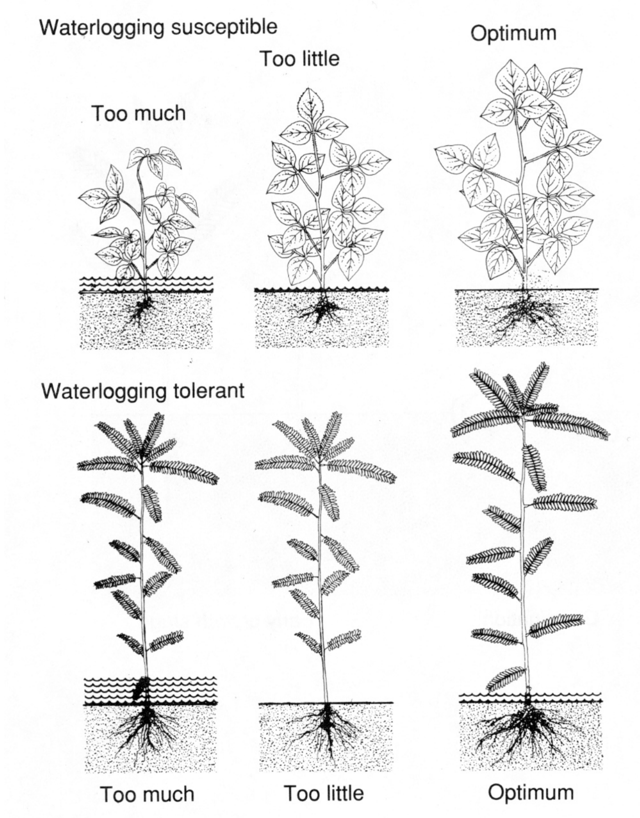
- Legume crops differ in their nitrogen-fixing capacity. Fast-growing crops usually fix nitrogen at higher rates than slow-growing crops. The total dry matter accumulated may be a good index of total nitrogen yield.

Growing season



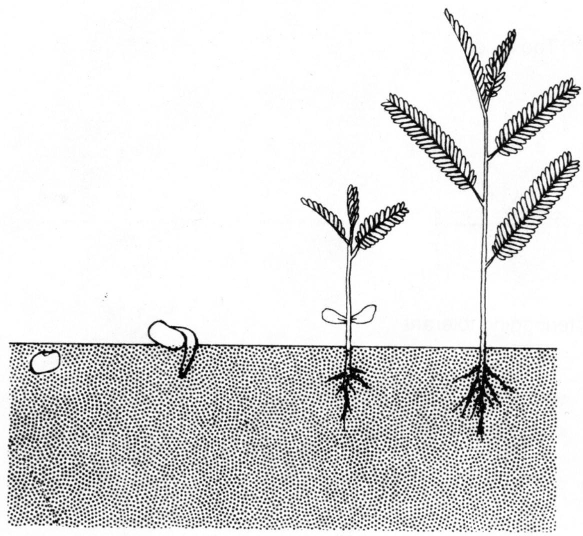
- Green manure crops differ in their response to rainfall, daylength, and temperature. Therefore, it is essential to match the crop to the season in which it is grown.

Water requirement



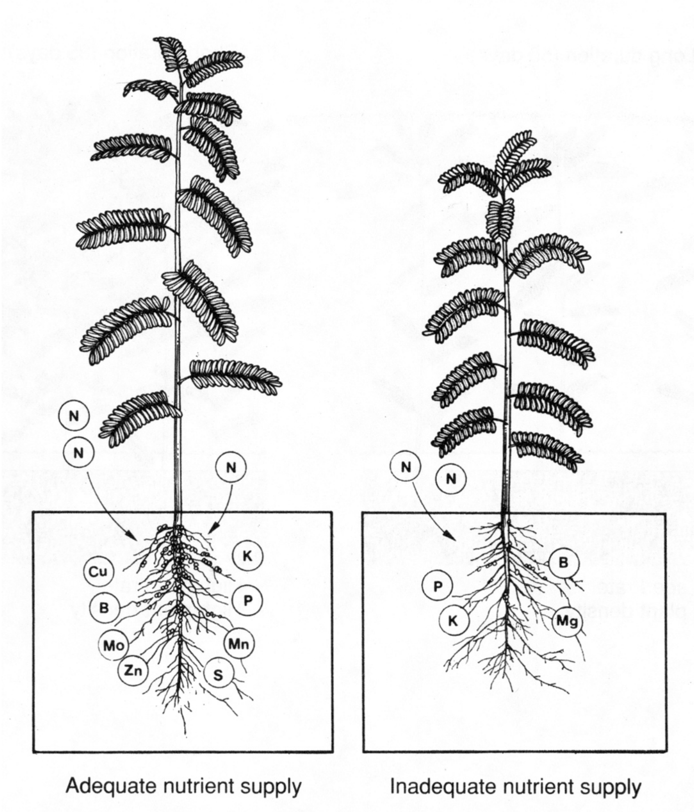
- Not only the total amount of water but the growth stages at which it is available will affect crop growth.
- Soil moisture is most needed during germination, early seedling growth, and rapid growth stages. Lack of water at these crucial stages will drastically reduce total biomass and nitrogen yield.

Water requirement



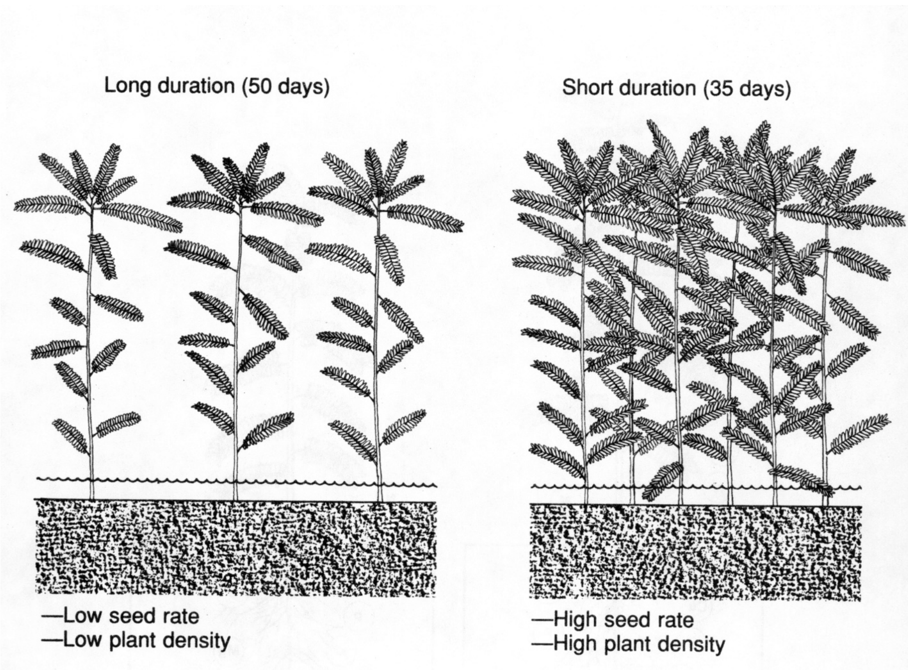
- Each green manure crop has specific water requirements. Both too little and too much water will reduce growth, nitrogen fixation, and dry matter accumulation.
- Some crops such as cowpea cannot stand waterlogging. Others, like *Sesbania rostrata,* can grow well in standing water.

Plant nutrients



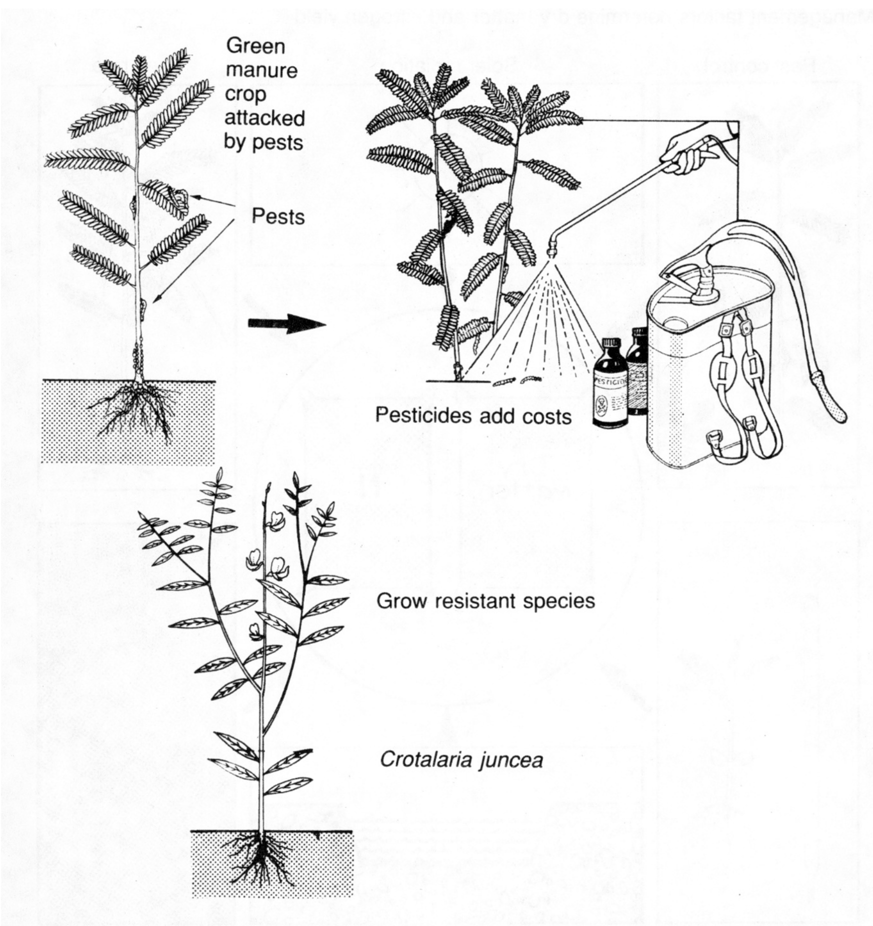
- Although legumes can fix nitrogen from the air and usually need no added nitrogen fertilizer, they need all other plant nutrients.
- Phosphorus is especially needed and should be added before growing green manure crops on phosphorus-deficient soils.
- To improve crop growth on generally poor soils, compost should be added before planting the green manure crops.

Seeding rate and planting density



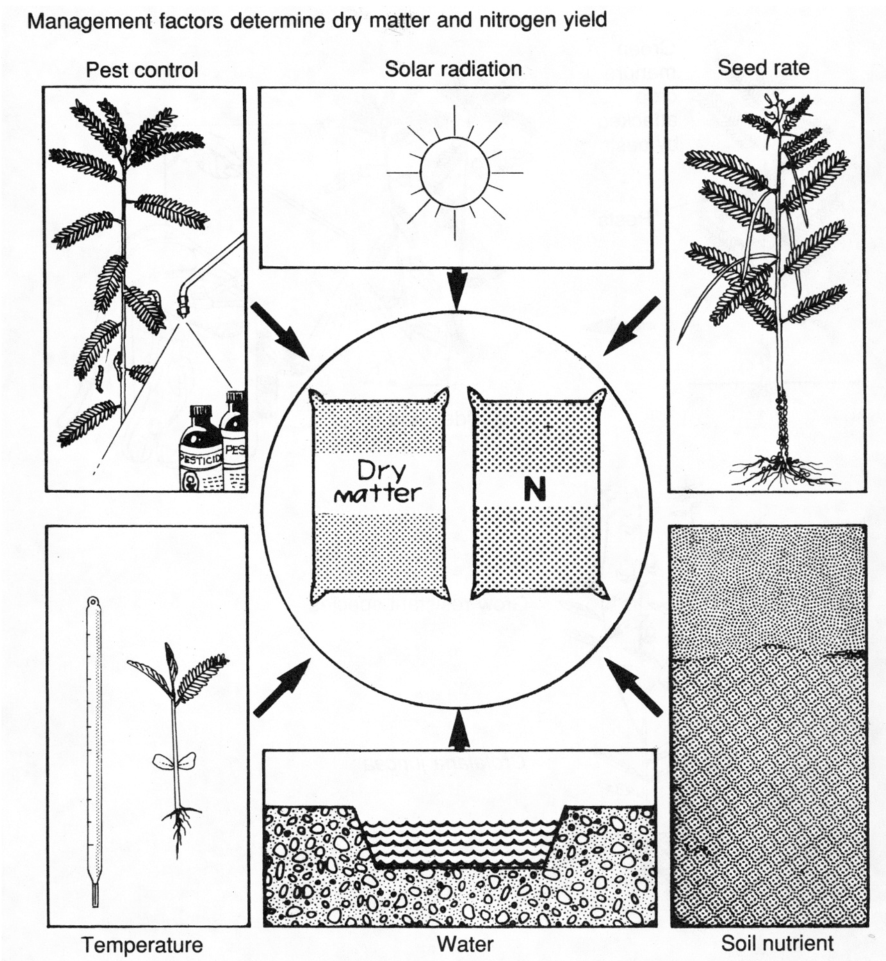
- A high seeding rate that gives high plant density will reduce the duration of green manure in the field, yet produce enough nitrogen to be profitable.
- If seeding rates and plant densities are low, the crop will have to stay in the field longer to amass enough nitrogen and dry matter.

Insect pests and diseases



- Insect pests and diseases can drastically reduce the biomass and nitrogen yield of a green manure crop.
- Grow resistant varieties or change to a different crop.

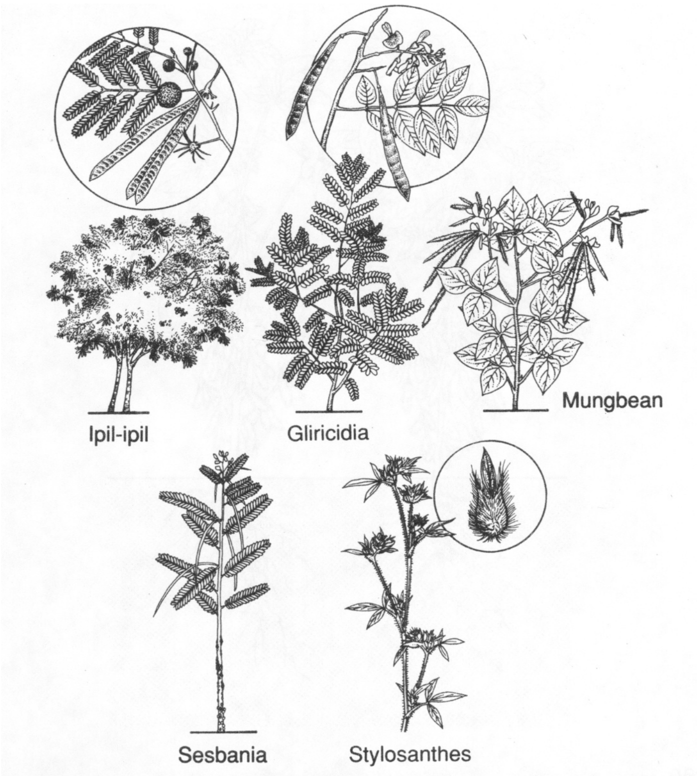
Getting the most from green manure



■ All these factors-crop species, seeding rate, growing season, plant density, water availability, and pest control-contribute to making the growing and use of a green manure crop profitable.

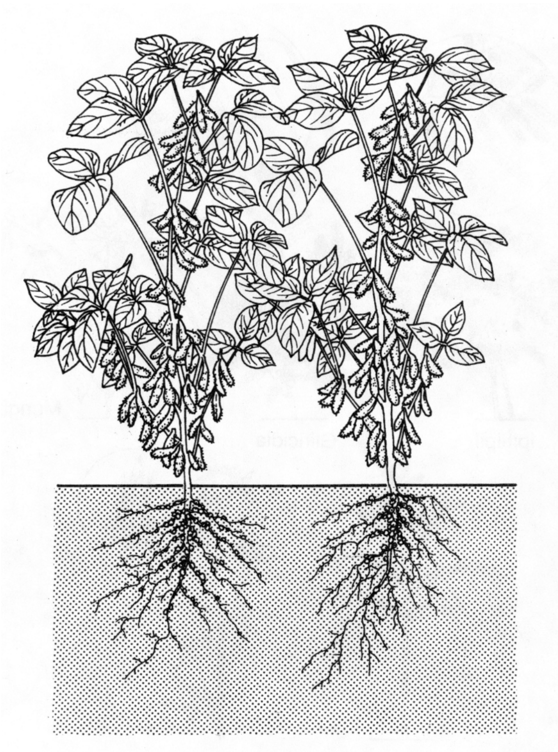
Green manure for different rice-growing environments

Green manure for different environments



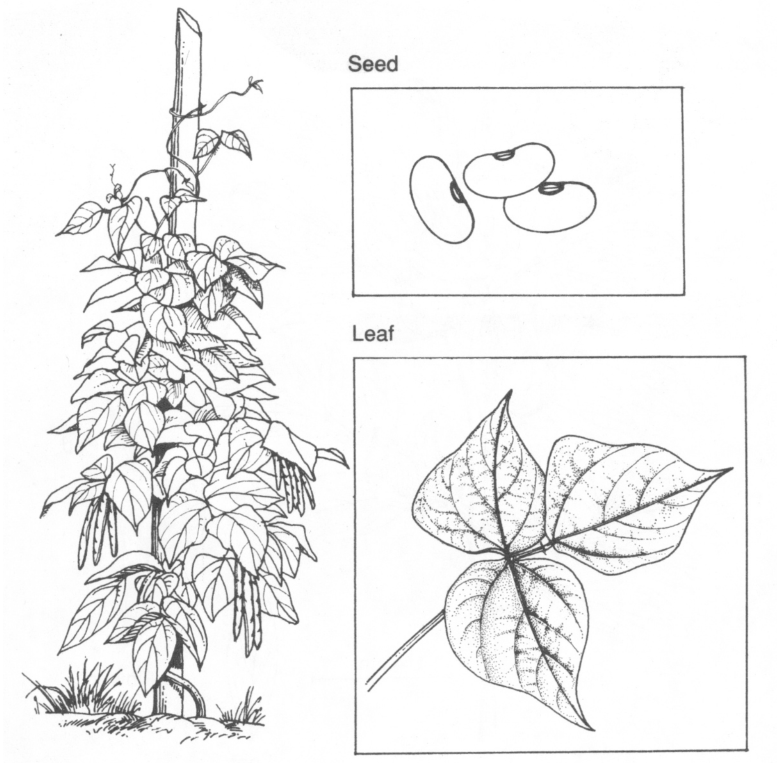
- In this section we list a wide range of legumes, grouped according to the rice-growing environment to which they are best suited.
- Other growing conditions for each legume—soil type, temperature range, planting time, and duration—are given. The amount of nitrogen each crop can contribute is also given.
- Most of these legumes are many-purpose crops. They are listed here chiefly for their value as green manure. But they can also supply food, forage, fiber, or fuel wood. These other uses are also listed.

Irrigated lowlands—food legumes



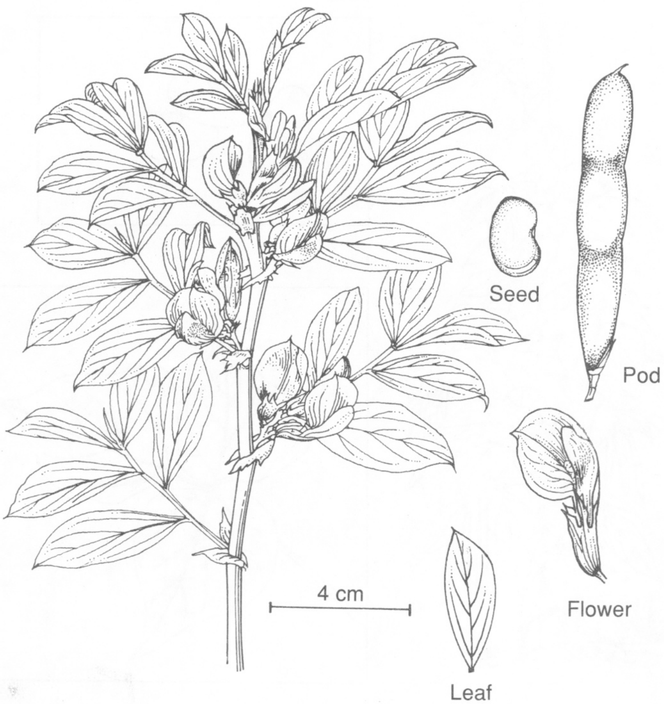
Soybean
Scientific name: *Glycine max* L.
Growth habit: annual, bush
Soil: deep, well-drained soils with good water-holding capacity
Temperatures: 15 to 35 °C
Planting time: after rice
Duration: 90 to 110 days
Nitrogen added: 40 to 50 kg per hectare
Other uses: green seed as vegetable; dry seed for processed foods and livestock feed

Irrigated lowlands—food legumes



Kidney bean
Scientific name: *Phaseolus vulgaris* L.
Growth habit: bush and climbing
Soil: fertile, well-drained
Temperatures: cool season, 5 to 25 °C
Planting time: after rice
Duration: 80 to 90 days
Nitrogen added: 55 kg per hectare
Another use: green pods and dry seed for food

Irrigated lowlands—food legumes



Faba bean
Scientific name: *Vicia faba* Linn.
Growth habit: bush
Soil: well-drained
Temperatures: cool season, 5 to 20 °C
Planting time: after rice
Duration: 95 to 130 days
Nitrogen added: 50 to 60 kg per hectare
Another use: dry seed for food

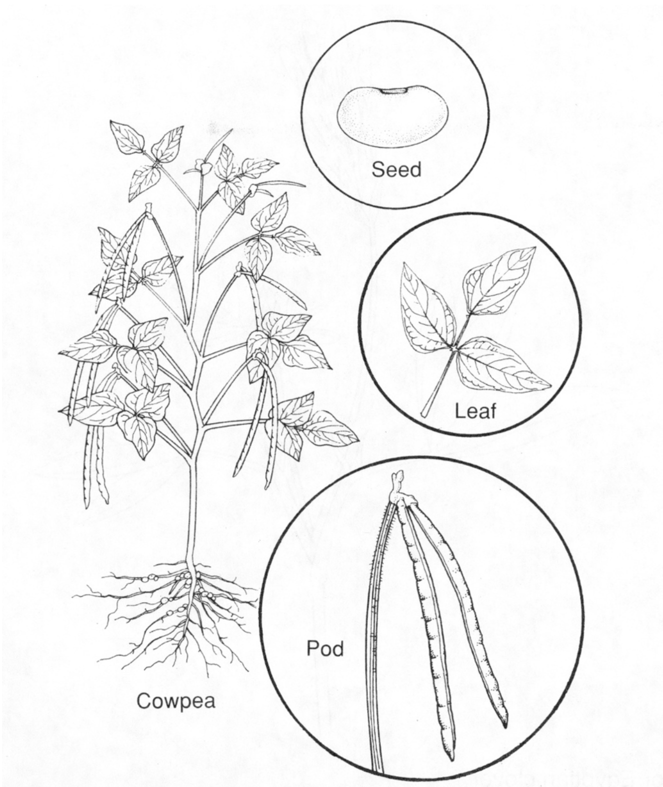
Irrigated lowlands—food legumes

Black gram
Scientific name: *Vigna mungo* L.
Growth habit: bush, semi-erect
Soil: well-drained; should not be waterlogged
Temperatures: 15 to 35 °C
Planting time: before rice
Duration: 70 days
Nitrogen added: 60 kg per hectare
Another use: dry seed for food

Irrigated lowlands—food legumes

Mungbean
Scientific name: *Vigna radiata* L.
Growth habit: bush and semi-erect
Soil: well-drained
Temperatures: 20 to 35 °C
Planting time: before rice in intensive cropping systems (mungbean - rice - rice)
Duration: 60 to 65 days
Nitrogen added: 55 kg per hectare
Another use: dry seed for human food
Mungbean is also suitable for growing in rainfed lowland areas.

Irrigated lowlands—food legumes

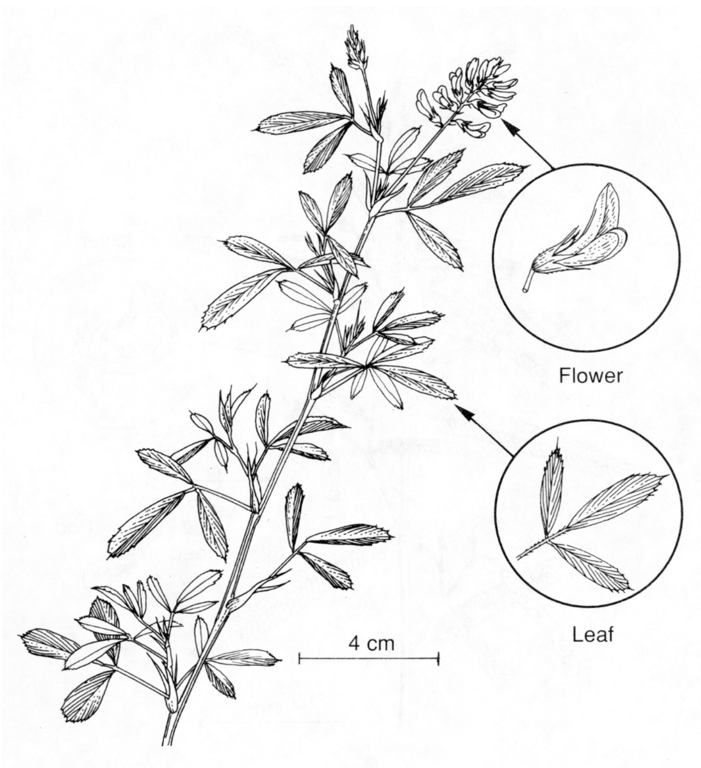


Scientific name: *Vigna unguiculata* L.
Growth habit: bush and semi-erect
Soil: well-drained soil (may be waterlogged); can grow on acid or sandy soils
Temperatures: 10 to 38 °C
Planting time: before rice, in intensive cropping systems (cowpea - rice - rice)
Duration: 45 days to green pods, 60 days to dry seed
Nitrogen added: 60 kg per hectare
Other uses: young leaves, green pods, and dry seed for food
Cowpea can stand drought and is also suitable for rainfed areas.

Irrigated lowlands—forage

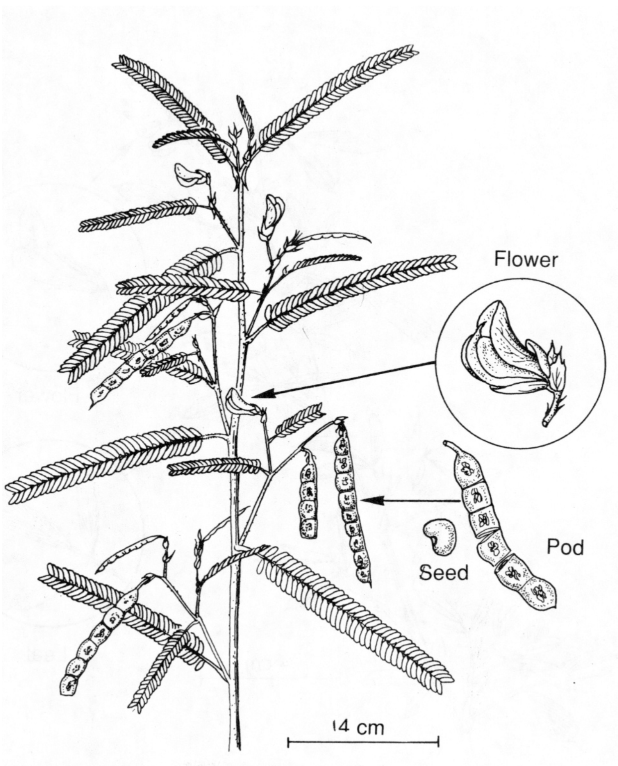
Berseem or Egyptian clover
Scientific name: *Trifolium alexandrinum* L.
Growth habit: annual, short bush
Soil: fertile, well-drained
Temperatures: 8 to 25 ºC
Planting time: after rice, in the cool season
Duration: 110 to 130 days
Nitrogen added: 80 kg per hectare
Other uses: forage, good for several cuttings before plowing under for green manure

Irrigated lowlands—forage



Sweet clover
Scientific name. *Melilotus officinalis*
Growth habit: annual, short bush
Soil: fertile, well-drained
Temperatures: 5 to 20 °C
Planting time: after rice
Duration: 140 to 180 days
Nitrogen added: 50 to 60 kg per hectare
Another use: forage

Irrigated lowlands—green manure

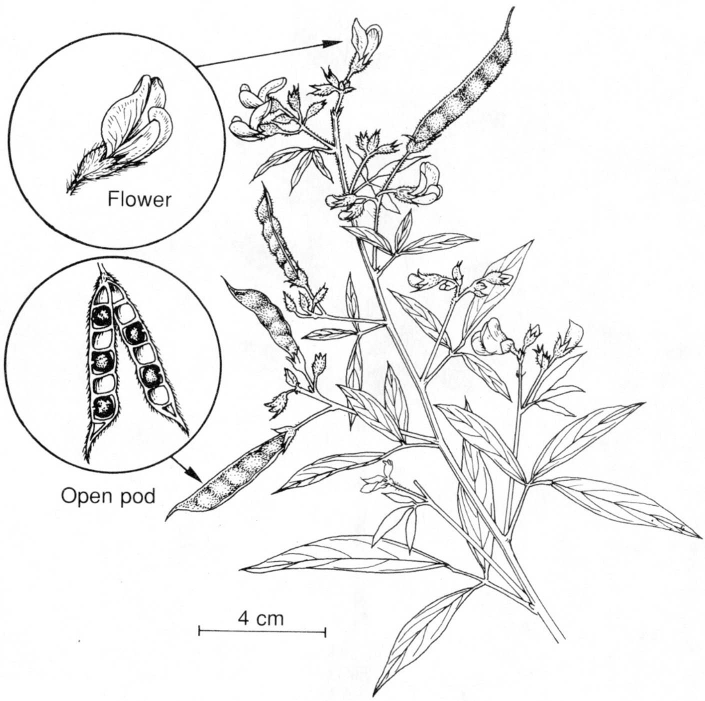


Scientific name: *Aeschynomene afraspera*
Growth habit: annual, bush
Soil: poorly drained (may be waterlogged)
Temperatures: 15 to 38 °C
Planting time: before rice
Duration: 40 to 50 days
Nitrogen added: 100 kg per hectare
Aeschynomene afraspera can also be grown in rainfed lowlands that are prone to waterlogging.

Irrigated lowlands—green manure

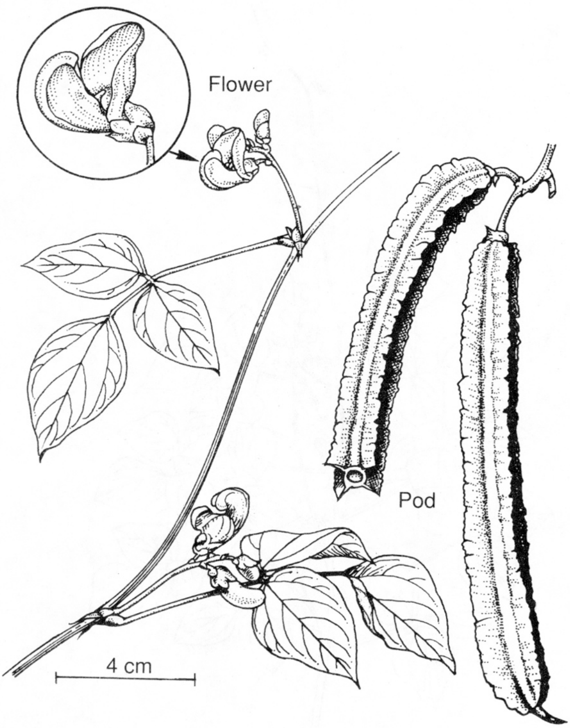
Sesbania
Scientific name: *Sesbania rostrata* L.
Soil: poorly drained (may be waterlogged)
Temperatures: 15 to 40 °C
Planting time: before rice
Duration: 45 to 50 days
Nitrogen added: 100 kg per hectare
Sesbania rostrata can also be grown in rainfed areas that are prone to waterlogging.

Rainfed lowlands—food legumes



Pigeonpea
Scientific name: *Cajanus cajan* L.
Growth habit: erect, tall, 1 to 4 m high
Soil: well-drained
Temperatures: 15 to 35 °C
Planting time: after rice in the field. (Pigeonpea can also be bund-planted, cut back to 40-cm height after pod harvest, and the ratoon growth used for green manure.)
Duration: 100 days to pod harvest, 40 to 50 more days for ratoon growth
Nitrogen added: 80 kg per hectare
Other uses: green seed and dry seed for food, crop stover and ratoon growth for green manure

Rainfed lowlands–food legumes



Winged bean
Scientific name: *Psophocarpus tetragonolobus*
Growth habit: climbing vine
Soil: well-drained
Temperatures: 15 to 35 °C
Planting time: after rice in the field (Winged bean can also be grown on field bunds.)
Nitrogen added: 60 to 70 kg per hectare
Other uses: roots, leaves, and green pods for food

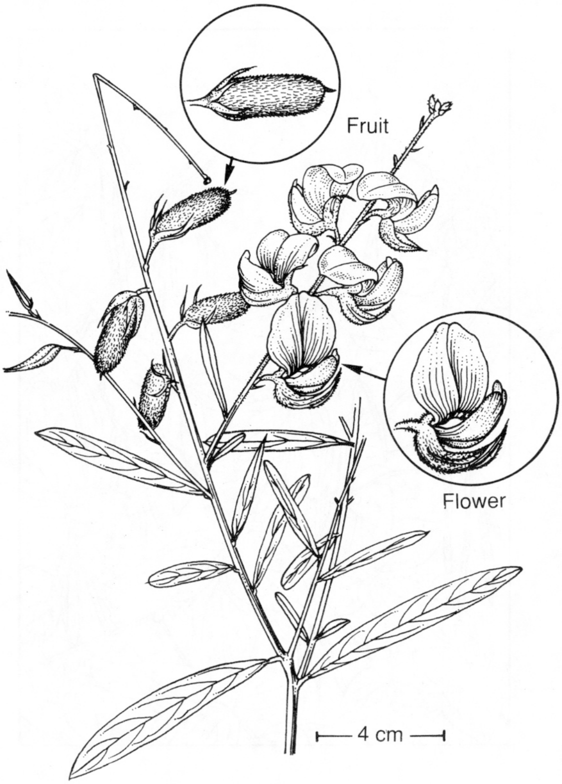
Rainfed lowlands—food legumes

Lablab bean
Scientific name: *Lablab purpureus*
Growth habit: bush as well as climbing type
Soil: well-drained (Lablab can stand drought but not waterlogging.)
Temperatures: 12 to 38 °C
Planting time: before rice for green manure only, after rice for seed
Duration: 50 to 60 days for green manure; 100 to 120 for dry seed
Nitrogen added: 70 to 90 kg per hectare
Another use: dry seed for food

Rainfed lowlands—food legumes

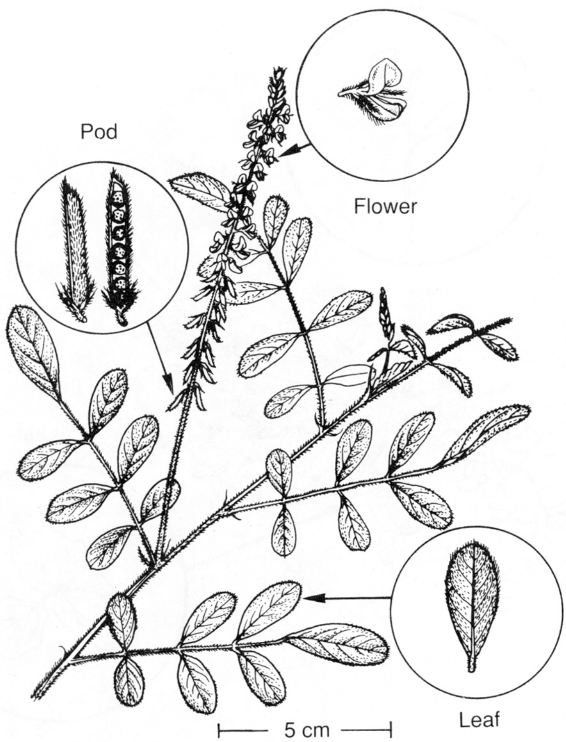
Rice bean
Scientific name: *Vigna umbellata* (Thunb.)
Growth habit: bush as well as climbing type
Soil: well-drained (should not be waterlogged)
Temperatures: 15 to 35 °C
Planting time: before rice for forage and green manure. after rice for dry seed
Duration: 60 days for forage and green manure, 110 days for dry seed
Nitrogen added: 90 kg per hectare
Other uses: young plants for forage and green manure. dry seed for human food, crop stover after pod harvest for green manure

Rainfed lowlands—forage and fiber



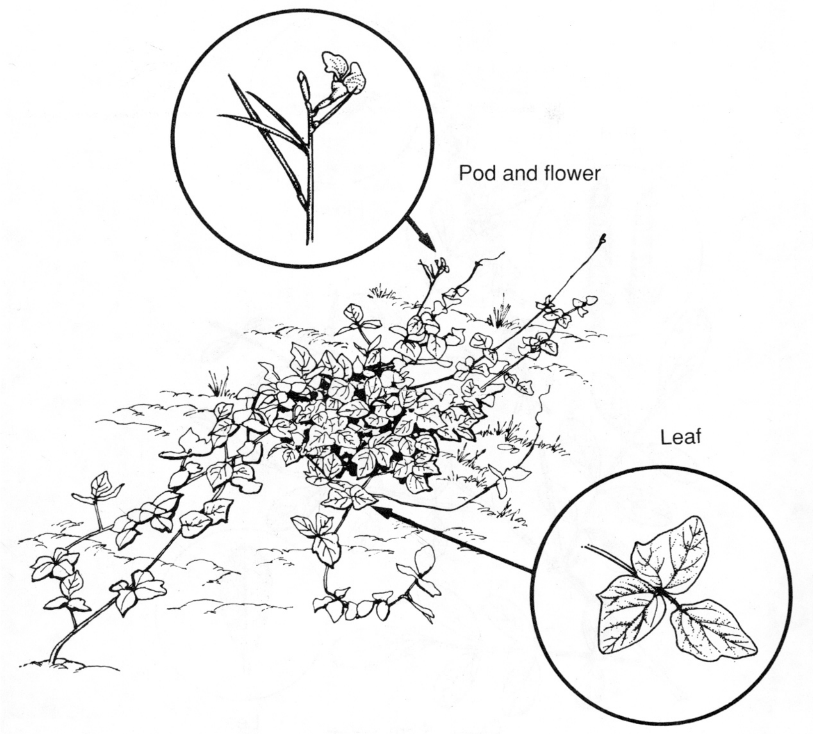
Sunn hemp
Scientific name: *Crotalaria juncea* L.
Growth habit: erect, tall, 1.5 to 2.5 m high
Soil: poorly drained, low fertility soils (Crotalaria can stand both drought and waterlogging.)
Temperatures: 12 to 35 °C
Planting time: before rice
Duration: 45 to 50 days
Nitrogen added: 120 kg per hectare
Other uses: forage, fiber, green manure

Rainfed lowlands—forage



Hairy indigo
Scientific name: *Indigofera hirsuta*
Growth habit: short, erect, annual
Soil: well-drained
Temperatures: 15 to 35 °C
Planting time: after rice
Duration: 100 to 120 days
Nitrogen added: 80 to 90 kg per hectare
Another use: forage

Rainfed lowlands—forage

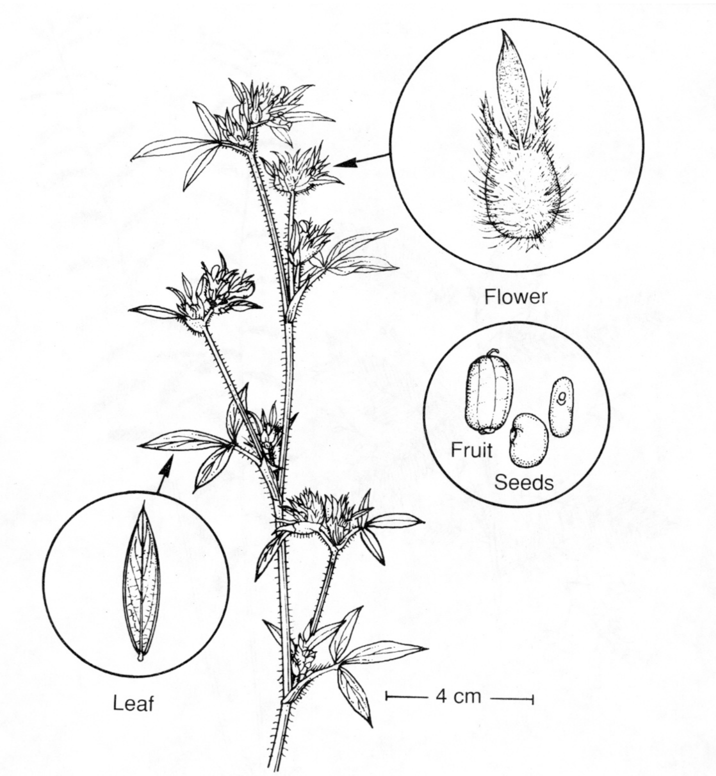


Siratro
Scientific name: *Macroptilium atropurpureum*
Growth habit: creeping, with long vines
Soil: well-drained
Temperatures: 15 to 35 °C
Planting time: after rice, intercropped with mungbean or cowpea
Duration: 150 to 180 days
Nitrogen added: 75 to 80 kg per hectare
Other uses: forage (can be cut several times before it is plowed in for green manure); also suited to upland areas, especially as a cover crop to check soil erosion

Rainfed lowlands—forage

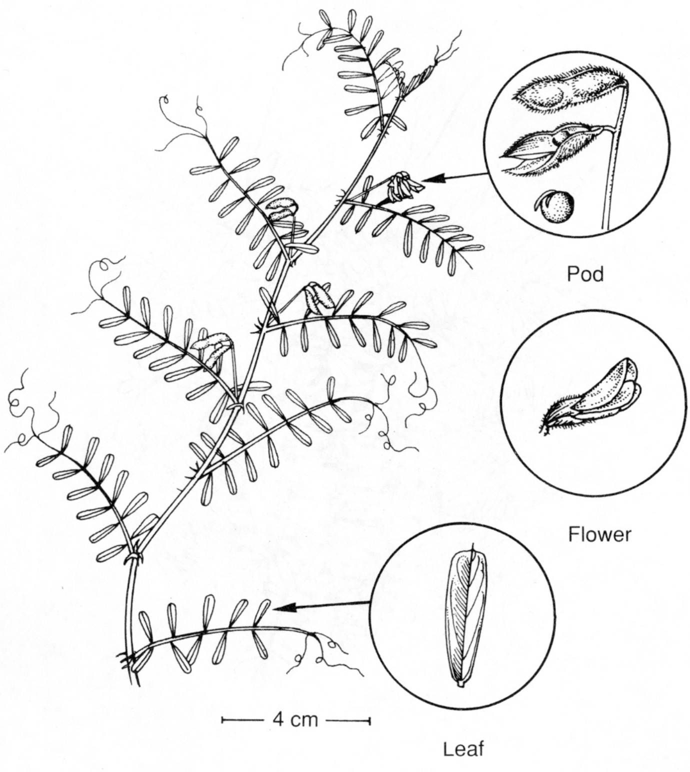
Scientific name: *Sesbania bispinosa* (Jacq.)
Growth habit: erect, tall, 1.5 to 3 m high
Soil: wet to waterlogged soils
Temperatures: 15 to 38 °C
Planting time: before rice
Duration: 45 to 50 days
Nitrogen added: 80 kg per hectare
Another use: forage

Rainfed lowlands—forage



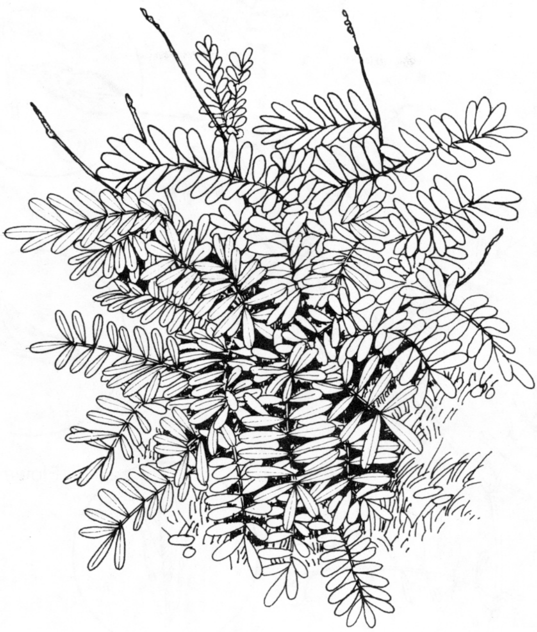
Stylo
Scientific name: *Stylosanthes humilis*
Growth habit: short bush, annual
Soil: well-drained
Temperatures: 15 to 35 °C
Planting time: after rice
Duration: 120 to 160 days
Nitrogen added: 75 to 90 kg per hectare
Other uses: forage; good for repeated cutting before it is plowed in for green manure

Rainfed lowlands—forage



Hairy vetch
Scientific name: *Vicia villosa* Roth.
Growth habit. erect to bushy type
Soil: marginal to fertile soils
Temperatures: 12 to 35 °C
Planting time: after rice
Duration: 110 to 140 days
Nitrogen added: 70 to 80 kg per hectare
Another use: forage

Rainfed lowlands—green manure

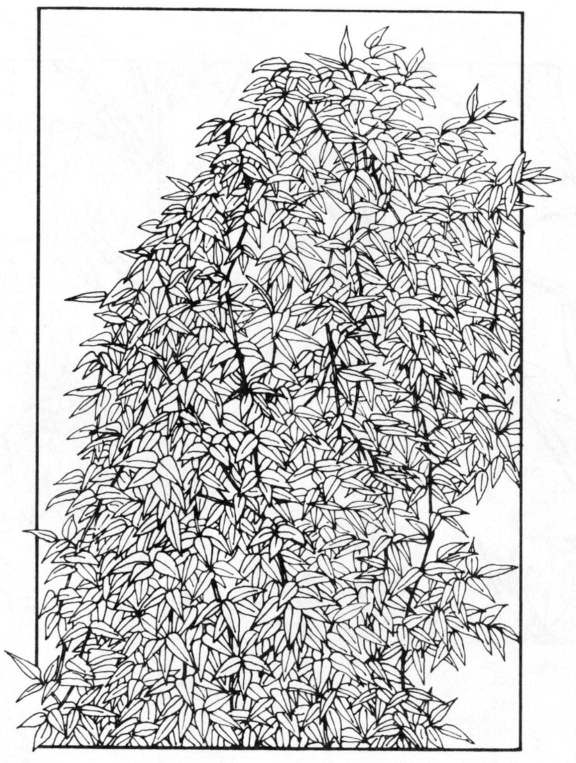


Scientific name: *Indigofera tinctoria*
Growth habit: bush, 80-100 cm tall
Soil: well-drained (can stand drought)
Temperatures: 15 to 38 °C
Planting time: after rice, intercropped with fast-growing food legumes such as cowpea and mungbean
Duration: 150 to 180 days
Nitrogen added: 80 to 90 kg per hectare
Another use: indigo dye

Upland areas—food legumes

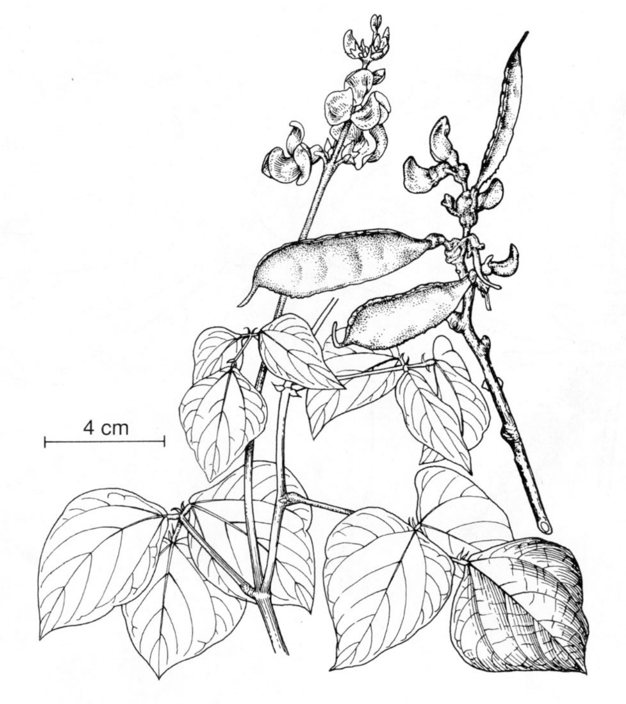
Cluster bean
Scientific name: *Cyamopsis tetragonoloba*
Growth habit: erect, tall, 110 to 130 cm
Soil: marginal soils (can stand drought)
Temperatures: 12 to 35 °C
Planting time: after rice
Duration: 50 to 60 days for green manure, 70 to 80 days for green pods, 110 to 115 days for dry seed
Nitrogen added: 80 to 90 kg per hectare
Other uses: green pods for food, dry seeds for livestock: used in industry for making gum

Upland areas—food legumes



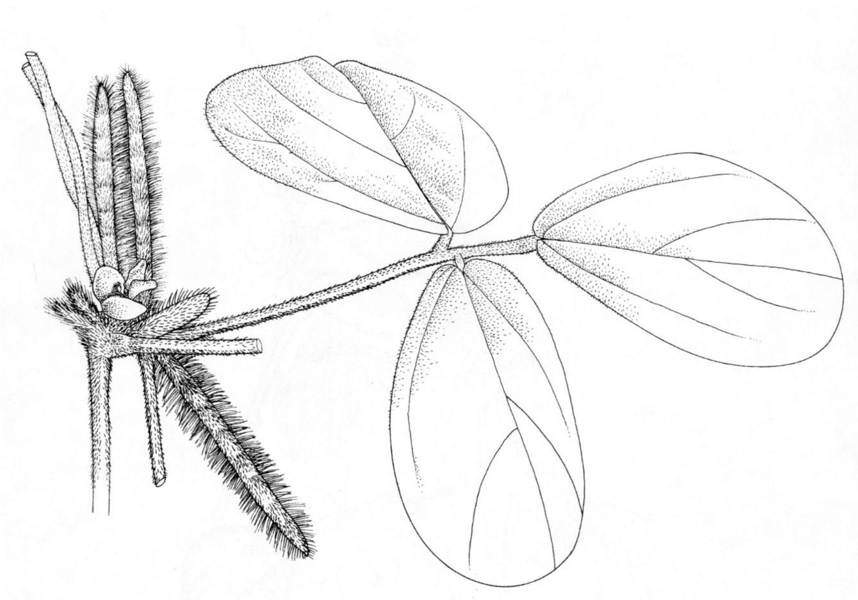
Lima bean
Scientific name: *Phaseolus lunatus*
Growth habit: climbing, with long vines
Soil: marginal, low-fertility soils (can stand drought)
Temperatures: 8 to 30 °C
Planting time: after rice
Duration: 100 to 130 days
Nitrogen added: 75 to 80 kg per hectare
Other uses: green seed and dry seed for food, dry seed for livestock feed

Upland areas—food legumes



Hyacinth bean
Scientific name: *Dolichos lablab*
Growth habit: bushy to climbing type
Soil: poor soils, acid to alkaline (pH 4-8)
Temperatures: 15 to 35 °C
Planting time: after rice
Duration: 110 to 150 days (can be cut back for fast growth where soil moisture is good)
Nitrogen added: 80 to 100 kg per hectare
Other uses: dry seed for food and feed, crop stover for forage and green manure

Upland areas—forage



Calopo

Scientific name: *Calopogonium mucunoides* Desv.

Growth habit: creeping, with long vines

Soil: acid, low-fertility soils

Temperatures: 15 to 35°C

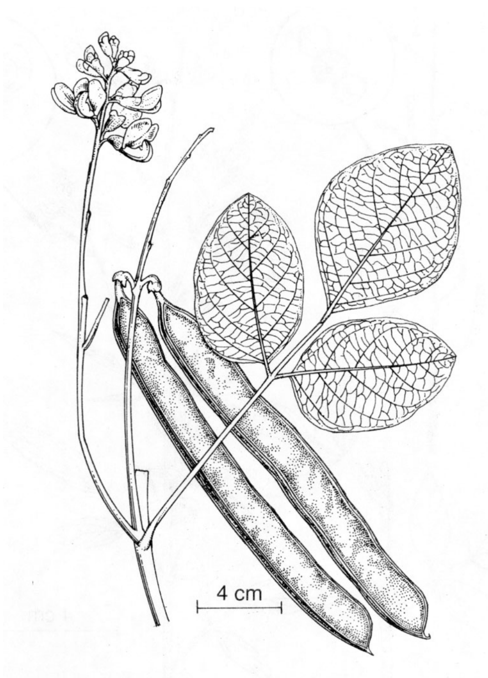
Planting time: after rice

Duration: 160 to 180 days

Nitrogen added: 80 to 100kg per hectare

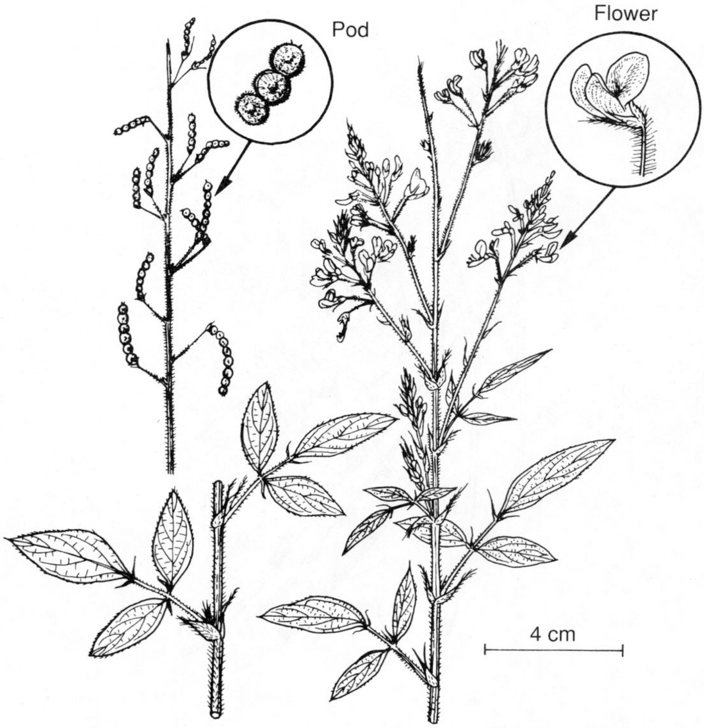
Other uses: forage (good for grazing or several cuttings before it is plowed under for green manure); cover crop to check soil erosion

Upland areas—forage



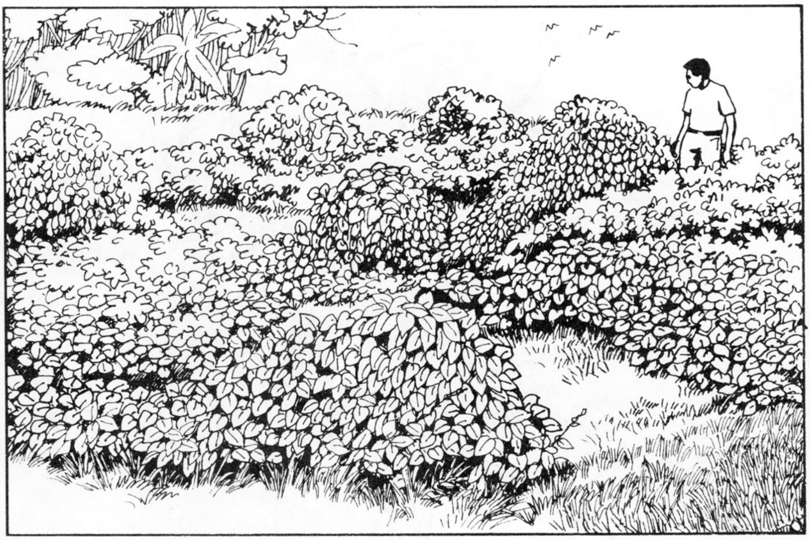
Jackbean
Scientific name: *Canavalia ensiformis*
Growth habit: erect, shrubby, annual
Soil: poor, acid soils (can stand drought)
Temperatures: 15 to 30 °C
Planting time: after upland rice
Duration: 11 0 to 130 days
Nitrogen added: 70 to 80 kg per hectare
Another use: forage

Upland areas—forage



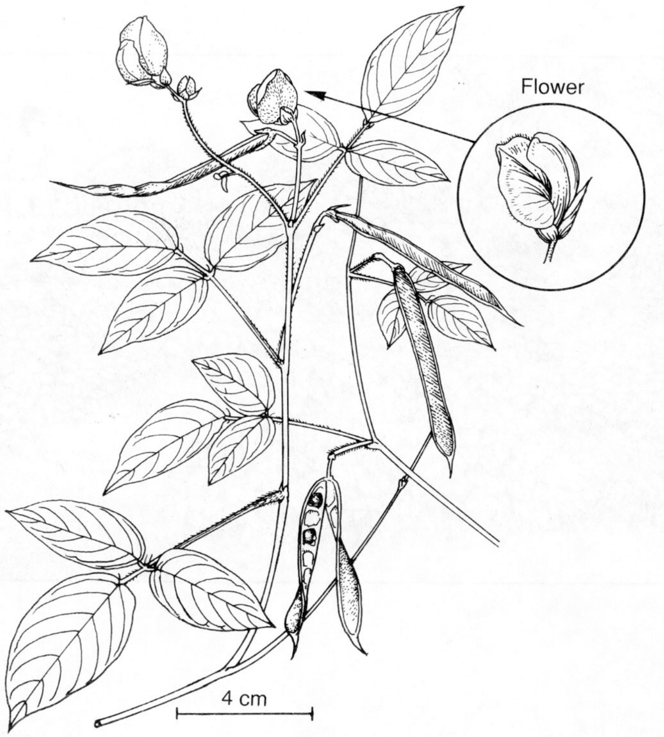
Scientific name: *Desmodium purpureum*
Growth habit: creeping, bushy type
Soil: marginal, eroded, low-fertility
Temperatures: 10 to 30 °C
Planting time: after rice
Duration: 180 to 210 days
Nitrogen added: 90 kg per hectare
Another use: cover crop to check soil erosion

Upland areas—forage



Velvet bean
Scientific name: *Mucuna pruriens*
Growth habit: creeping, with long vines
Soil: acid soils subject to erosion
Temperatures: 15 to 35 °C
Planting time: after rice
Duration: 150 to 180 days
Nitrogen added: 80 to 100 kg per hectare
Other uses: forage, good for grazing, cover crop to check soil erosion

Upland areas—forage

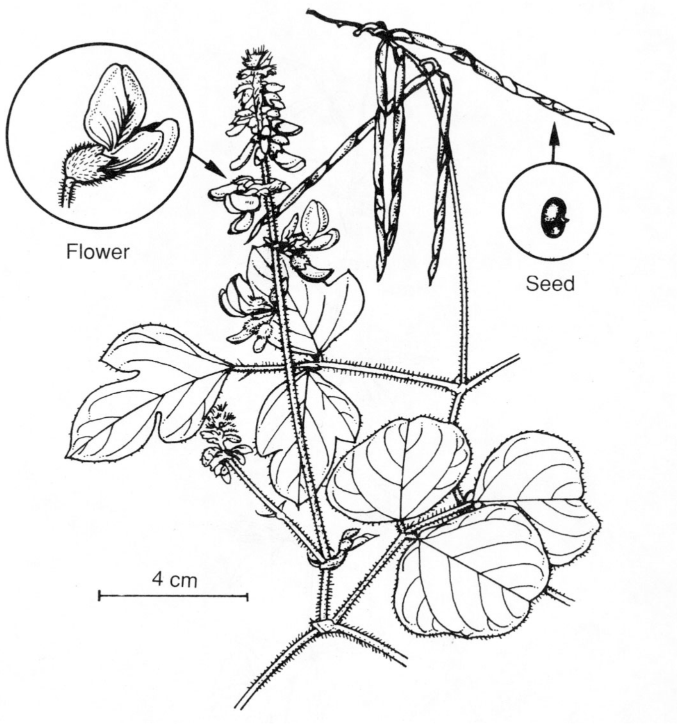


Centro
Scientific name: *Centrosema pubescens*
Growth habit: creeping, with long vines
Soil: acid soils, subject to erosion
Temperatures: 15 to 35 °C
Planting time: after rice (can stand long, dry season)
Duration: 150 to 180 days
Nitrogen added: 80 to 100 kg per hectare
Other uses: forage (good for repeated cutting before it is plowed in for green manure); cover crop to check soil erosion

Upland areas—forage

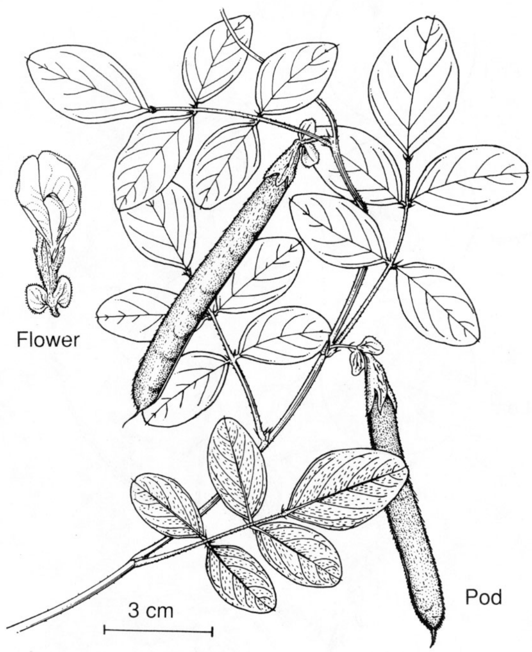
Scientific name: *Flemingia congesta*
Growth habit: erect, tall shrub
Soil: acid, low-fertility soils
Temperatures: 15 to 35 °C
Planting time: after rice
Duration: 150 to 180 days
Nitrogen added: 80 to 120 kg per hectare
Other uses: forage; good for grazing; cover crop to check soil erosion

Upland areas—forage



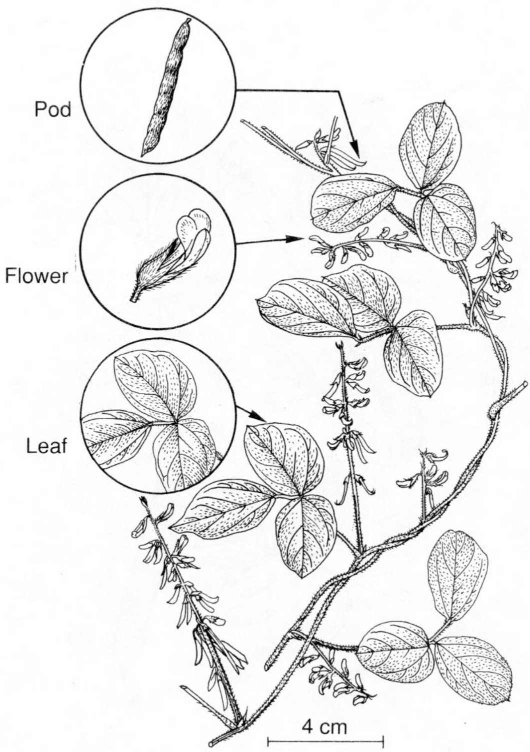
Puero
Scientific name: *Pueraria phaseoloides*
Growth habit: creeping, with long vines
Soil: acid soils, low-fertility soils
Temperatures: 15 to 35 °C
Planting time: after rice
Duration: 120 to 150 days
Nitrogen added: 90 kg per hectare
Other uses: forage, especially good for early grazing; excellent cover crop to check soil erosion, since it forms a dense mat.

Upland areas—forage



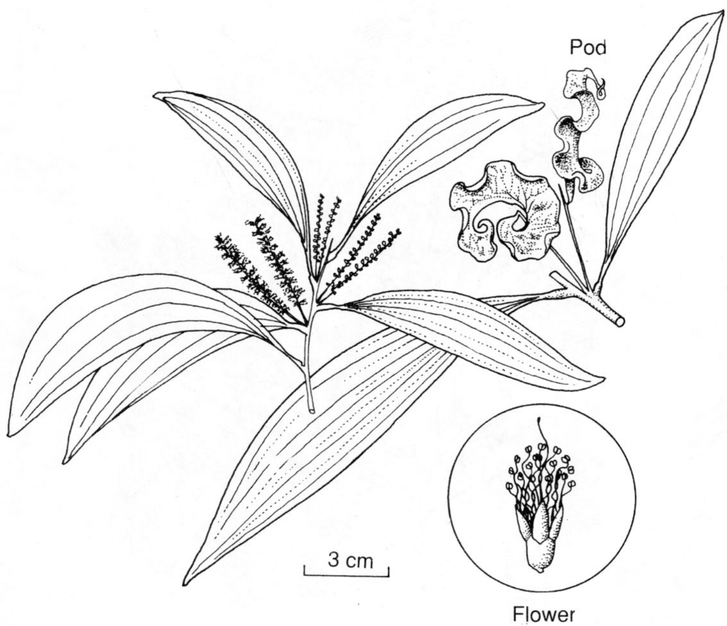
Blue pea
Scientific name: *Clitoria ternatea*
Growth habit: erect, tall
Soil: marginal. low-fertility soils
Temperatures: 15 to 35 °C
Planting time: after rice, in the dry season (can stand drought)
Duration: 1 10 to 140 days
Nitrogen added. 80 to 100 kg per hectare
Another use: forage

Upland areas—forage

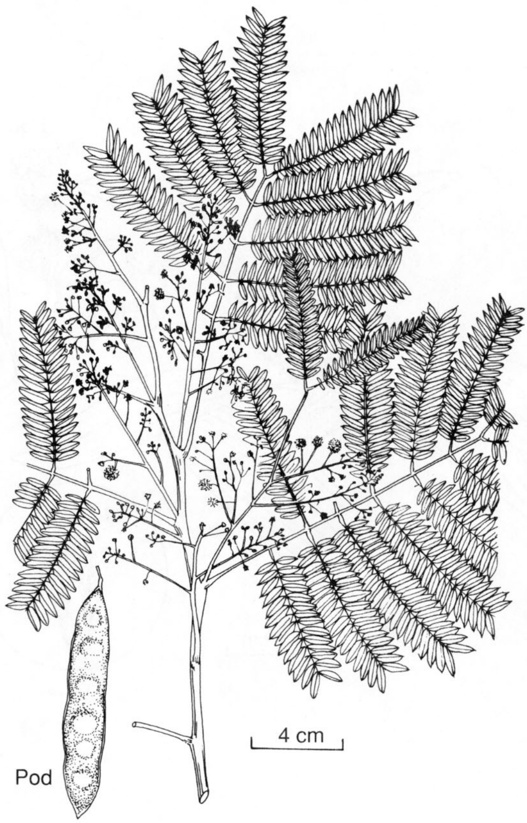


Wild soybean
Scientific name: *Glycine javanica*
Growth habit: creeping vine
Soil: marginal, low-fertility soils
Temperatures: 10 to 35 °C
Planting time: after rice
Duration: perennial
Nitrogen added: 80 to 90 kg per hectare
Another use: forage

Upland areas—perennials for bunds and hedgerows

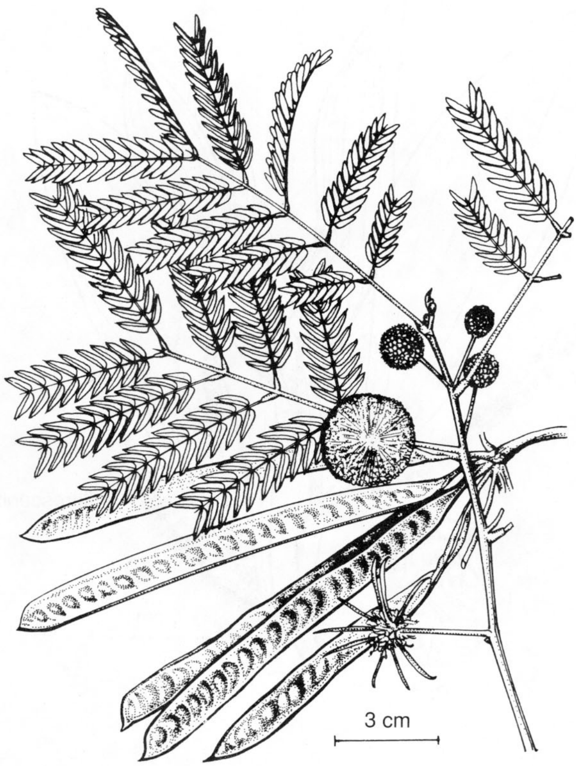


Scientific name: *Acacia auriculiformis*
Growth habit: drought-resistant, fast-growing tall tree, 20 to 30 m high
Soil: poor, acid soils; wasteland
Temperatures: 20 to 35 °C
Nitrogen added: 120 kg from about 5 tons biomass
Other uses: fuel wood; leaves for fodder and leaf green manure



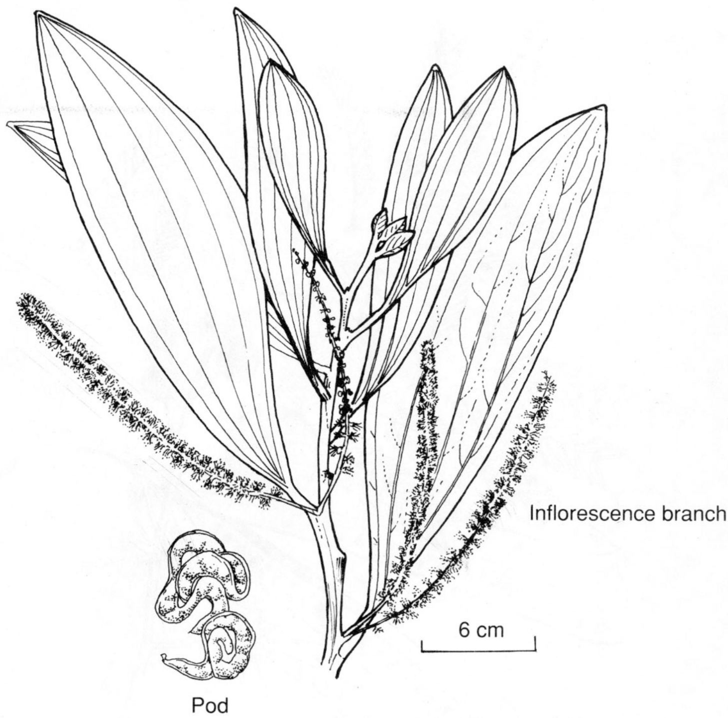
Miracle tree
Scientific name: Albizia falcataria
Growth habit: tall tree, 30 to 40 m; fast-growing, 6 to 7 m a year
Soil: good soils, in the wet tropics
Temperatures: 15 to 35 °C
Nitrogen added: 120 to 140 kg from 6 to 7 tons biomass
Other uses: pulpwood, fuel wood, leaf green manure

Upland areas—hedgerows



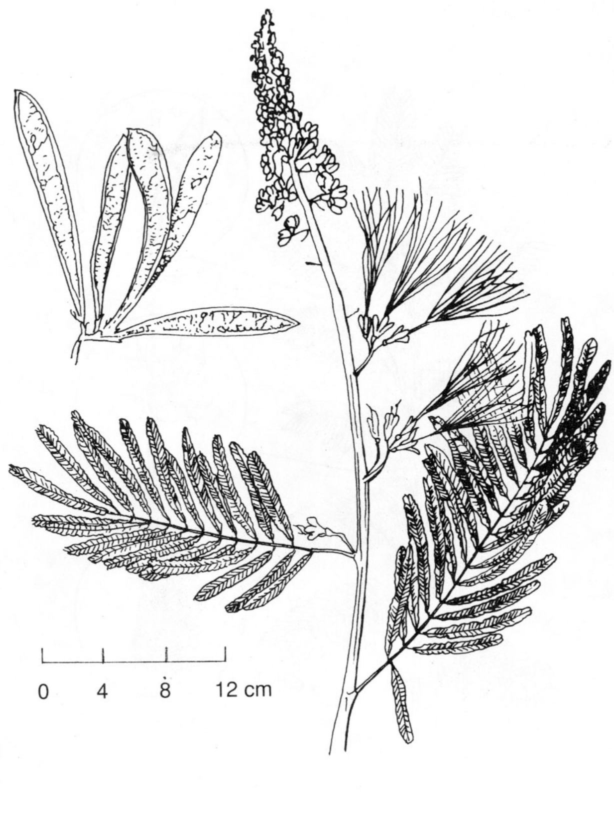
Ipil-ipil, subabul
Scientific name: *Leucaena leucocephala*
Growth habit: tree, 4 to 8 m tall
Soil: fertile soils
Temperatures: 15 to 35 °C
Nitrogen added: 125 kg from 5 tons biomass
Other uses: forage from green leaves (can stand repeated cutting), fuel wood

Upland areas —perennials for hedgerows



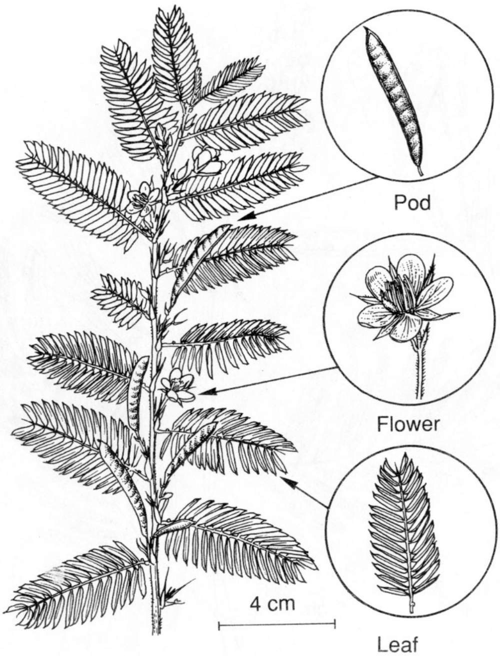
Scientific name: *Acacia mangium*
Growth habit: drought-resistant, fast-growing tall tree
Soil: poor, acid soils
Temperatures: 20 to 35 °C
Nitrogen added: 100 to 120 kg from 4 to 5 tons biomass
Other uses: fodder (can be cut up to four times a year), good for alley cropping

Upland areas—perennials for hedgerows



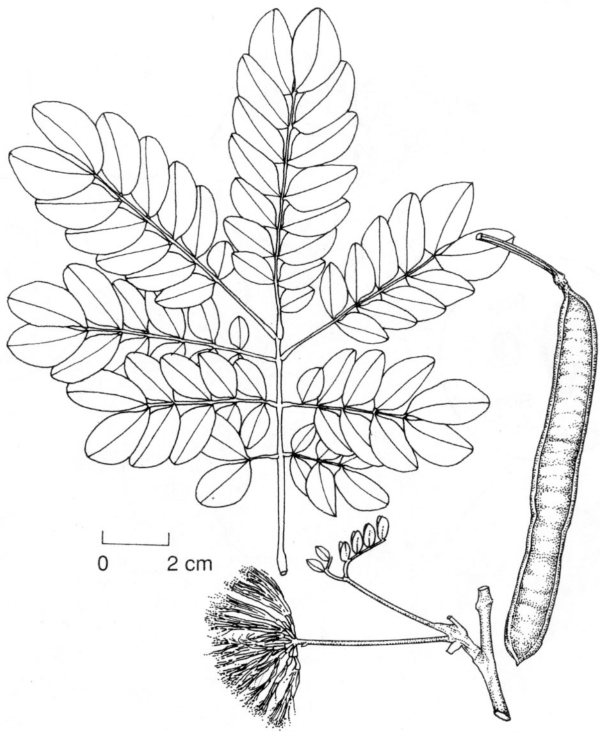
Calliandra
Scientific name: *Calliandra calothyrsus*
Growth habit: small tree/shrub, 3 to 4 m tall
Soil: poor acid soil
Temperatures: 10 to 35 °C
Nitrogen added: 80 to 100 kg from 4 to 5 tons biomass
Other uses: fuel wood, good for making charcoal; shade plant and green manure

Upland areas—perennials for hedgerows



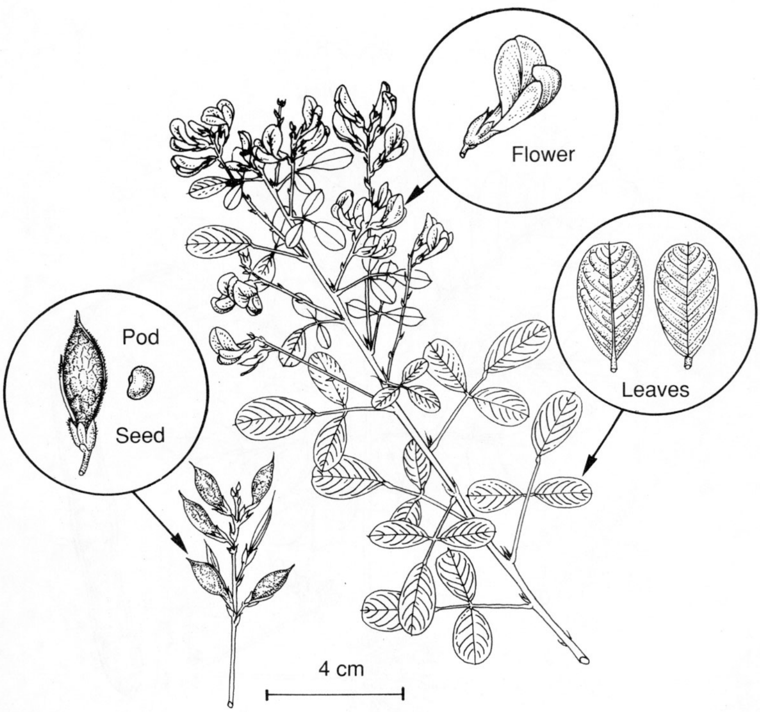
Cassia
Scientific name: *Cassia siamea*
Growth habit: small to medium tree, 20 m tall
Soil: poor acid soil
Temperatures: -5 to 45 °C
Nitrogen added: 80 to 100 kg from 4 tons biomass
Other uses: forage (can be pruned three times a year); good for alley cropping

Upland areas—perennials for hedgerows



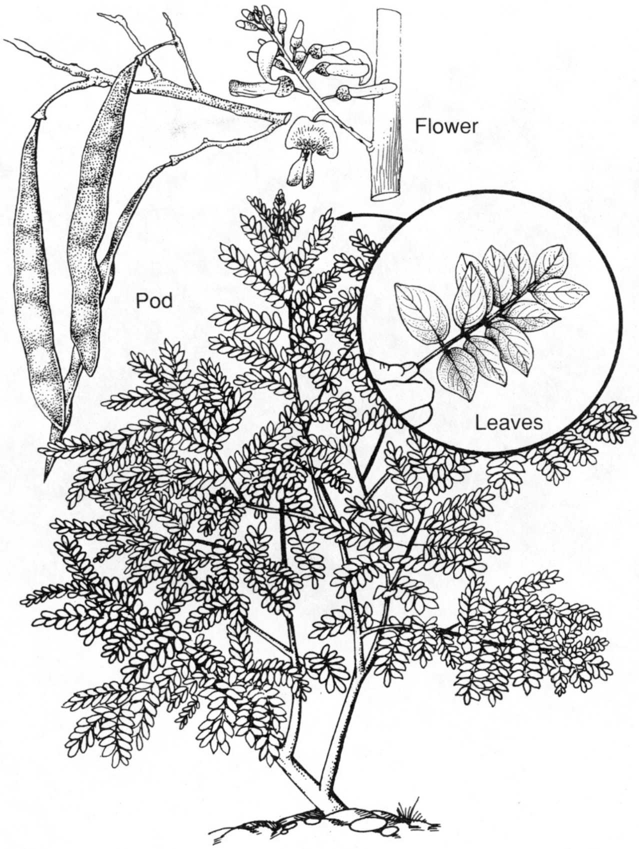
Scientific name: *Samanea saman*
Growth habit: tree, 20 m tall, heat- and drought-resistant
Soil: shallow, compacted clay, alkaline and poorly drained soils; good for low-rainfall areas
Temperatures: 10 to 35 °C
Nitrogen added: 180 to 240 kg per hectare
Other uses: fuel wood, fodder, shade tree

Upland areas—perennials for hedgerows



Lespedeza
Scientific name: *Lespedeza pubescens*
Growth habit: shrub, 1-2 m tall, drought-resistant
Soil: marginal, low-fertility
Temperatures: 10 to 38 °C
Nitrogen added: 90 to 100 kg from 5 tons biomass
Another use: fodder

Upland areas—perennials for hedgerows

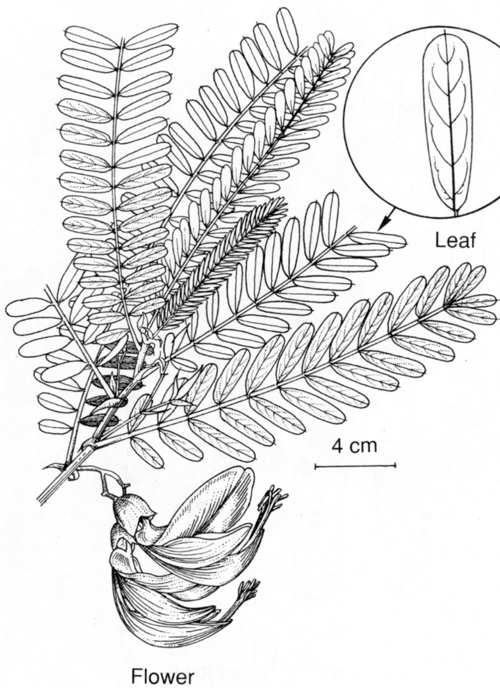


Gliricidia
Scientific name: *Gliricidia sepium*
Growth habit: fast-growing shrub/tree, 3-4 m tall
Soil: acid, low-fertility
Temperatures: 8 to 35 °C
Nitrogen added: 80 to 100 kg from 4 to 5 tons biomass
Other uses: fuel wood, shade plant, green manure

Upland areas—perennials for hedgerows

Desmanthus
Scientific name: *Desmanthus virgatus*
Growth habit: small shrub, 2-3 m tall
Soil: marginal, eroded, acid upland
Temperatures: 10 to 38 °C
Nitrogen added: 80 to 100 kg from 4 to 5 tons biomass
Other uses: forage, good for heavy grazing (can be cut four times a year); fuel wood

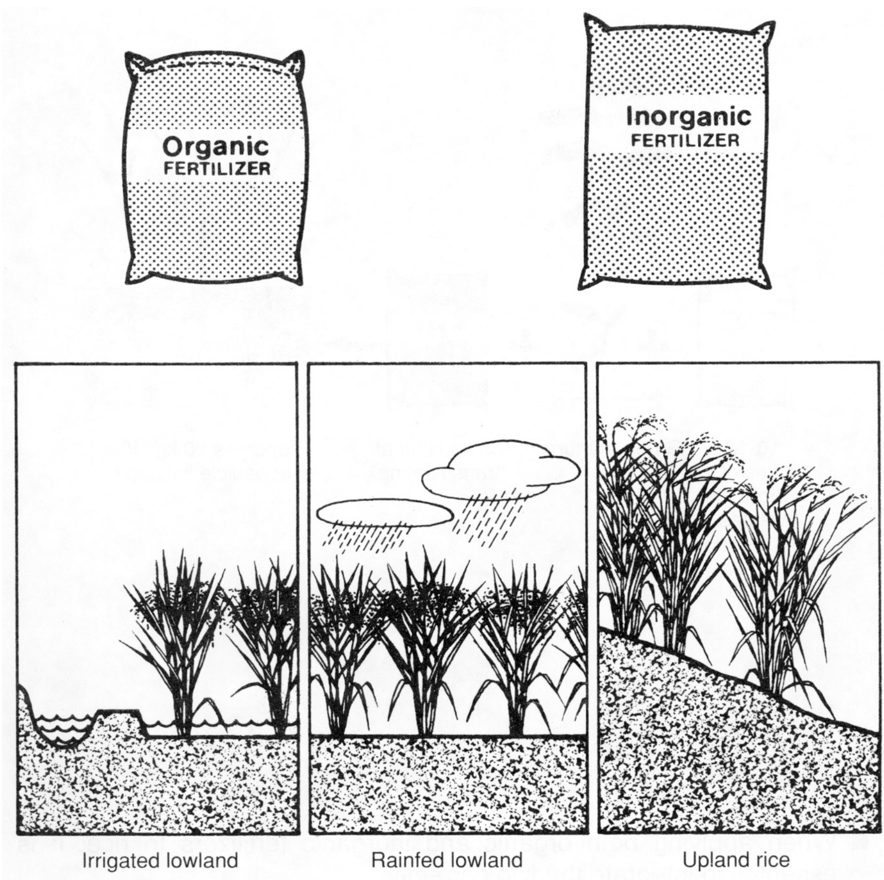
Upland areas—perennials for hedgerows



Scientific name: *Sesbania grandiflora*
Growth habit: tall tree, 20-30 m high
Soil: wornout, eroded land; slash-and-burn agriculture areas
Temperatures: 8 to 38 °C
Nitrogen added: 150 kg from 6 tons biomass
Another use: fuel wood

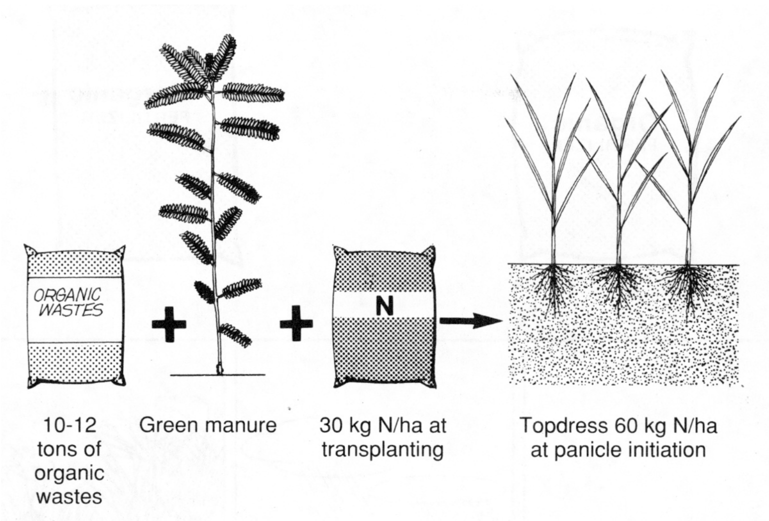
Managing nutrients in rice-based systems

Applying organic and inorganic fertilizers in different rice environments



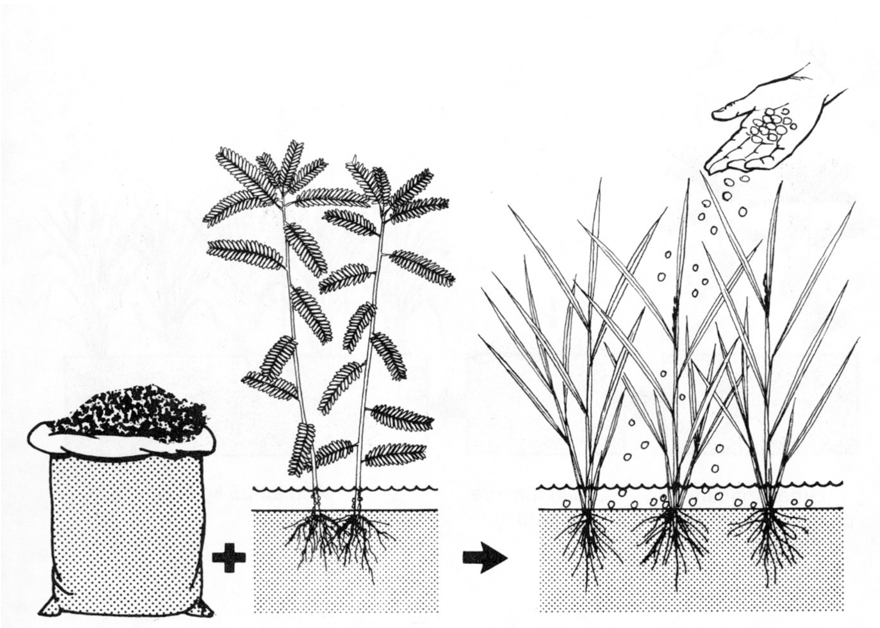
- Integrating organic and inorganic fertilizer use
  - — Irrigated lowland rice
  - — Rainfed lowland rice
  - — Upland rice

Integrating organic and inorganic fertilizer use



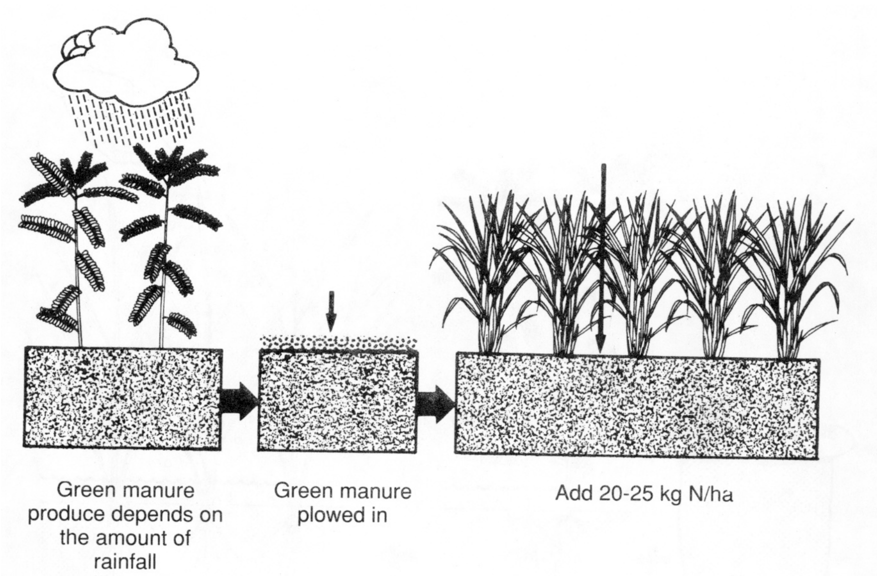
- When applying both organic and inorganic fertilizers to rice, it is essential to integrate the two correctly.
- The amount and time of application will vary with the environment. The amount of nutrients from different sources must be adjusted to the rice culture.
- If organic wastes and green manure are available in large quantities, less inorganic fertilizer will be needed.

Irrigated lowland rice



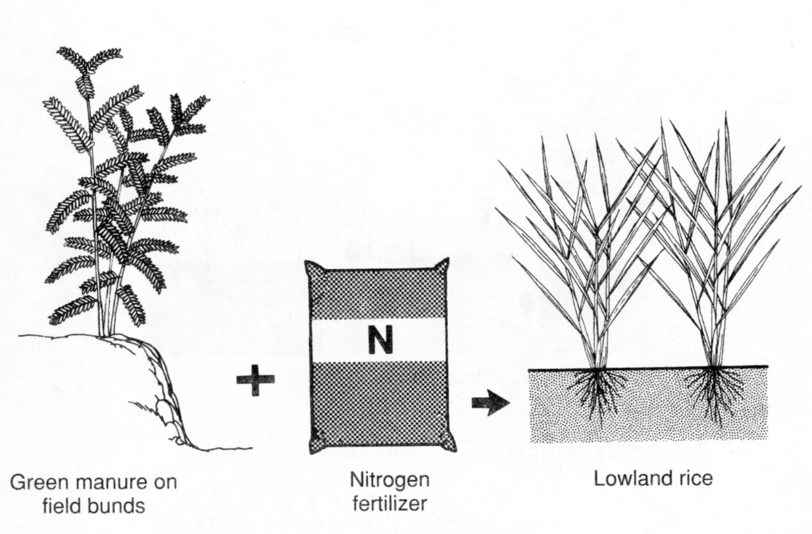
- Irrigated rice responds well to proper fertilizer application.
- Plow in green manure and organic matter during land preparation. If both together total less than 7 tons per hectare, add a basal dose of 30 to 40 kg fertilizer nitrogen per hectare.
- Extra nitrogen is needed during rapid crop growth. Topdress 40 to 60 kg nitrogen per hectare when panicles begin to form.

Rainfed lowland rice



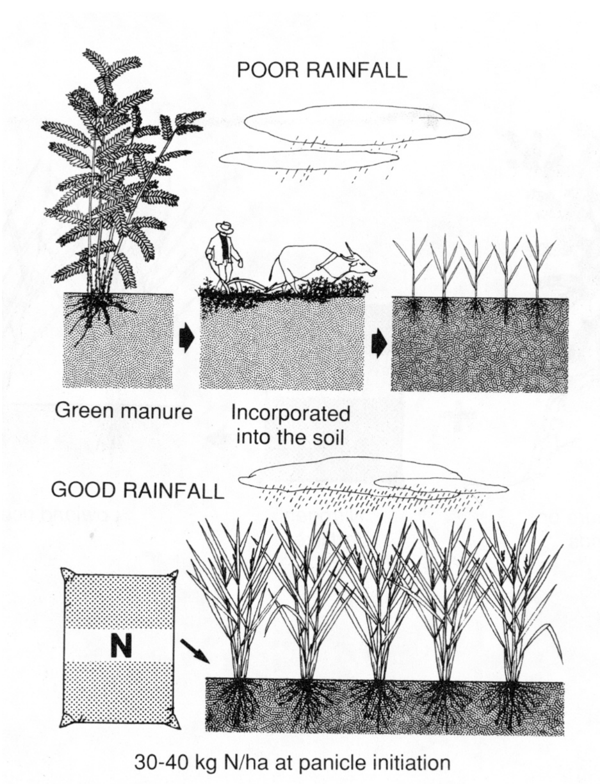
- In rainfed areas, the amount of green manure produced will depend on the rainfall. If the amount plowed in is less than 2 tons per hectare, add fertilizer nitrogen basally (20 to 25 kg per hectare).
- If rainfall is good, topdress fertilizer nitrogen at 40 to 50 kg per hectare when panicles begin to form.

Rainfed lowland rice



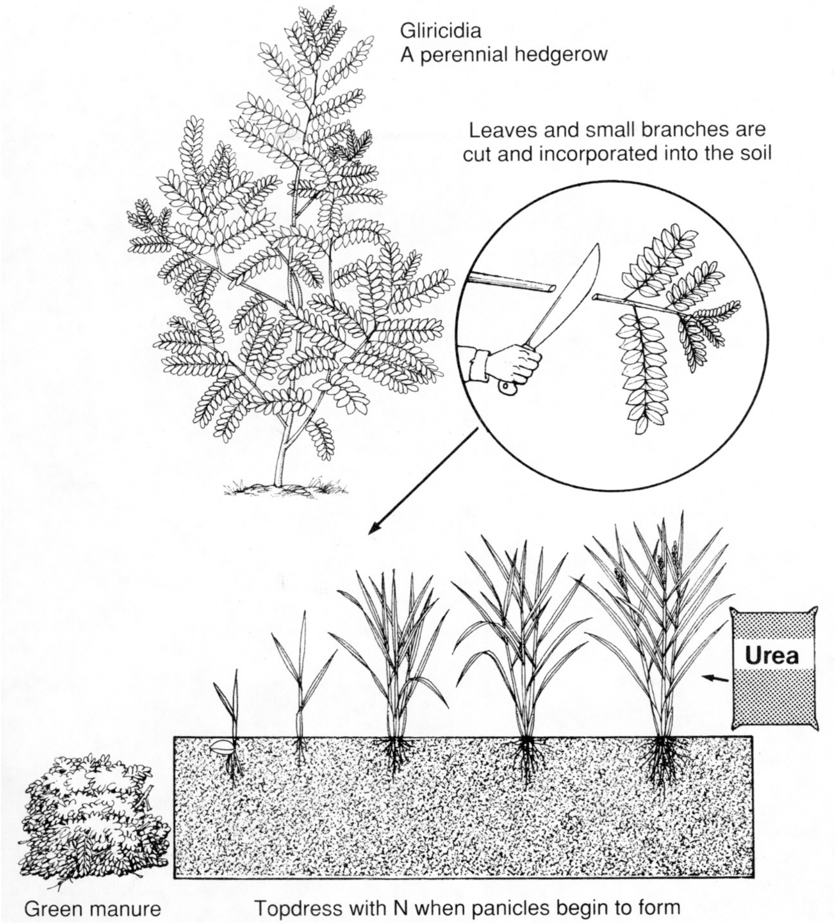
- Green manure grown on field bunds or green leaf manures will usually supply only a part of the basal nitrogen need of lowland rice. To make up the rest, add fertilizer nitrogen at 20 to 30 kg per hectare basally.
- At panicle initiation, topdress 40 to 50 kg nitrogen per hectare.

Upland rice



- In upland rice, nitrogen applied at the wrong time can reduce yields when soil moisture is low.
- A green manure crop planted in the field before rice should be plowed into the soil during land preparation for the rice crop. If it is more than 3 tons per hectare, no additional basal nitrogen is needed.
- If rainfall is good, 30 to 40 kg fertilizer nitrogen per hectare, applied when panicles begin to form, will increase yield.

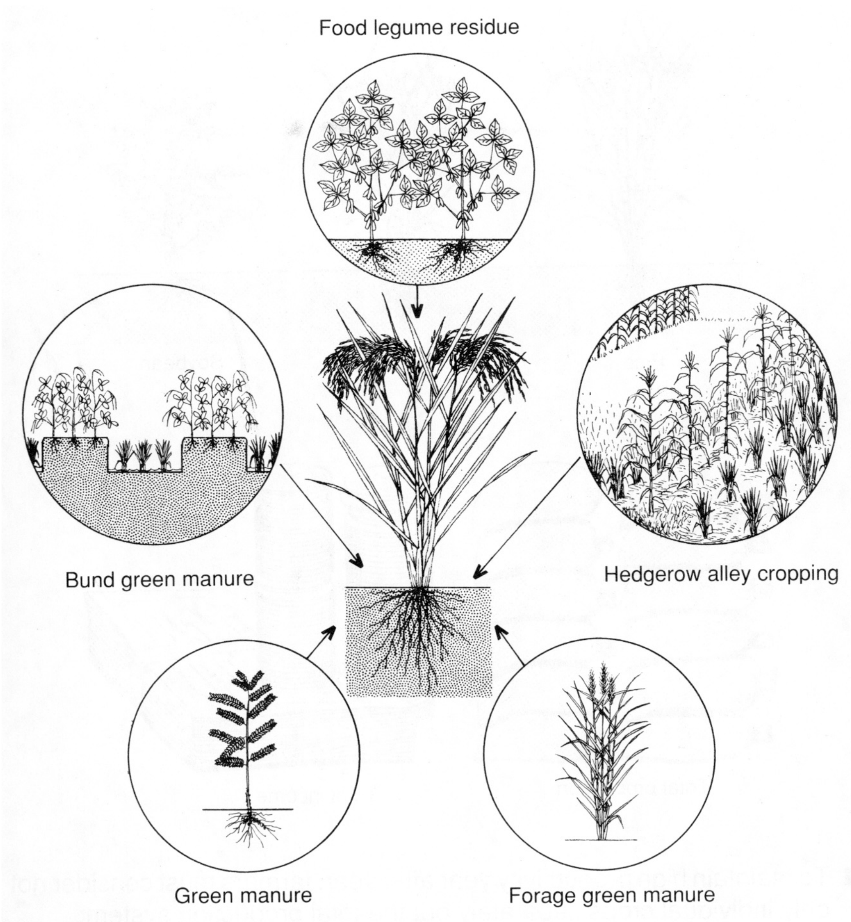
Upland rice



- Where a green manure is planted as a perennial hedgerow, leaves and small branches are cut and incorporated into the soil. If this totals more than 4 tons per hectare, no more basal nitrogen is needed.
- Topdress 30 kg fertilizer nitrogen per hectare when panicles begin to form.

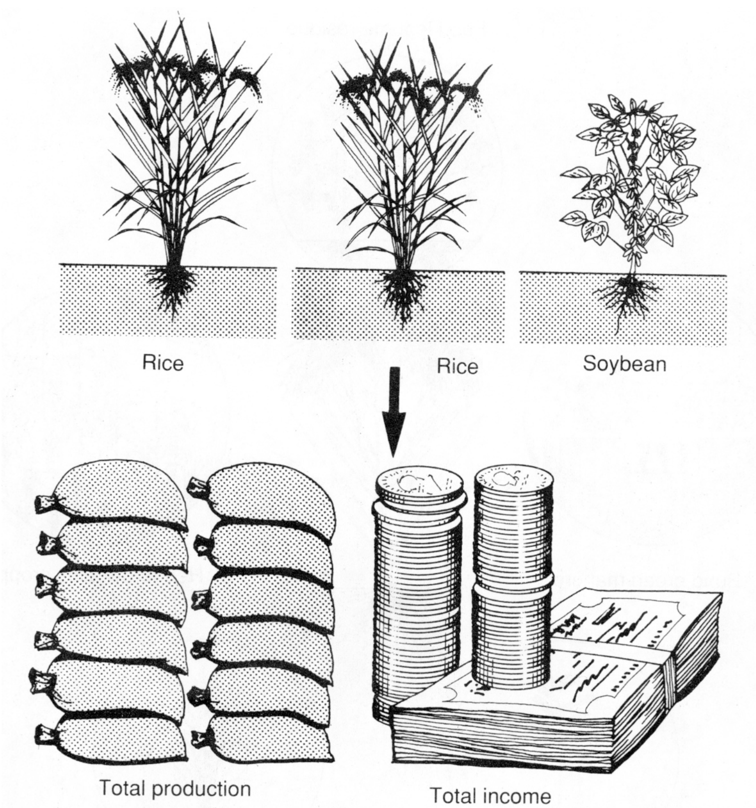
Cropping systems for high productivity

Rice-based cropping systems



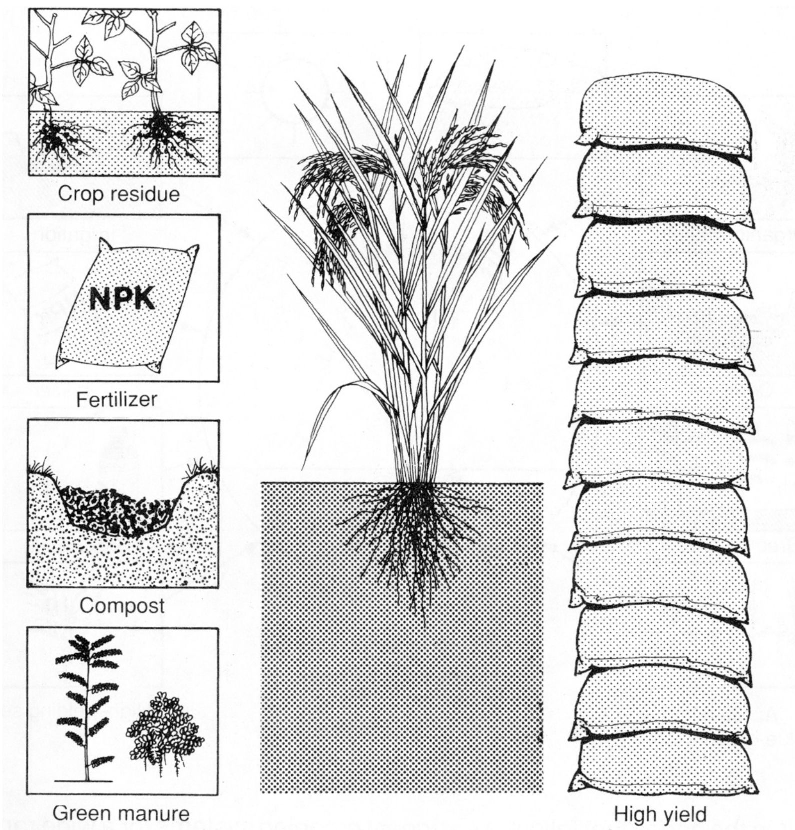
■ Rice production is the central activity in a rice-based cropping system. Other crops are arranged around the main crop to make optimum use of cropland and maintain high productivity.

Maintaining high productivity



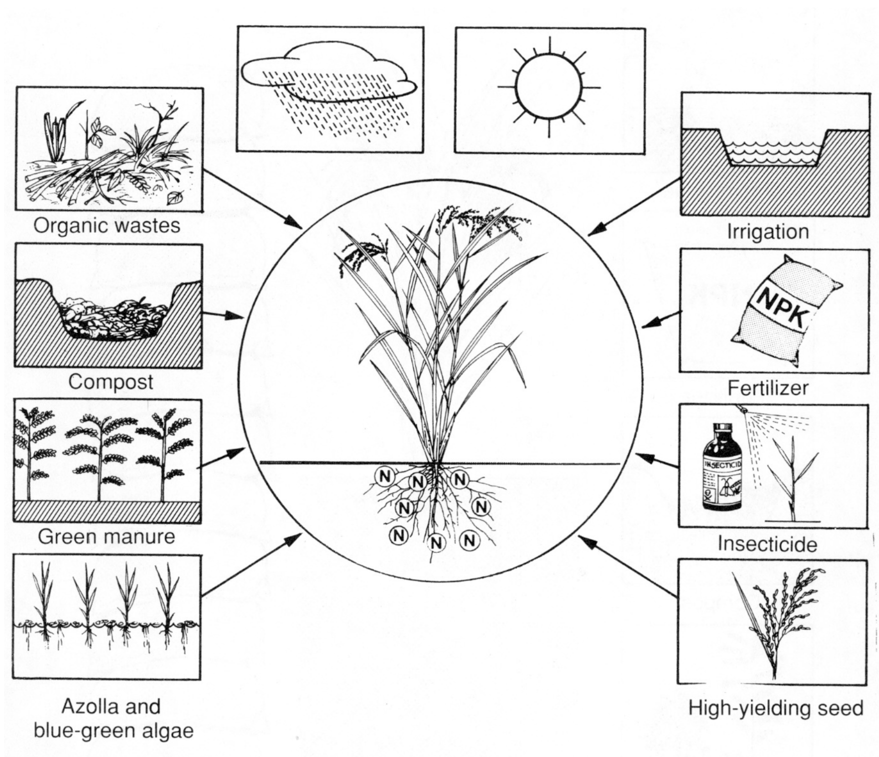
- To maintain high productivity year after year, farmers must consider not only individual crops separately but the total production system:
  - — Both yields and income from the system should be high.
  - — Production should be stable through the year and from year to year.
  - — The system should be designed to be self-sufficient, with minimum dependence on off-farm resources.

Maintaining high productivity



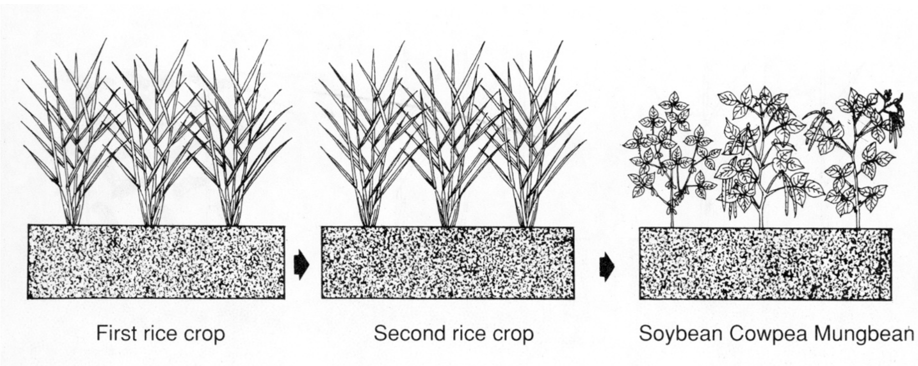
- To maintain high productivity, farmers must consider
  — cropping sequence;
  — crop rotation: cereal - cereal versus cereal - legume;
  — nutrients used by each crop and by the whole sequence:
  — amount of nutrients added through fertilizer, crop residue, green manure, and compost; and
  — time and method of nutrient application.

Cropping systems for efficient land use



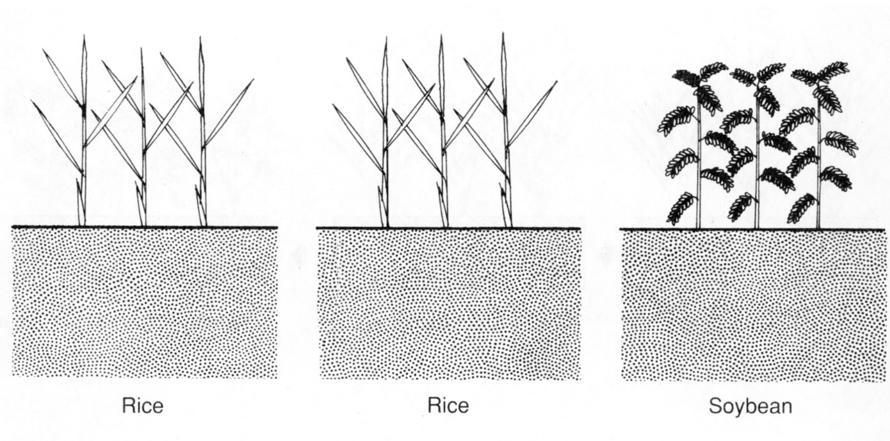
- On the pages that follow, we suggest cropping systems for a wide range of growing conditions.
- Rice is the central crop. Other crops in the sequence are to supplement income and sustain soil fertility.
- In all these systems, the nutrient needs of the crop are partly met by plowing in green manure and crop residues. The balance must be made up by adding organic waste compost and inorganic fertilizer, as outlined earlier in this book.

Irrigated lowland rice systems—rice - rice - grain legume



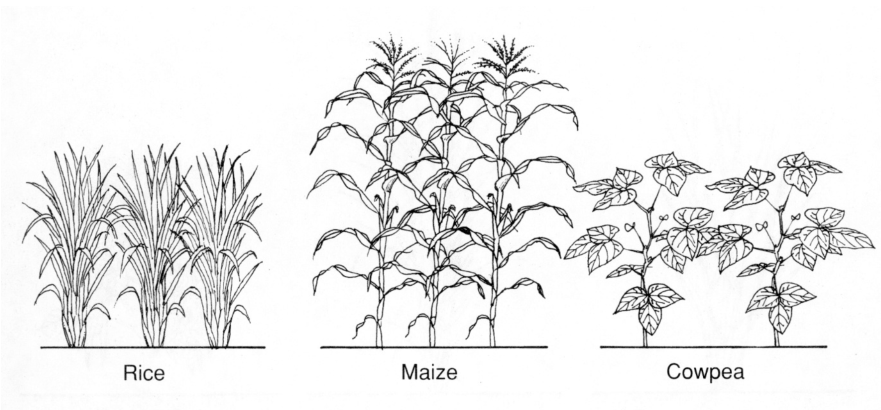
- A fast-growing grain legume such as rnungbean is planted following the second rice crop. The legume supplies food, and crop stover serves as green manure for the next rice crop.
- Rice crop residue should be returned to the soil unless it harbors pests and diseases that may survive to attack the following rice crop.

Rice - rice - *Sesbania rostrata*



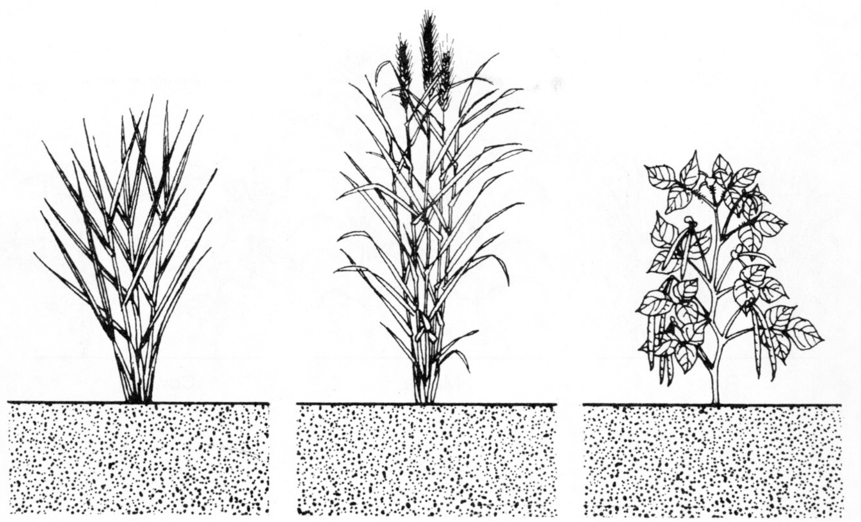
- On poorly drained soils with continuous rice cropping, pests and diseases build up and soil fertility goes down.
- Plant *Sesbania rostrata,* which can stand waterlogging, to break this cycle. After 45 days' growth, this green manure can be plowed under to increase soil fertility.

Rice - maize - grain legume



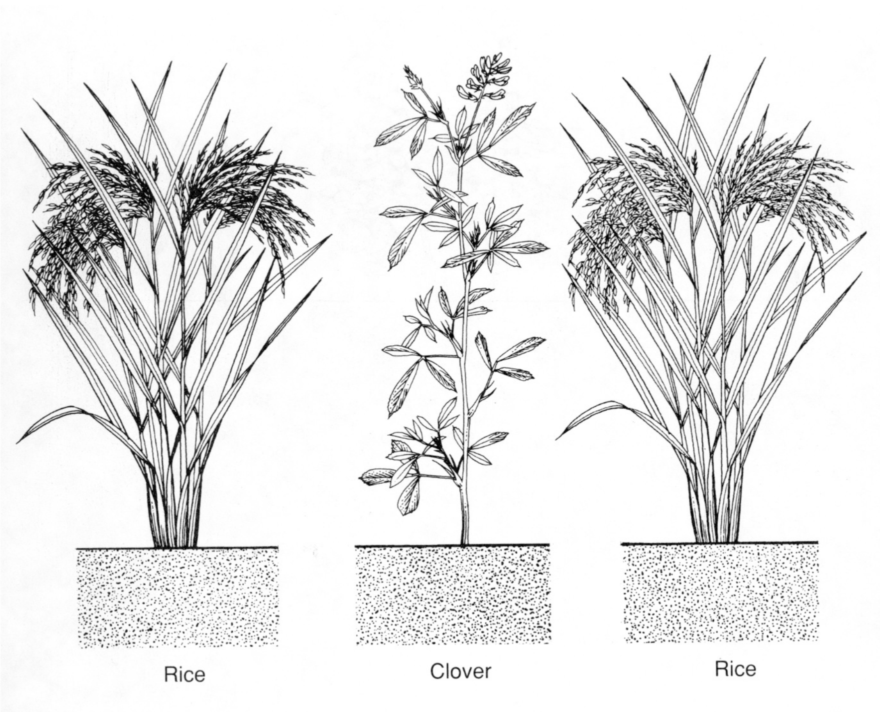
- Maize is grown following rice in irrigated areas. After the maize harvest, plant mungbean or cowpea varieties that mature in 70 days.
- Seed yield from the legume will be about 1 ton per hectare. Stover used as green manure will supply 50 to 60 kg nitrogen per hectare. Plow in rice and maize crop residues for additional nutrients.

Rice - wheat - grain legume



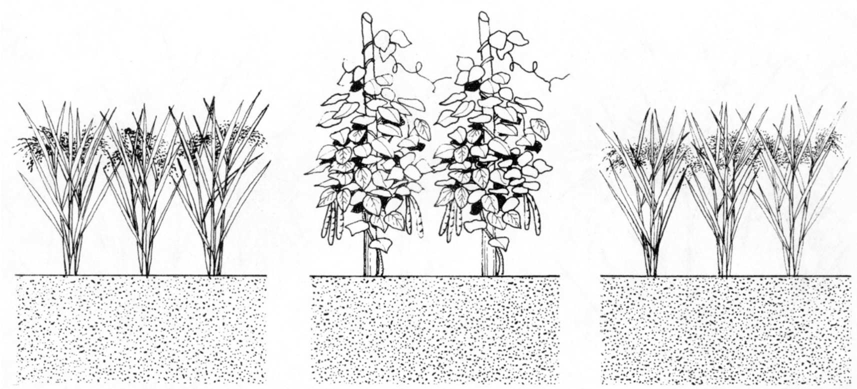
- In irrigated areas with cool winters, a rice - wheat rotation is common.
- A grain legume can be fitted in after the wheat harvest, to give a seed yield of about 1 ton per hectare. Crop stover used for green manure will provide 50 to 60 kg nitrogen per hectare for the following rice crop.

Rice - forage - rice



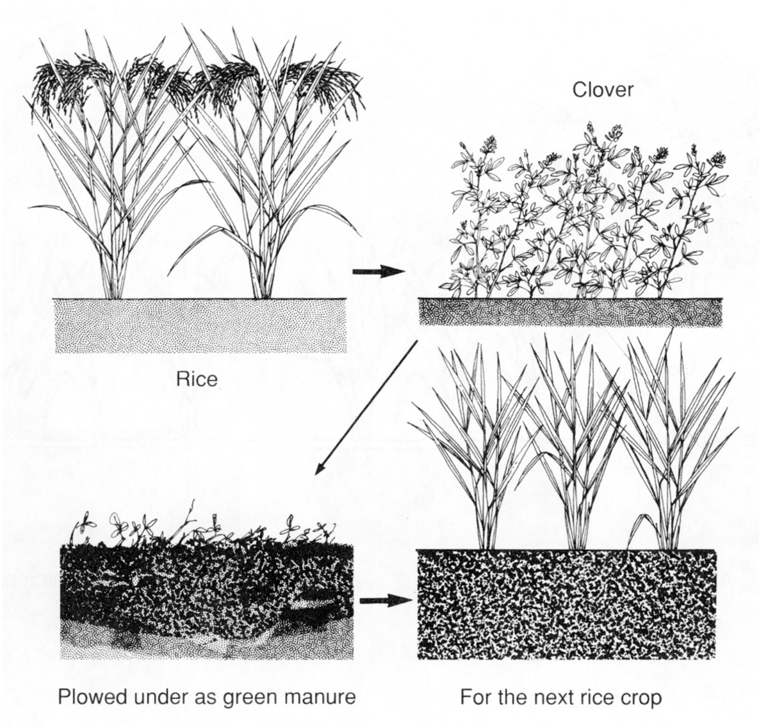
- In irrigated areas with cool winters where two rice crops are grown, Egyptian clover can be planted between rice crops.
- The first two cuttings are used for fodder; then the clover is plowed under before the second rice crop is planted.

Rice - grain legume - rice



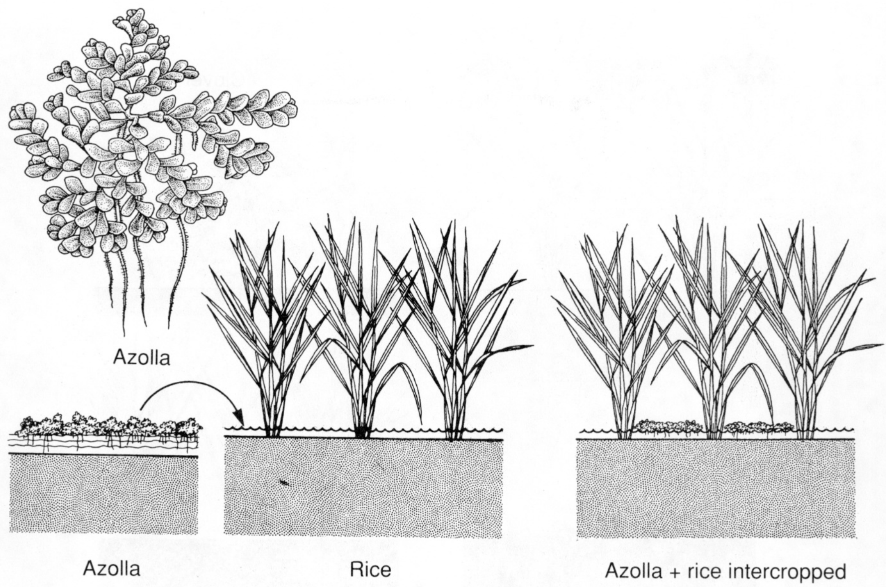
- On well-drained rice soils, kidney bean and faba bean grow well in the cool season.
- Green pods can be eaten as a vegetable, and dry seed can be harvested in 95 to 120 days. The legume crop residue serves as green manure.

Rice - forage



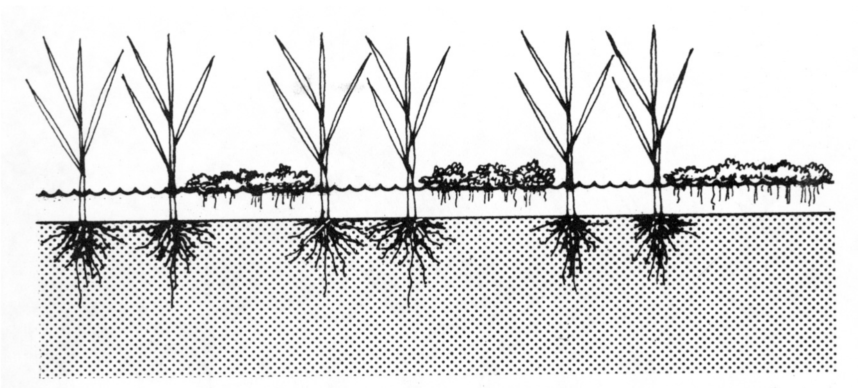
■ In temperate zones, clover, vetch, lupin, or medicago can be grown, following rice in the cool season. After one or two cuttings for forage, the legume is plowed under as green manure.

Rice - azolla



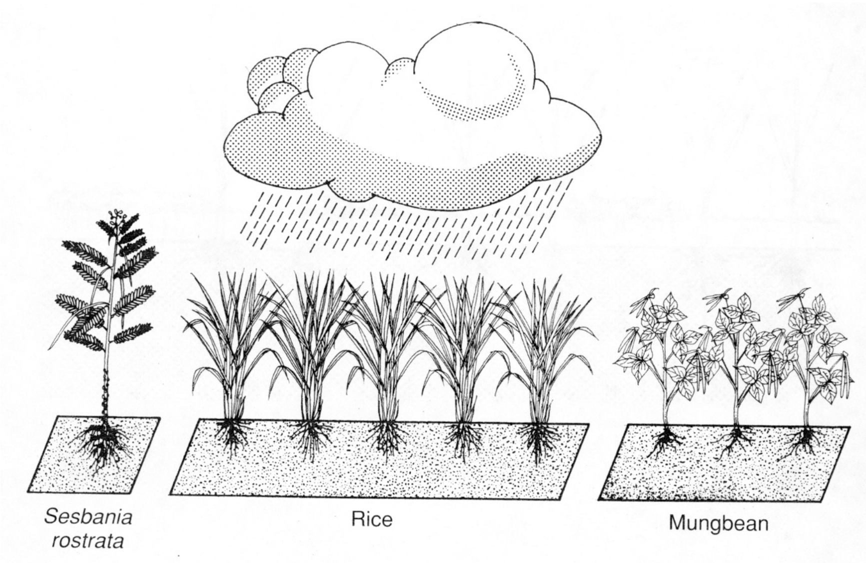
- Azolla is applied basally and then incorporated into the soil before rice planting. It may also be intercropped in standing rice.
- As a topdressing, azolla is applied at 10 to 15 tons of fresh biomass per hectare. Two harvests of azolla provide rice with 40 to 50 kg nitrogen per hectare.

Rice - azolla - rice - azolla



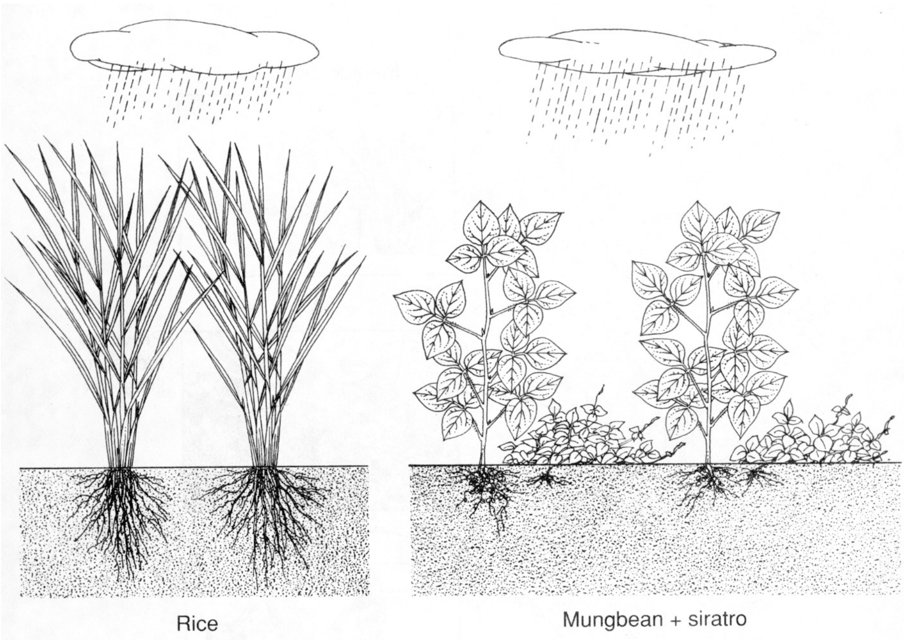
- Large-scale use of azolla requires good water control, adequate soil phosphorus (at least 25 ppm), and insect control.
- High temperature retards azolla growth and, along with high humidity, results in a high incidence of insect pests.

Rainfed lowland rice systems



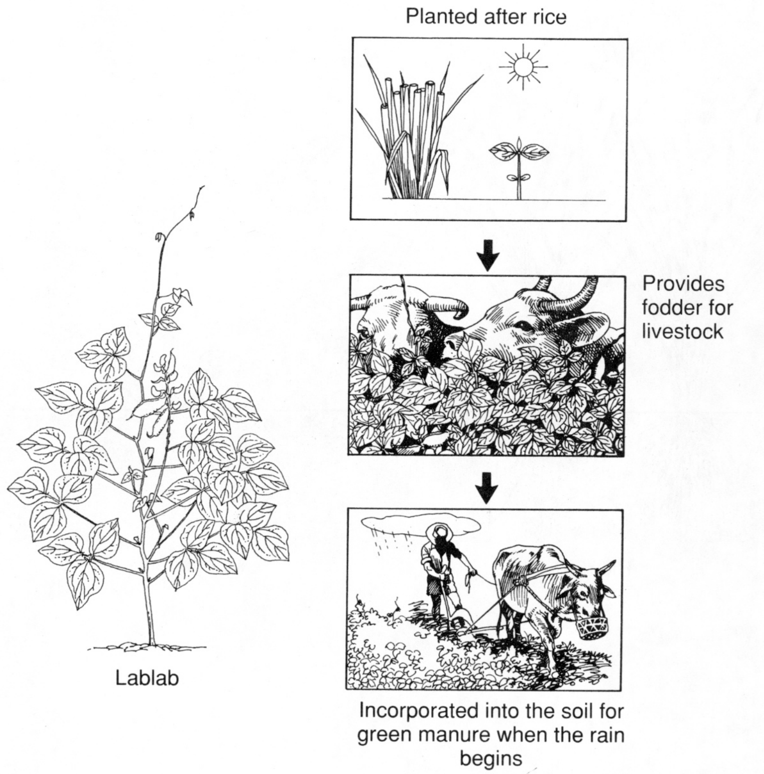
- In rainfed areas, the most important factor to consider in planning a cropping system is rainfall.
- In lowland areas with favorable rainfall, the short-duration grain legume sesbania can be planted at the start of the rains and harvested by the time enough water accumulates for rice. Crop stover is used as green manure for rice. The remaining nutrients are applied through organic wastes and inorganic fertilizer to sustain high productivity.

Rice - grain legume
+ forage legume intercrop



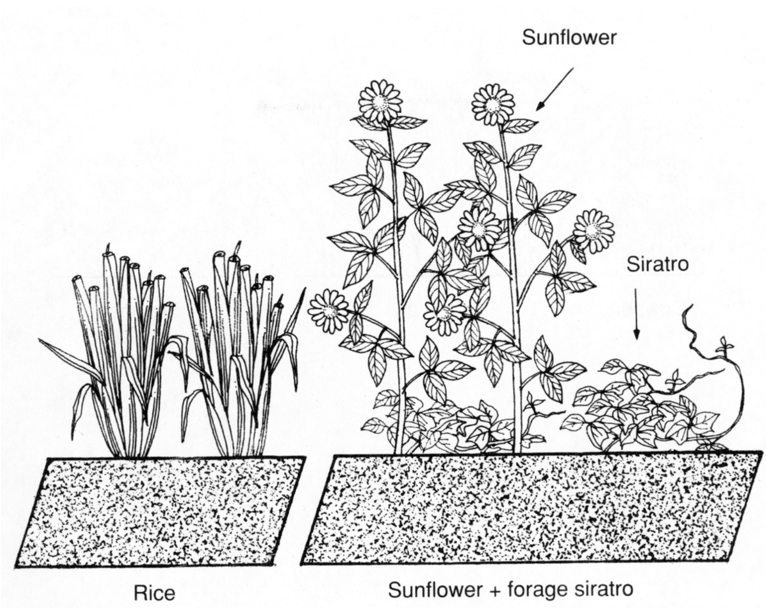
- To make the best use of soil moisture in rainfed areas, two legumes can be Intercropped following a main crop of rice, for example fast-growing mungbean and slow-growing siratro.
- Siratro continues to grow after the mungbean harvest and provide a ground cover and forage. The legumes together can supply 3 to 4 tons of green manure per hectare.

Rice - forage legume



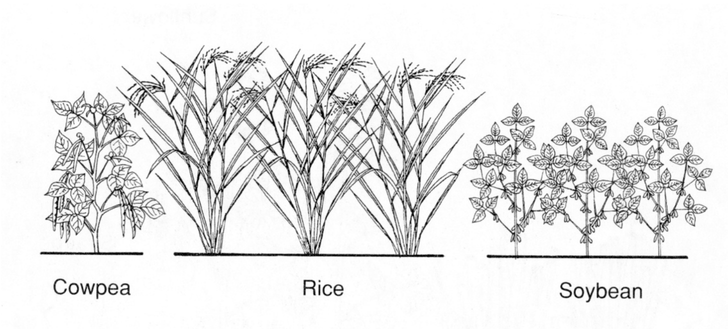
- In areas with a long dry season, drought-tolerant forage legumes such as *Lablab purpureus* should be planted after rice to provide fodder for livestock.
- When the rains begin, the crop is plowed into the soil for green manure.

Rice - oilseed + forage legume intercrop



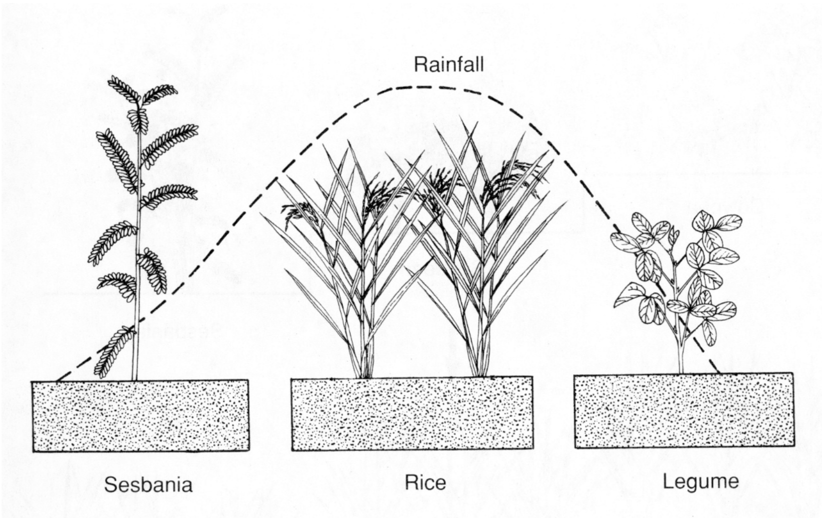
- An oilseed crop such as sunflower can give high returns. To make maximum use of land area and soil moisture, intercrop the oilseed with a forage crop such as siratro, following rice.
- Sunflower grows fast and tall; slow-growing siratro will cover the ground after the sunflower harvest. This combination can give up to 70 kg nitrogen per hectare.

Legume - rice - legume



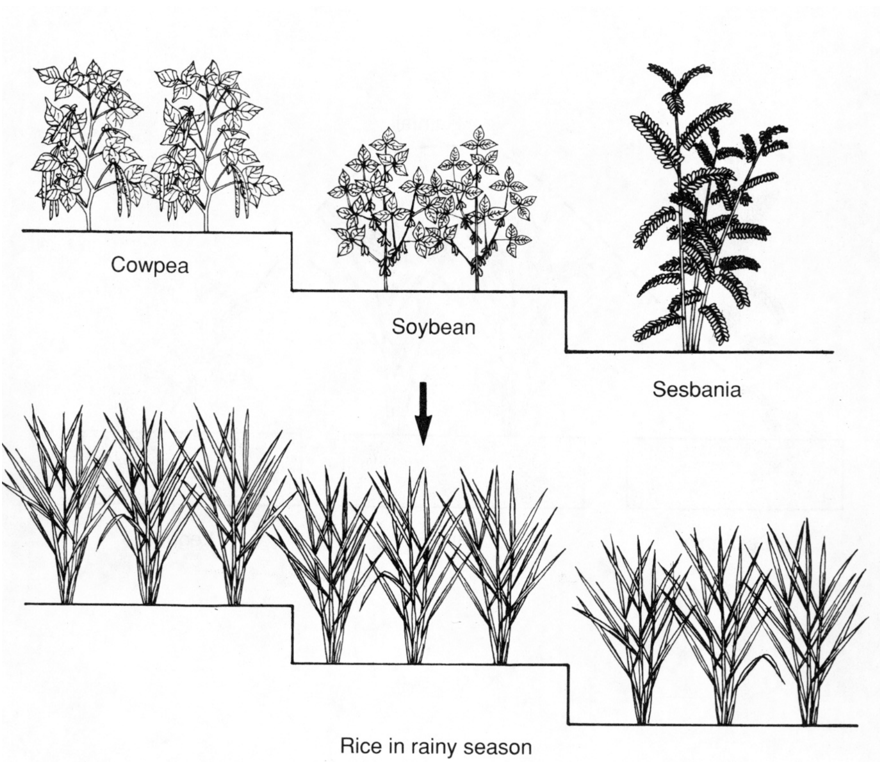
- In areas with good rainfall, legumes can be grown both before and after rice. For example, green pods of short-duration cowpea can be picked two or three times before the crop is turned under for green manure.
- After rice, a grain legume such as mungbean or soybean can again be planted for dry seed and green manure.

Sesbania rostrata - rice - grain legume



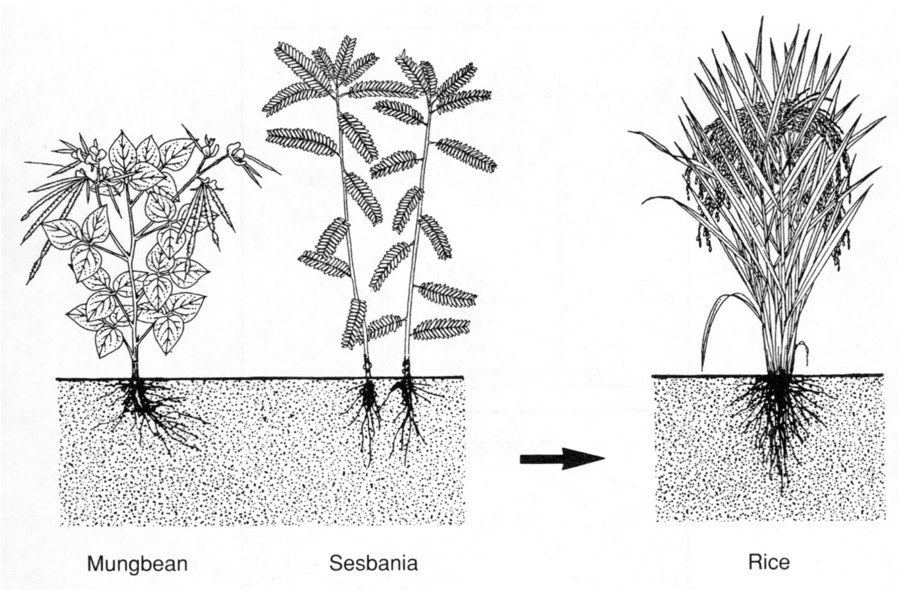
- *Sesbania rostrata* is planted at the start of the rains and plowed under after 45 days.
- After the rice harvest, a grain legume is grown on residual moisture.

Legume - rice



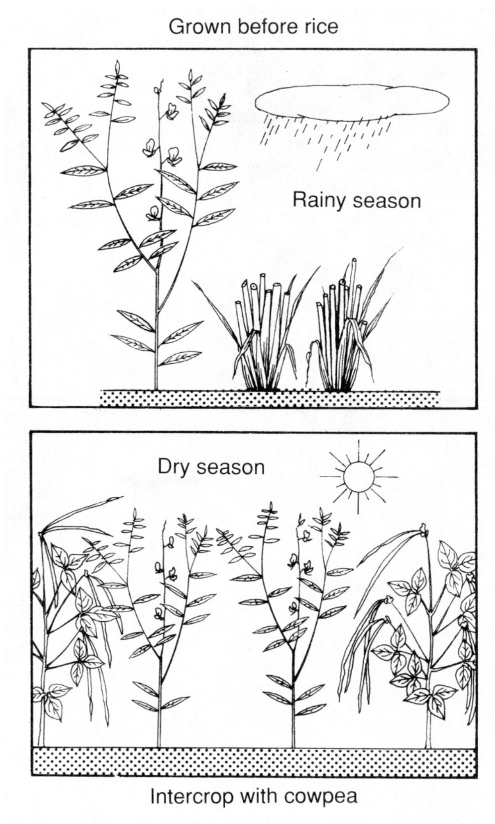
- On sloping landforms, grain legumes are planted in the well-drained areas to provide food, added income, and green manure nitrogen.
- In the lower fields, waterlogging-tolerant legumes are planted for green manure.

Food legume + green manure - rice



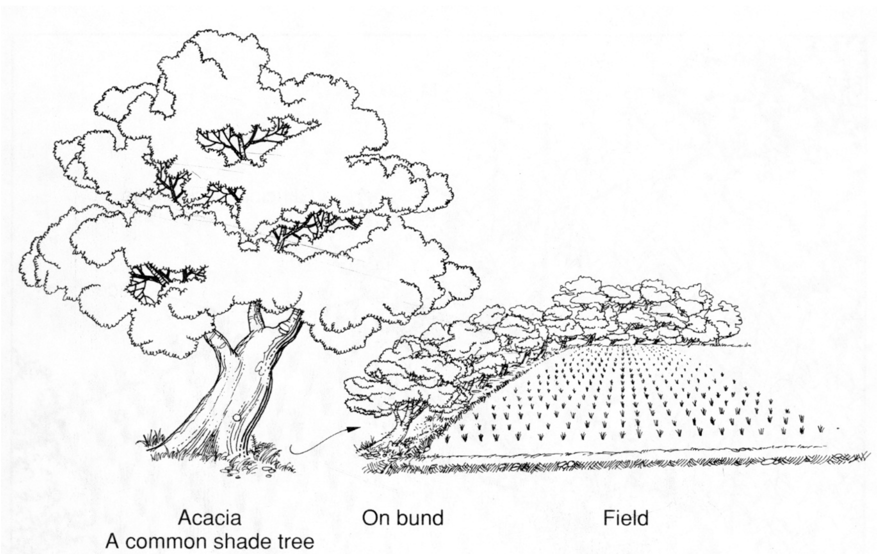
- Where rainfall is erratic, intercropping two legumes reduces the risk of crop failure.
- Interplant *Sesbania rostrata,* which tolerates waterlogging, and a grain legume such as mungbean. If rainfall is very heavy, sesbania will survive and yield about 3 tons green manure per hectare.
- If rainfall is moderate and evenly distributed, mungbean will also thrive and yield up to 600 kg seed per hectare. Mungbean stover provides additional green manure.

Green manure - rice



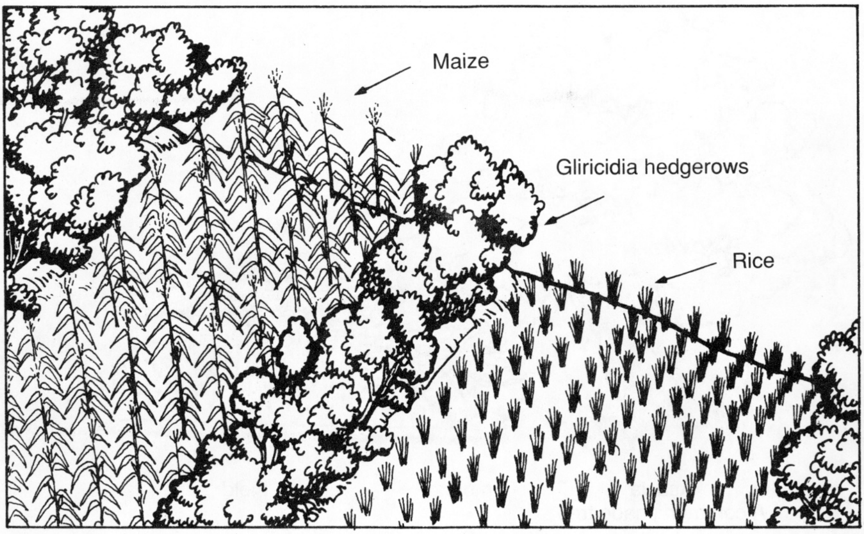
- Sunn hemp *(Crotalaria juncea)* grown before rice will yield 4 to 5 tons green manure per hectare (100 to 120 kg nitrogen).
- It can also be grown after rice, either alone or intercropped with cowpea. Sunn hemp can be cut two or three times for forage in the dry season before being plowed under for green manure.

Bund-grown green manure - rice



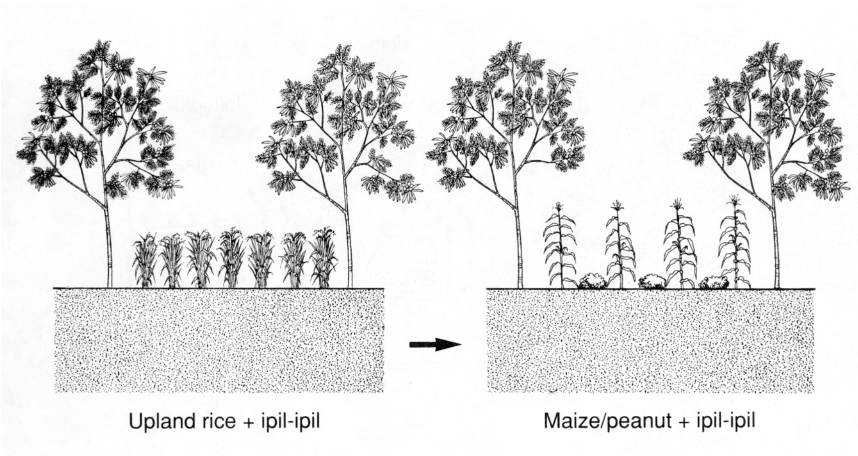
- Annual or perennial shrubs can be grown on field bunds and the biomass incorporated into the ricefield during puddling. This can add 40 to 50 kg nitrogen per hectare.
- Regrowth from perennials can be cut and spread as green leaf manure in the standing rice crop, adding 30 to 40 kg nitrogen per hectare.
- Small trees can also be grown on bunds. Because trees absorb nutrients fromdeep layers *of* the soil, their leaves, when returned to the field, add substantial amounts of nutrients to the soil.

Upland rice systems



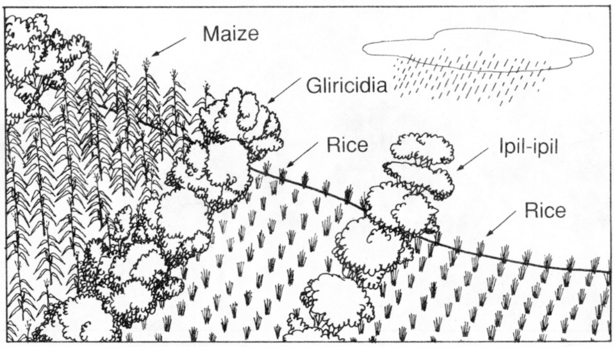
- Upland systems are usually less stable than lowland ones and need carefully planned cropping patterns to sustain their productivity.
- Upland soils are often acid (pH 4.0 to 5.5) and eroded. They can be protected by planting legume cover crops and perennial hedgerows.

Upland rice - cereal + legumes

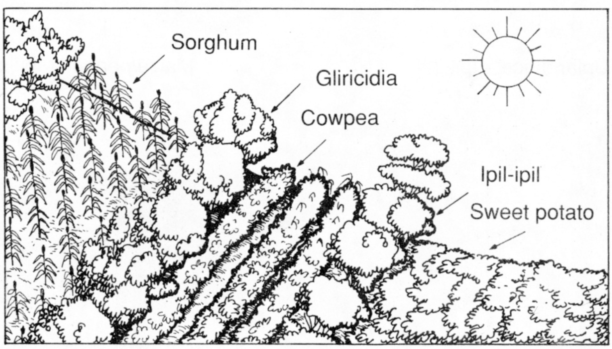


- Upland rice can be followed by another cereal, such as maize, either alone or intercropped with peanut.
- Perennial hedgerows of *Desmanthus virgatus* or *Leucaena leucocephala* are planted for green manure. Green biomass produced during the dry season is incorporated into the soil before rice is planted; that produced during the wet season is used for the following maize crop.

Upland rice - cereal + legume; upland rice - sweet potato



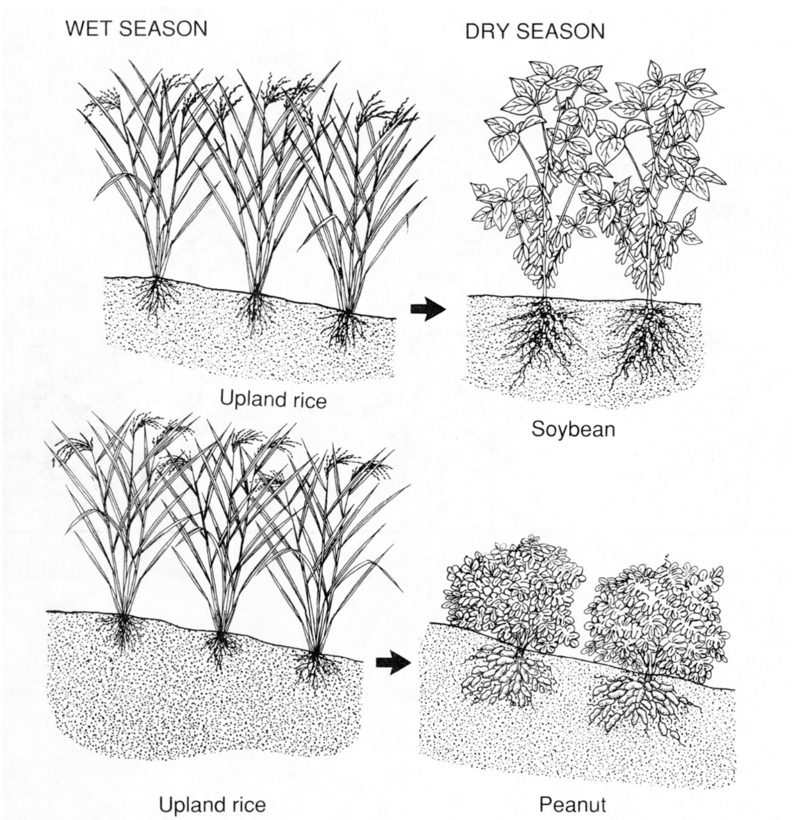
WET SEASON



DRY SEASON

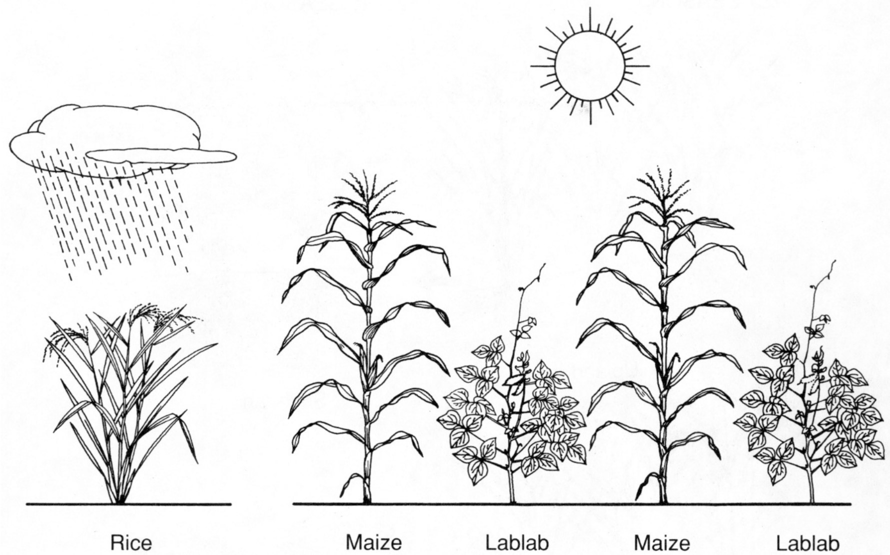
- Perennial hedgerows are also used to provide green manure for other upland systems, for example:
  — rice - sorghum,
  — rice - sorghum + cowpea, or
  — rice - sweet potato
- Hedgerows are made up of shrubs planted about 6 m apart. Calliandra or gliricidia hedgerows can provide up to 4 tons biomass per hectare as green manure for each crop.

Upland rice - peanut



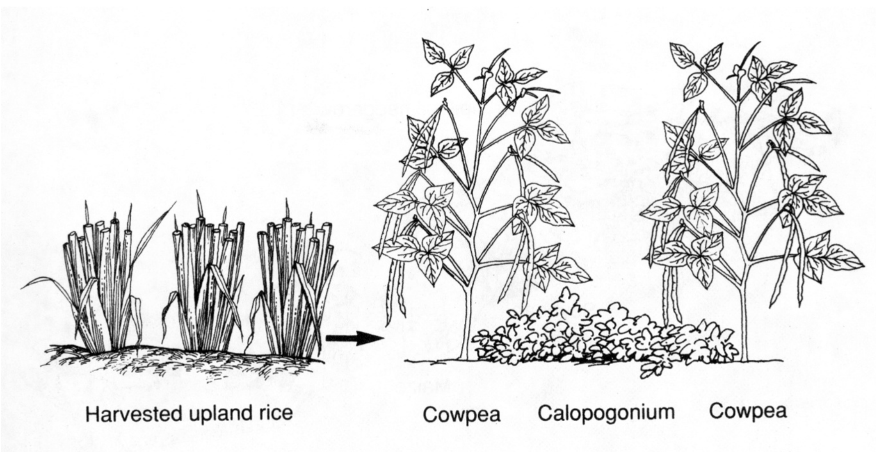
- On flat land with soil pH 5.5 to 6.5, soybean can be planted after upland rice.
- Soybean crop residues, used as mulch, can add 40 to 50 kg nitrogen per hectare for the next rice crop.
- If the soil is more acid (pH 4.0 to 5.5), peanut or cowpea can be grown after rice. Both soybean and peanut are high-value crops and can give farmers substantial extra income.

Rice - maize + lablab



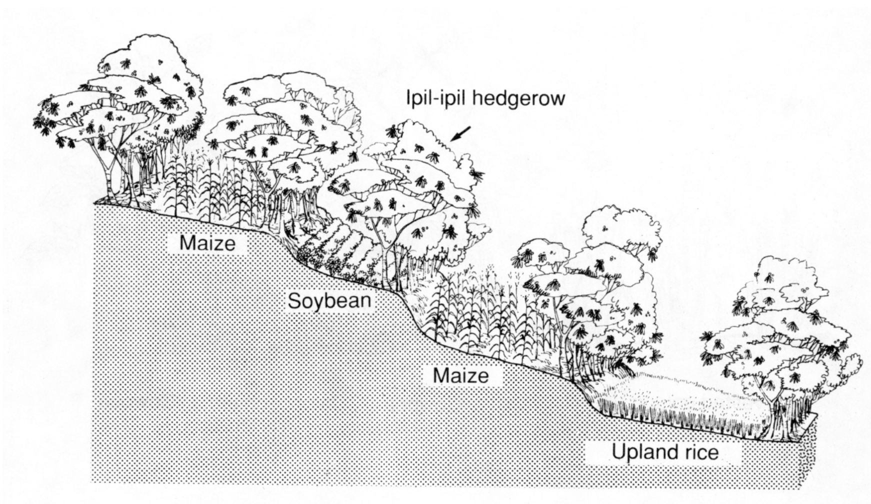
- Upland rice is planted in the rainy season. Maize, intercropped with a cover crop such as lablab, is grown after the rainy season.
- The cover crop can also provide forage in the dry season. During land preparation for the following rice crop, lablab is chopped and plowed into the soil.

Rice - cowpea + calopogonium



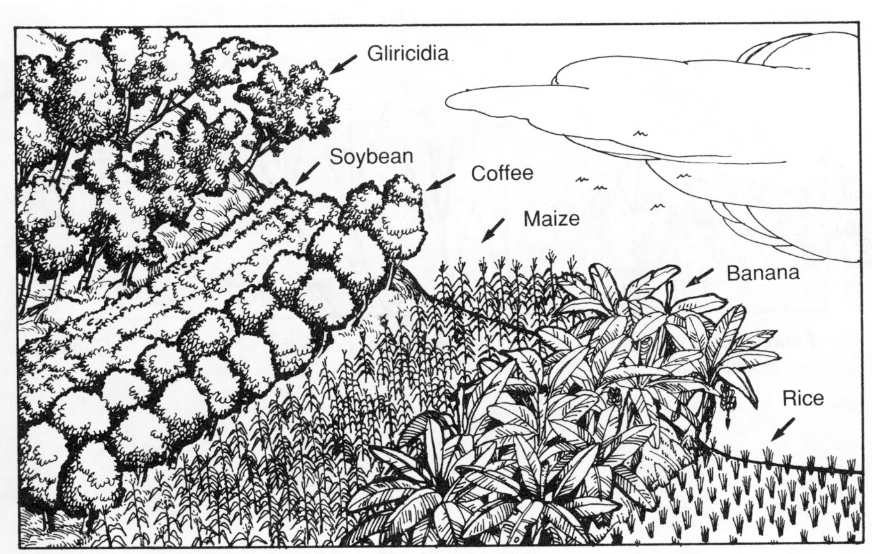
- On eroded acid soil (pH 4.0 to 5.5) after harvest of upland rice, cowpea is intercropped with a slow-growing cover crop such as calopogonium.
- Dry seed of cowpea is harvested. Both cowpea residue and cover crop are plowed under for green manure.

Rice - upland crop



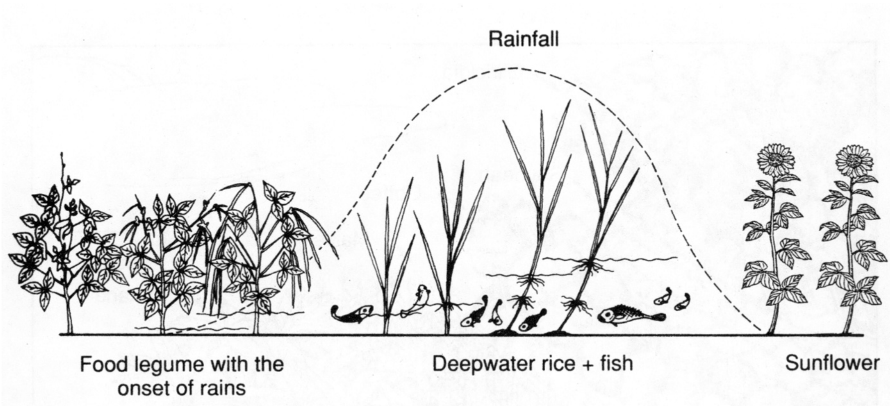
- On rolling upland terrain, terrace farming is practiced to prevent soil erosion. Double hedgerows of small trees or tall shrubs are planted along the edge of each level to hold the soil. These also provide leaf mulch and fuel wood.
- Upland rice is grown on the lowest level. Maize and soybean can be planted on better drained upper levels. Maize, soybean, or peanut can be planted after rice harvest.

Rice - perennial plantation crops



- On steeply sloping terrain, hedgerows of leguminous trees, such as gliricidia, planted in double rows along the contour, can be used instead of rock walls or bunds.
- Trees hold the soil at each level and also provide green leaf manure and mulch that will contribute about 60 to 80 kg nitrogen per hectare.
- Perennial crops, such as banana, coffee, or citrus, are planted every third strip. Maize and soybean are planted on the upper strips. Rice is grown on the lowest levels.

Deepwater rice systems—green manure - deepwater rice



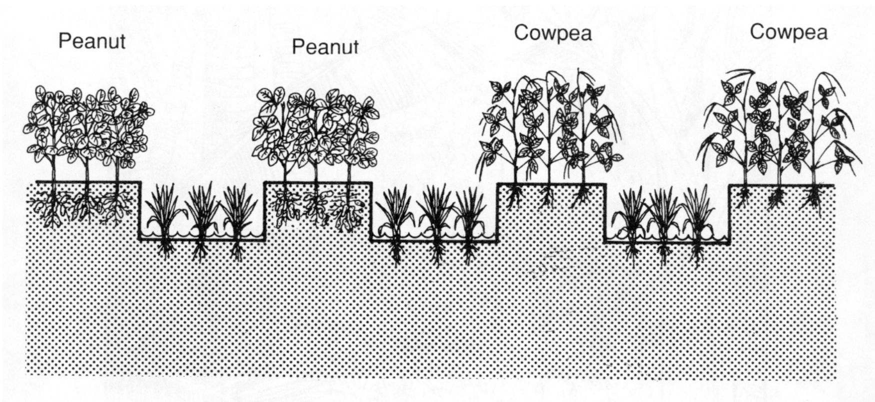
- A green manure crop (cowpea or mungbean) is planted as an intercrop with the onset of rains and harvested before deep water accumulates. The biomass is used as green manure to supply a part of the nitrogen needs of the rice crop.
- A grain legume can also be planted after the water recedes, to grow on residual moisture.
- In some areas, an oilseed such as sunflower can also be planted after the water recedes.

Tidal wetland systems

Coconut/banana + rice

- In tidal wetlands, rice is grown as a strip crop with perennial plantation crops such as banana and coconut, which are high-value cash crops. Crop residues of the plantation crops are returned to the soil for green manure.

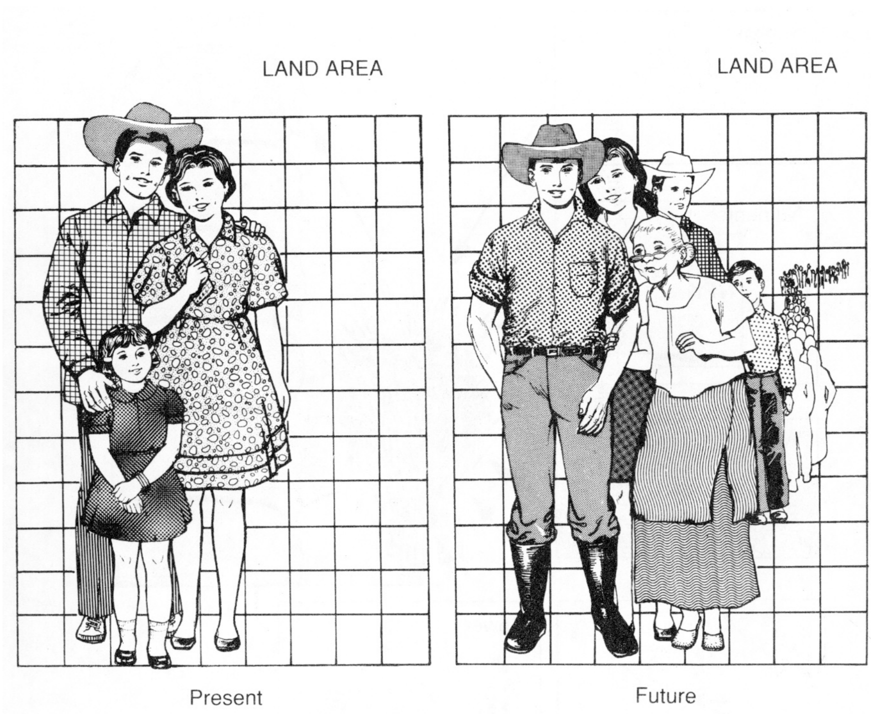
Sorjan farming system for tidal wetlands



- The *sorjan* system practiced in tidal swamps in parts of Asia uses a pattern of raised beds and sunken beds to grow upland crops and rice.
- Peanut, maize, and cowpea are grown on the raised beds and rice in the sunken beds. Legume stover is used as green manure for the rice.

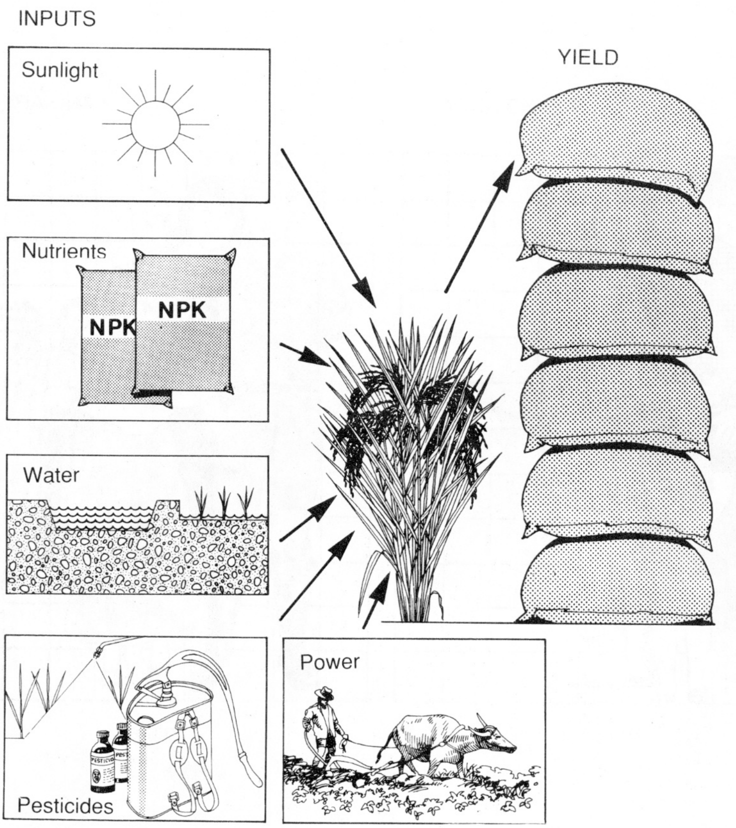
The future

The challenges



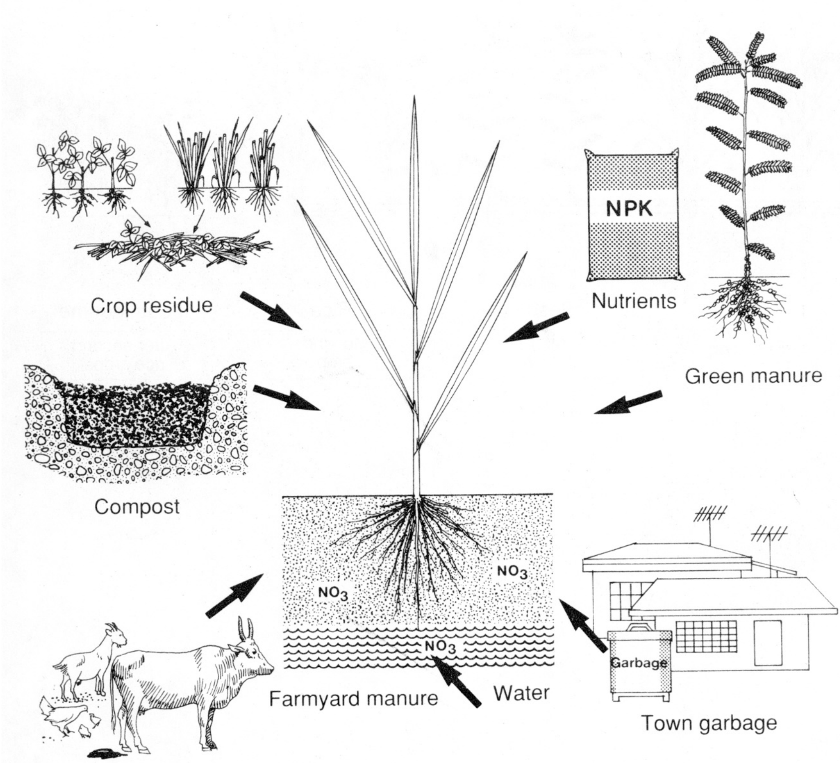
- The biggest challenge for rice farmers in the coming years will be to produce more food from less land.
- As cities and towns spread out, the area of farmlands is shrinking. At the same time, because the world's population is Increasing, there are more people to be fed every year.
- The question then is how to increase yields.

Increasing yields



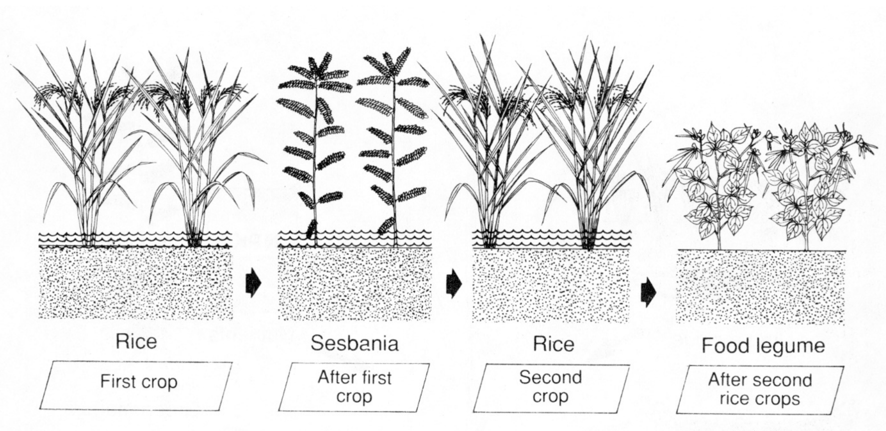
- Top yields can be obtained when all inputs for the rice crop are supplied in the right amounts.
- Water, soil nutrients, and power must be supplied. Weeds, insect pests, and diseases must be suppressed.
- An optimal supply of nutrients can come from a balanced use of organic wastes, green manure, and commercial inorganic fertilizer.

Ecologically sustainable productivity



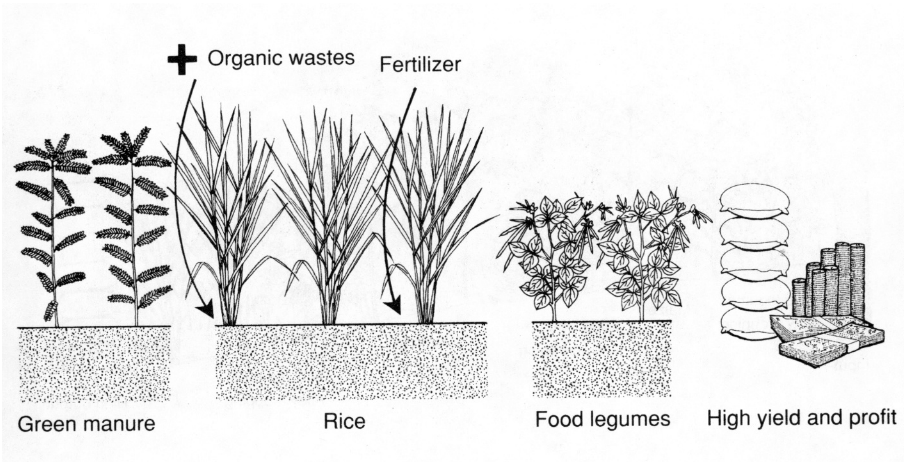
- Top yields, however, must not be obtained at the expense of the environment.
- Overuse of chemical inputs endangers soil and water. Continuously growing a single crop such as rice exhausts particular nutrients in the soil.
- Here again, balanced use of nutrients from organic and inorganic sources will promote sustainable productivity.

Irrigated areas



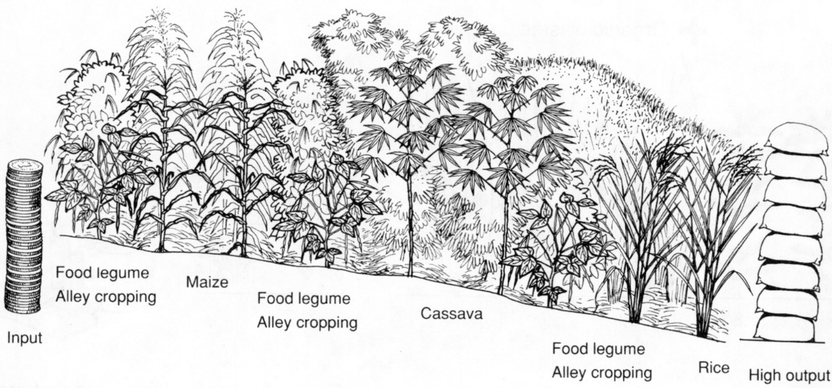
- Intensive cropping, or growing two or three crops a year, is usual in irrigated areas. This demands a large cash outlay for purchased inputs.
- To increase profits from such a system, a quick-growing legume should be planted between rice crops to supply nitrogen for rice and to reduce rice pests and diseases.
- After harvest of the second crop of rice, a high-value food legume can be planted for added income.

Rainfed lowland areas



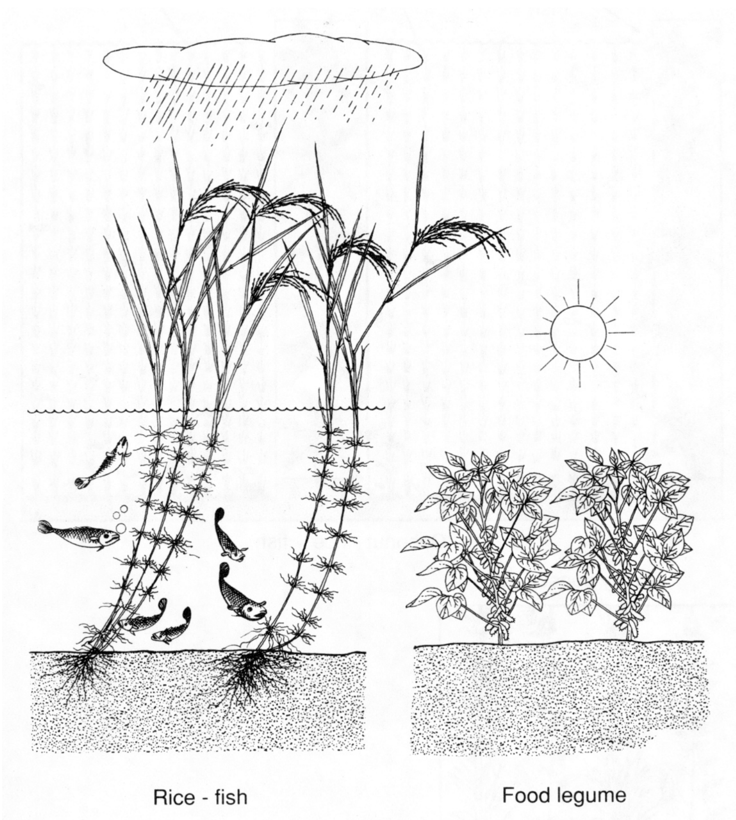
- Variable water supply and low nutrient input often limit productivity in rainfed lowland areas.
- Green manure crops can contribute substantially to maintaining soil fertility in rainfed lowlands and help increase cropping intensity.

Upland areas



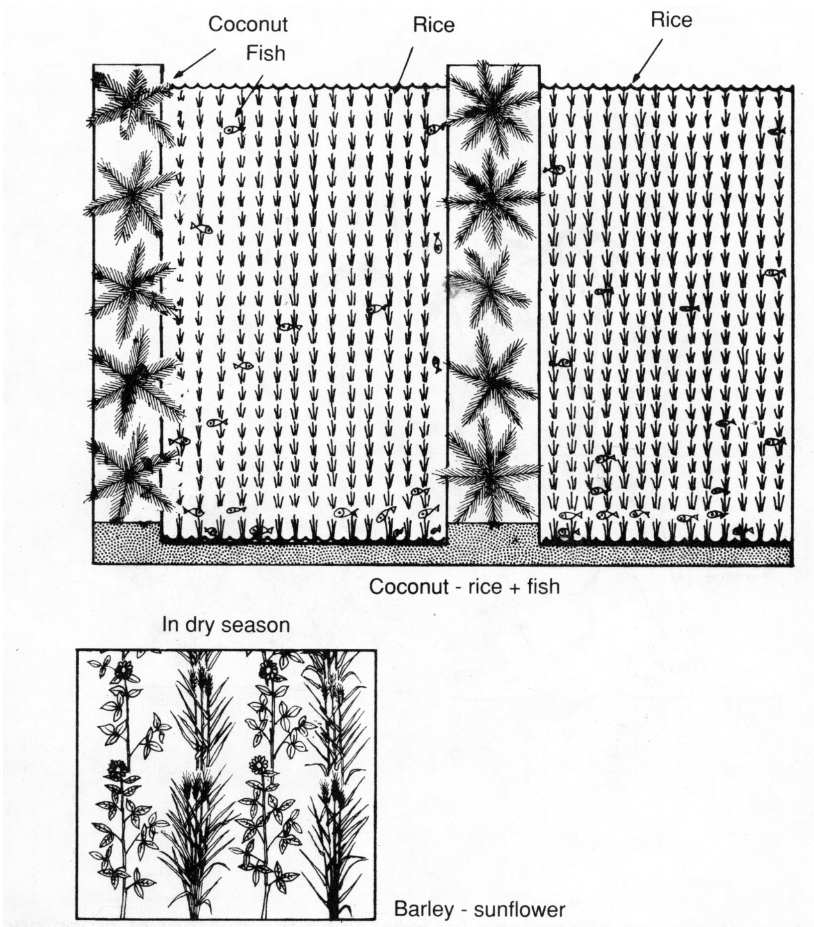
- Sustaining high rice yields and productive farming systems will require carefully planned land use, and balancing of crops, livestock, and agroforestry in upland areas.
- Alley cropping, with two or three rows of perennial legumes planted at intervals and field crops grown in between, offers great scope in upland farming.
- Proper management of upland soil will increase its carrying capacity and sustain the system over time.

Deepwater rice areas



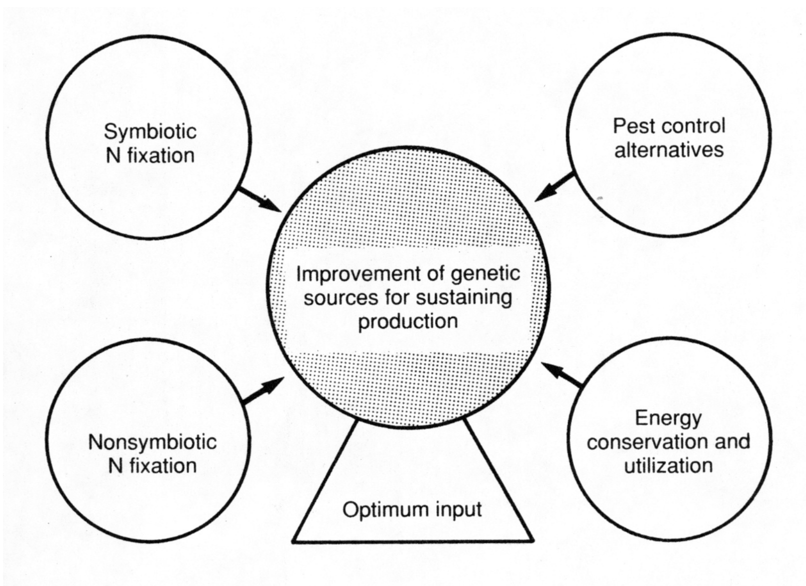
- Deepwater areas offer scope for increasing the number of crops per year. However, cropping systems need to be carefully planned to use land effectively before and after the rice crop.
- To use natural resources to the fullest, other enterprises such as aquaculture should also be explored.

Tidal wetland areas



- In tidal wetlands, where water is available and temperatures are favorable, two rice crops may be possible.
- Aquaculture can also be practiced in some areas.
- Where water recedes and soil dries out, salt-tolerant upland crops such as barley and sunflower could be grown instead of a second crop of rice.

Cost-reducing technology



- Advances in plant breeding are likely to produce new cultivars for a wide range of growing conditions.
- Development of other cost-reducing technologies will make rice farming more profitable.