Intercropping of Annual Foodcrops

Agrobrief

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Maintaining soil fertility is often one of the main challenges in agricultural production. Intercropping is one of the options available to maintain soil fertility and crop yields. Other benefits of intercropping are risk spreading, weed control and the decrease of pest and disease incidence. In this Agrobrief, advantages and disadvantages of intercropping are discussed. Examples of intercropping systems in all parts of the world and practical implementations are presented for farmers who would like to start experimenting with intercropping. Growing (fodder) trees in association with annual food crops and agroforestry are other ways to maintain agricultural production in a sustainable manner. For these topics you are referred to the Agrobrief 'Fodder Trees' and the Agrodok 'Agroforestry', also available from Agromisa Foundation.

1. Why intercropping?

Definition

Intercropping is '*the cultivation of two or more crops at the same time in the same field*'. A wide range of crops can be used for intercropping. In Cuba, for example, farmers use 'traditional' crop associations such as maize-bean and maize-pumpkin, but also less usual combinations, such as maize-tomato.

Biodiversity and stability

Intercropping is a way to increase the diversity of the farming system. More diversity in the farming system generally means more stability, resulting in risk spreading and reduced pest and disease incidence.

Increased yields

When two or more crops with different rooting systems, a different pattern of water and nutrient demand, and a different above-ground habit are planted together, water, nutrients and sunlight are used more efficiently. Therefore, the combined yields of two crops grown as intercrops can be higher than the yield of the same crops grown as pure stand.

Crop arrangements:

- Strip intercropping: growing two or more crops in strips, wide enough to permit independent cultivation, but narrow enough for the crops to interact.
- Row intercropping: growing two or more crops in well-defined rows.
- Mixed intercropping: growing two or more crops together in no distinct row arrangement.
- Relay intercropping: planting a second crop into a standing crop at a time when the standing crop is at its reproductive stage but before harvesting (see figure 1).

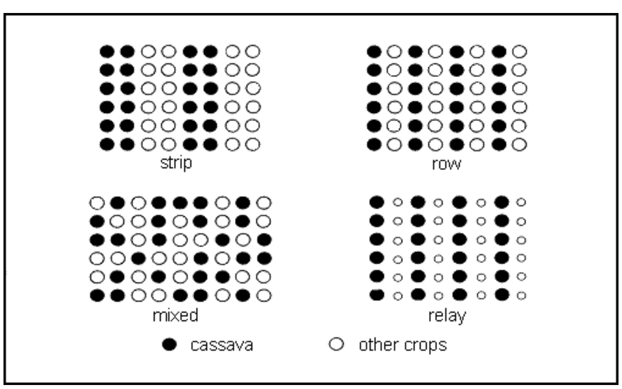


Figure 1. Example of crop arrangements

2. Soil fertility

Nutrients

All plants need water and nutrients ('plant food') to grow and to produce a yield. Most of the water and nutrients a plant needs is taken up from the soil. If there is a lack of water and/or nutrients, crops do not grow well and produce low yields. An important nutrient for crop growth is nitrogen. A lack of nitrogen in crops can be recognized by the light green colour of the leaves and results in low yields.

Nitrogen fixation

If the right bacteria are present in the soil, pulse crops can fix nitrogen gas from the air in pores in the soil, thereby reducing the need for nitrogen from manure or (synthetic) fertiliser.

An important reason for intercropping is the improvement and maintenance of soil fertility. This is reached when a cereal crop (such as maize or sorghum) or a tuber crop (such as cassava) is grown in association with a pulse (beans, peas, etc). Pulses (also called 'legumes') are a protein rich source of food. Some pulse crops provide oil and may be important as cash crop, e.g. peanut (Arachis hypogaea) and soybean (Glycine max). Leaves and immature pods of cowpea (Vigna unguiculata) and common bean (Phaseolus vulgaris) can be eaten as a vegetable. See Table 1 for more examples of pulse crops in tropical climates.

Deep-rooting pulse crops, such as pigeon pea, also take up nutrients from deeper soil layers; thereby recycle nutrients leached from the surface. Legumes also grow well in soils low in phosphate.
After the intercrop is harvested, decaying roots and fallen leaves provide nitrogen and other nutrients for the next crop. This 'residual effect' of the pulse crop on the next crop is largest when the remains of the pulse are left on the field and ploughed under after harvest. However, when a large amount of nitrogen is removed in the grain harvest, more nitrogen is removed from the field than fixed by the pulse crop. Thus soil depletion can still occur in a grain-pulse intercrop when the nutrients taken up by the crops are not replaced with manure or fertilisers (Giller, 2001).

Fodder and manure

The crop residues of the pulse crop can also be used as fodder, by cutting and carrying them to the animals, or by letting the animals graze the residues in the field. The nutrients in the crop residues can then be recycled when manure is used to fertilise crops. Animal manure improves soil fertility through supply of nutrients and soil structure, as it increases the amount of humus in the soil. It should be spread evenly over the field, whether the manure is left on the field during grazing or collected from the stable and applied later.

Humus and organic matter

Organic matter in the soil consists of *fresh organic material* (plant and animal waste) and *humus* (decomposed organic material). Fresh organic material provides nutrients to the soil. Humus helps to improve soil structure and soil fertility. It has a great capacity to hold nutrients and water. A soil with a lot of humus is dark in color.

Soil cover

Pulse crops in an intercropping system do not only provide a source of nitrogen and other nutrients to the associated crops, but also increase the amount of humus in the soil, due to decaying crop remains. This results in an improved soil structure, reducing the need for soil tillage. Water losses, soil erosion and leaching of nutrients are also reduced in intercropping systems, due to the improved soil structure and because of a better soil cover, especially when creeping pulse crops are used. With a good soil cover, the impact of rain drops on disruption of the soil is reduced. In relay-intercropping, the pulse crop is planted some time after the main crop and continues growing after harvest of the main crop. This results in a more efficient use of soil water and prevents leaching and erosion, as the soil is still covered after harvest of the main crop.

Table 1 Tropical grain legumes

Scientific name	English name	Climate/water requirements/temperature	Soil
Arachis hypogaea	groundnut, peanut	250-650 mm in 3-4 months or 650-1300 mm in 4-5 months; cannot tolerate too much water; 20°-35°C	Light sandy soil with sufficient nutrients for pods which grow under the ground
Cajanus cajan	pigeon pea, congo pea, red gram	800-1000 mm; 20°-40°C	Only legume on this list that can tolerate slightly saline (salty) soils
Cicer arietinum	chickpea, gram, Bengal gram	Demanding in terms of requirements: sufficient water during vegetative growth; will not tolerate heavy rainfall during flowering period; 15°-30°C	Grows on light soils and on well-drained heavier soils. Requires a pH of 6-9, cannot tolerate saline or acid soils
Glycine max	soybean, soyabean	700-1000 mm; 20°-30°C	Grows well on heavier soils that are well drained. Cannot tolerate saline or alkaline soils
Lablab purpureus	butterbean, hyacinth bean	600-900 mm drought resistant, better than soya or *Phaseolus sp.*	
Lens culinaris	lentil, gram	800-2000 mm ; 20°-30°C	
Phaseolus lunatus	butterbean, lima bean	700-1000 mm	
Phaseolus vulgaris	garden bean, kidney bean, haricot, common bean	700-1000 mm; cannot tolerate too much water; 10°-30°C Higher altitudes in tropics	Loamy soil, reasonably fertile, pH 5.0-7.5 crumbly soil structure important for a good yield.
Pisum sativum	pea	500-800 mm; 10°-30°C survives frost	pH 5.5-6.8, can tolerate somewhat saline soils. Requires a well-prepared soil with crumbly structure and good drainage.
Vigna unguiculata	cowpea, black-eyed pea	600-900 mm; 20°-35°C	
	bambara groundnut	Dry, Sahel; cannot tolerate too much water	Light sandy soil with sufficient nutrients, because beans grow underground

Inorganic fertilisers

In intercropping, nitrogen fixation by the legume is not enough to maintain soil fertility. If chemical fertilizers are applied, it is however not necessary to use a nitrogen fertiliser on the legume, N-fertilisers should be targeted on the cereal crop. A basal fertiliser is generally needed for both the cereal and the legume. Fertilisers are more efficiently used in an intercropping system, due to the increased amount of humus and the different rooting systems of the crops, as well as differences in the amount of nutrients taken up.

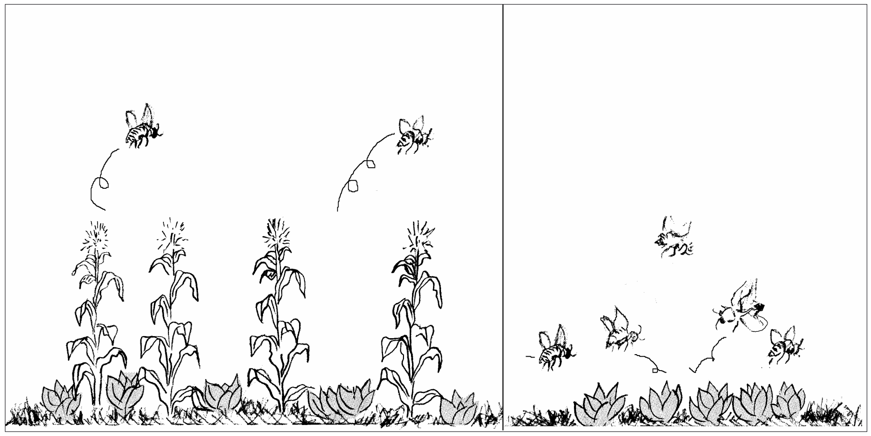
Risk spreading and food security

When two or more crops are grown on the same field, the risk for crop failure is spread over the different crops as the different crops have different periods and patterns of growth, and are affected by different diseases. If one of the crops fails (due to drought, pests or diseases), there still is a harvest from the other crops. This increases food security. In good years, the yield of two crops grown on the same field as an intercrop is often higher than the yield of the same crops grown separately.

Weed control

In an intercropping system, weeds are often more easily controlled. For example in a maize-bean intercrop, the bean covers the soil, preventing weeds to grow. On the other hand, weeding can also be more complicated in an intercrop.

Pest and disease control



Pests and diseases often are less abundant in intercrops. There are different ways to explain this. If the pest or disease has a specific host, it does not spread as easily through an intercrop as it does in a monocrop. Insects or other pests can also be mislead by the canopy of an intercrop and not recognize the specific crop they use as a host. Substances that other crops produce may drive insects away from the main crop or natural enemies of insects may be attracted by one of the crops in the intercrop. In some cases, diseases and pests may also be stimulated by the intercrop, for example diseases or pests that prosper in shady conditions. Therefore, try it out on a small scale first.

Microclimate

When the intercrop provides a good soil cover, soil temperature will stay relatively low. This prevents burning of the organic matter in the soil and loss of nutrients. It also provides a micro-climate that can be favourable for associated crops.

Physical support

In a maize-bean intercrop, climbing beans can use the maize stalks for support.

Figure 2. Maize-bean intercrop

Tomato and maize intercrop in Cuba

Tomato was a typical monocrop in Cuba before 1989. Tomato requires a combination of temperature, solar radiation and relative humidity. Producing tomatoes out of season is lucrative. The solution was found in using maize as natural shade for tomato, and thus modifying the micro-environment favoring tomato production off-season. The most productive spatial arrangement was found to be three rows of tomato planted between two rows of maize. Maize was sown 30 days before tomato was transplanted. Every row was oriented from north to south.

This spatial arrangement led to a reduction of the radiation intensity by about 25% and a temperature decrease of approximately 3°C. Yields of tomatoes produced under maize shade increased by 5-6 tonnes/ha in comparison with tomatoes grown as a monocrop. In the tomato-maize intercrop, adult white fly presence and virus infections were decreased and fruit quality was better. The most important advantage of the tomato-maize intercrop is the possibility for farmers to sell fresh tomatoes off-season and thereby increase income.

3. Potential problems with intercropping

Competition

Depending on the crops intercropped, competition for water, light and nutrients may result in lower yields. Changes in the spatial arrangement of the crops will reduce the competition. A larger distance between plants reduces root competition for water. Light competition can be reduced by an arrangement as in the 'MBILI' system (p. 7).

Mechanisation

When machines are used for weeding or harvesting, intercropping can be difficult. However, strip intercropping is a useful alternative to mixed or row intercropping.

Labour

Labour requirements of an intercropping system may be higher than in sole cropping, as two or more different crops are planted at the same time or shortly after one another. On the other hand, labour requirements may also be less in an intercropping system, for example due to a reduction of weeding requirements, when weeds are suppressed by the intercrop. If sowing and harvesting periods of the different crops vary, it is easier to spread the available labour over the entire season, avoiding high peaks of labour.

4. How to start intercropping

When two or more crops are cultivated in an intercropping system, each crop should have adequate space, to maximize cooperation and minimize competition between them. To accomplish this, attention should be paid to the specific local conditions (climate), the choice of crops, the arrangement of crops in space and time, the plant density, maturity dates of the different crops and plant architecture.

Climate

The best design of an intercropping system depends on the specific local conditions and the climate (Table 2).

Table 2. Intercropping: advantages, crops and risks under different climatic conditions

	Humid	*Sub-humid*	*Semi-arid and savannah*
Climate	*Rains throughout the year*	*(Distinguished) (Pronounced?) dry periods*	*Very short rainy season*
Advantages of intercropping	*Prevention of leaching and erosion through constant soil cover*	*Better utilization of water and nutrients; erosion prevention; risk spreading*	*Risk spreading; nitrogen fixation (with leguminous intercrop)*
What kind of crops	*Soil covering intercrop or green manure cover crop*	*Intercropping with many different crops possible; green manure on fallow fields*	*Intercropping with deep rooting crops and low water demand*
Risks		*Competition for water and nutrients*	*Competition for water*
Risk prevention		*Sufficient space between plants*	*Sufficient space between plants*

Crop choice

Almost any type of crop or combination of crops can be used for intercropping. Choose crops that are locally grown and well-adapted to the climatic conditions. Seeds or other plant material can be obtained from other farmers, on local markets or from specialized seed producers. Consider including a pulse crop in the intercrop, as pulses fix nitrogen and help to improve soil fertility and soil structure

Plant densities

When two or more crops are combined in a field, plant densities need to be adapted to maximise yields. The individual crops should not be planted at the same density as usual in a sole crop, as the crop densities would be too high and yields of both crops would be reduced. The best way to find out what the optimal plant densities are, is to experiment with different seeding rates. In an intercrop with two crops, experiment with 3 small plots with each crop at different percentages of the normally recommended planting rates: 1/3 + 2/3, ½ + ½ and 2/3 + 1/3. From there, make adjustments for future plantings, based on the results of the experiment.

Planting and maturity dates

In intercropping systems, it is an advantage if the different crops in the mixture have different maturity dates, with different times of peak demand for nutrients, water and sunlight, thereby reducing competition. In a sorghum-pigeon pea intercrop, as is common in India, the sorghum matures in about four months. After harvest of the sorghum, the pigeon pea flowers and ripens. The slow-growing pigeon pea, therefore, does not affect the sorghum yield. Another aspect of the timing of the sowing dates of nitrogen-fixing legumes is the release of nitrogen from crop remains after harvest. If the nitrogen-fixing crop matures and is harvested first, then the added nitrogen and phosphate already become partially available to the other crop. If it matures after the other crop, then the nitrogen and phosphate will be available to the subsequent crop. Adaptations in the planting dates of the different plants in an intercrop can help to reduce competition and to maximise yields.

Plant architecture

Different crops may have a different architecture, i.e. height and width of the plant. In designing an intercropping system, it is useful to pay attention to differences in plant architecture between the crops in the mixture. In a maize-groundnut intercrop for example, the tall maize crop should be planted in rows far enough apart to allow sunlight to reach the smaller groundnut plants.

Crop arrangements (see figure 1)

Crop arrangement refers to the way the crops are sown in the field. Crops can be sown in rows, in strips, mixed or otherwise. All different crops can be sown at the same time, or one later than the other (relay intercropping).

When crops are planted in rows, the interaction between the crops is maximised. A maize-bean intercrop, for example, can be planted in rows with a row of maize alternated with a row of beans, or two-by-two, as in the MBILI system (see example 1, p.7). This allows more light to penetrate and reach the beans or other small crops. On level land, the rows should run in east-west direction, allowing the morning and afternoon sun to reach the beans. On sloping land, however, rows should be planted on the contour, to prevent soil erosion.

Strip intercropping generally makes it easier to harvest the crops, especially when machines are used for the harvest. However, the interaction between the crops is less than in row intercropping.

Mixed intercropping is often found in home gardens, where many different crops are planted in a mixture, without a specific pattern. It is also useful when a mixture of grains is sown at the same time on the same field. When the grains are ripe at the same time, they can be harvested together and used as a mixture. In semi-arid regions in Africa, for example, sorghum, millet and maize can be planted as a mixture.

Relay intercropping is possible and useful when the growing season is long enough to grow two crops, or when there are two growing seasons. In a maize-bean intercrop, for example, the maize is planted first and when it is established, the bean is sown in between the maize. After the maize harvest, the bean continues growing and may use the maize as stakes. In relay intercropping, the soil moisture is used very efficiently and the soil is covered for a longer period, preventing nutrient losses and erosion. Competition for water and nutrients is also less. In Figures 3 and 4 some examples of spatial arrangements in an intercropping system are illustrated.

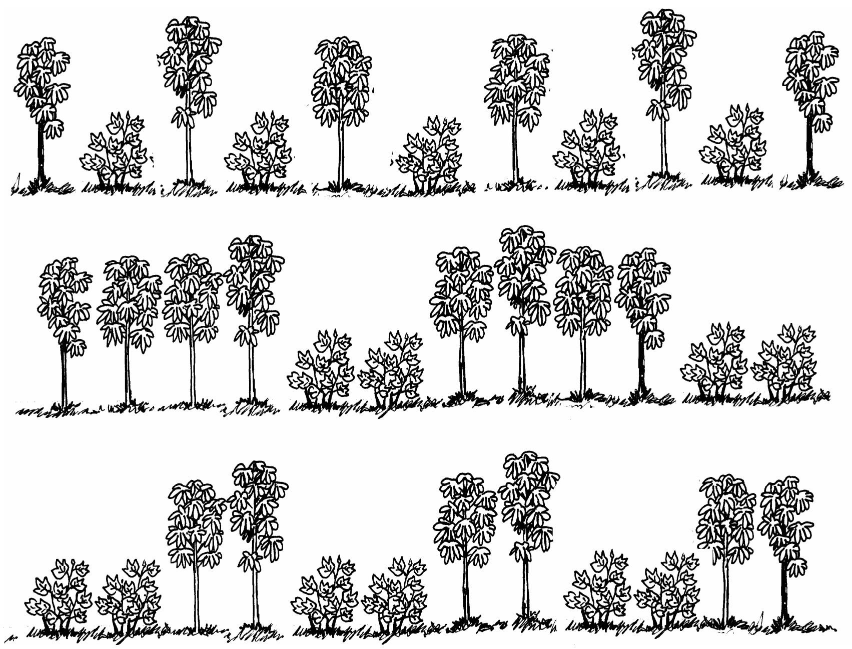


Figure 3. Examples of row intercropping of cassava and other crops.

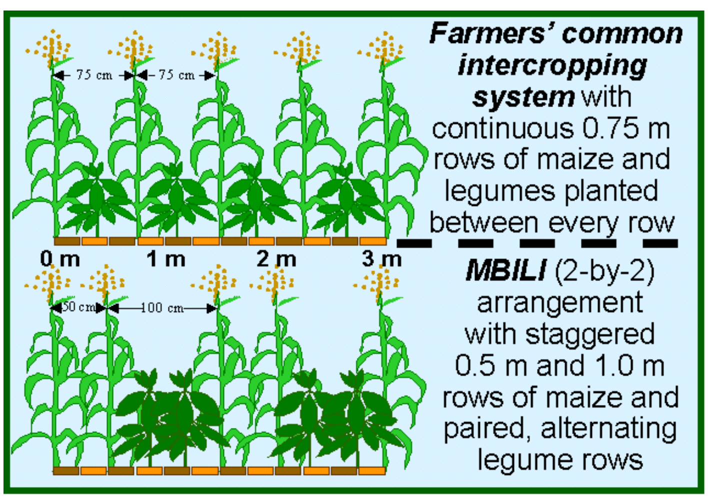
Figure 4. Strip intercropping

5. Examples of intercropping systems

5.1 Africa

Kenya: 'MBILI is number 1' – maize/legume intercropping
Farmers in Kenya have planted maize with beans as an intercropping for many years. This allowed them to produce crops for both household food supply and, during better years, for sale. But the yields of maize and beans on most farms declined due to nutrient depletion and pest and disease accumulation resulting from continuous maize-bean intercropping. Even during the best years, it was difficult to get a profit because the price of maize and beans was too low to offset the cost of inputs. Rotation of beans with other legumes would reduce the pest and disease incidence and improve soil fertility, but the maize canopy (especially of large-stature, long-maturing varieties) does not allow sufficient light for intercropping with groundnut, green gram (also known as mung bean (Vigna radiata)[not in list]) or soybean. The Sustainable Agriculture Centre for Research Extension and Development in Africa (SACRED Africa) worked closely with farmers to develop an innovative intercropping system that is designed to overcome these problems and produce a marketable yield. Reorganizing the arrangement of the rows of maize (see Figure 4) and intercropping with different legumes improved yields and increased farm incomes. The key was to stagger the rows of maize, while maintaining the same crop population, allowing for greater light penetration to the understorey legume. Due to the increased light penetration, other legumes than bean could be combined with maize in an intercropping system. Growing different legumes in intercrop rotations resulted in healthier crops, through the disruption of pest and disease cycles. Both farmers and researchers found out that the rotation intercropping system not only improved the production of the legumes, but also of maize.

Figure 5. Crop arrangement in the common system and the MBILI intercropping system



This project is called 'Managing Beneficial Interactions in Legume Intercrops', or MBILI. Mbili is also the Kiswahili word for two, referring to the arrangement of the maize-legume intercrop: in two-by-two staggered rows, instead of alternating rows of maize and legumes, as is the conventional recommendation. Legumes that are used in the MBILI maize-legume intercrop are common bean (Phaseolus vulgaris), green gram (Vigna radiata), groundnut (Arachis hypogaea) and soybean (Glycine max). The MBILI system also resulted in greater returns to fertilizer inputs and provides food security when the maize crop fails due to drought.
The MBILI system can be modified and adapted to specific circumstances or needs of farmers. The rows of maize or legumes can be planted closer together or further apart, resulting in wider or smaller gaps for the legumes. It is also possible (depending on the climate) to grow more than one legume or maize crop in one season. (Source: Sacred Africa, 2002.)

5.2 Central-America

Cuba: intercropping for food security

Until 1989, the agricultural system of Cuba was characterized by its dependency on foreign external inputs, although in some parts of the country traditional agriculture still played a dominant role. After the collapse of the socialist countries in 1989, the share of monoculture-based agriculture diminished drastically. The use of fuel, chemical fertilizers and pesticides reduced to a very low level. Traditional crop associations, such as maize-bean and maize-pumpkin that had been used before by small farmers, became a common practice in large areas. At the same time, unusual crop combinations, such as carrot-cabbage, lettuce-cabbage, carrot-garlic, tomato-beans, sweet potato-pumpkin, maize-tomato, banana-beans, banana-taro-beans-maize and sugarcane-beans began to appear in areas that had long been dominated by monoculture practices.

In this new situation with almost no external inputs, most of the new crop associations were found to be more productive than monocultures. Many farmers practicing crop associations were able to obtain two or more crops on the same piece of land that was previously monocropped. Planting more than one crop also allowed farmers to sell one to the state market, as is obligatory, and keep the other crop for own consumption or to sell on the free market. Intercropping also led to better control of pests and diseases in the absence of (chemical) pesticides, to more efficient use of very scarce inputs and to higher economic profitability.

Honduras: maize-velvet bean

A widespread crop used in intercropping systems is velvet bean (Mucuna pruriens). It is often grown in association with maize. Velvet bean is sown after the maize crop has established. It rapidly produces a lot of leafy material that continues growing after harvest of the maize crop, using the residual moisture. In the dry season, the crop can be left on the soil or ploughed under. This increases the amount of soil organic matter and the amount of soil nitrogen, available for the next crop.

5.3 Asia

Pigeon pea-maize intercrop in Indonesia

On the island Timor in Indonesia pigeon pea (Cajanus cajan) is intercropped with maize. At the onset of the rains, maize and pigeon pea are planted in rows. After 5 months the maize is harvested at the time pigeon pea starts to flower and fruit. No fertilisers are applied on the intercrop. Pigeon pea is a deep-rooting crop and improves soil fertility through biological nitrogen fixation. Falling litter and decomposing roots contribute to soil fertility. The production of pigeon pea is also important for food security and risk spreading; when the maize harvest fails, there still is a yield from the pigeon pea. The fresh and dried peas are eaten and pigeon pea is an important cash crop in the region. After harvest, the dried stems are used as firewood. Pigeon pea is also used as an early shade crop for cash-crops such as coffee and cocoa. Pigeon pea is suitable for a semi-arid climate. It is resilient to drought and produces good yields even in dry years. (Source: GMCC)

Sweet potato-maize intercrop in Indonesia

On the Indonesian island Bali, sweet potato (Ipomoea batata) is intercropped with maize. The leaves and stems of sweet potato are harvested for pig feed. Farmers in this area are not interested in the tubers. Maize is grown as a second-season crop. After land preparation, maize is sown in rows. After a single weeding and fertilisation, sweet potato cuttings are planted in between the maize. Leaves and stems of sweet potato are harvested when needed, even after the maize harvest. Before the next soil preparation, roots and tubers of sweet potato are ploughed in the soil. According to the farmers, the advantages of the sweet potato-maize intercrop are a diversification of crops and more efficient use of land. The labour requirements for weeding are reduced due to the permanent soil cover by the sweet potato. The leaves and stems are good quality food for pigs and provide a marketable cash crop. (Source: GMCC)

Maize-cowpea relay intercropping in The Philippines
Maize is sown first. After 45 days, cowpea (also named 'string bean') [is yard-long bean meant here? string bean is a cultivar of common bean] is sown. The maize serves as support for the cowpea. After harvesting maize and cowpea grains, crop remains and manure are incorporated in the soil. The cowpea harvest is used for own consumption and for sale. (Source: Garden organic)

Sources and Further reading

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