

Chapter 1

Cassava, a 21st century crop

The “food of the poor” has become a multipurpose crop that responds to the priorities of developing countries, to trends in the global economy, and to the challenge of climate change.

Cassava (*Manihot esculenta* Crantz) is one of some 100 species of trees, shrubs and herbs of the genus *Manihot*, which is distributed from northern Argentina to the southern United States of America. While some studies indicate that cassava has multiple centres of origin, others suggest that the cultivated species originated on the southern edge of the Brazilian Amazon¹⁻⁴. Botanically, cassava is a woody perennial shrub, which grows from 1 m to 5 m in height. It is believed to have been cultivated, mainly for its starchy roots, for 9 000 years, making it one of agriculture's oldest crops. In pre-Colombian times, it was grown in many parts of South America, Mesoamerica and the Caribbean islands.

Following the Spanish and Portuguese conquests, cassava was taken from Brazil to the Atlantic coast of Africa. By the 1800s it was being grown along Africa's east coast and in Southern Asia. Farming of cassava expanded considerably in the 20th century, when it emerged as an important food crop across sub-Saharan Africa and in India, Indonesia and the Philippines. Since it is sensitive to frost and has a growing season of nearly one year, cassava is cultivated almost exclusively in tropical and subtropical regions. It is grown today by millions of small-scale farmers in more than 100 countries, from American Samoa to Zambia, under a variety of local names: *mandioca* in Brazil, *yuca* in Honduras, *ketela pohon* in Indonesia, *mihogo* in Kenya, *akpu* in Nigeria and *sán* in Viet Nam.



Manihot esculenta has characteristics that make it highly attractive to smallholder farmers in isolated areas where soils are poor and rainfall is low or unpredictable. Since it is propagated from stem cuttings, planting material is low-cost and readily available. The plant is highly tolerant to acid soils, and has formed a symbiotic association with soil fungi that help its roots absorb phosphorus and micronutrients. To discourage herbivores, its leaves produce two glycosides which, when digested, produce highly toxic hydrogen cyanide. Since most of the soil nutrients absorbed during growth remain in the above-ground part

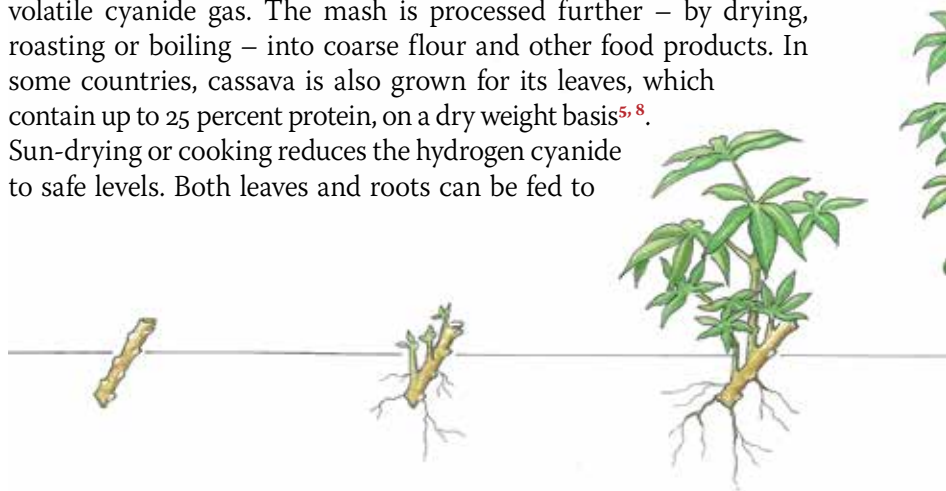
Studies suggest that cassava was first cultivated, as many as 9 000 years ago, on the southern edge of the Brazilian Amazon, where it is still grown today

of the plant, recycling the plant tops helps to maintain soil fertility. Under drought stress, leaf production is reduced until the next rains. Thanks to its efficient use of water and soil nutrients, and tolerance to sporadic pest attacks, cassava growers, using few if any inputs, can expect reasonable harvests where other crops would fail.

Cassava roots are more than 60 percent water. However, their dry matter is very rich in carbohydrates, amounting to about 250 to 300 kg for every tonne of fresh roots. When the root is used as food, the best time to harvest is at about 8 to 10 months after planting; a longer growing period generally produces a higher starch yield. However, harvesting of some varieties can be “as needed”, at any time between six months and two years. Those attributes have made cassava one of the world’s most reliable food security crops.

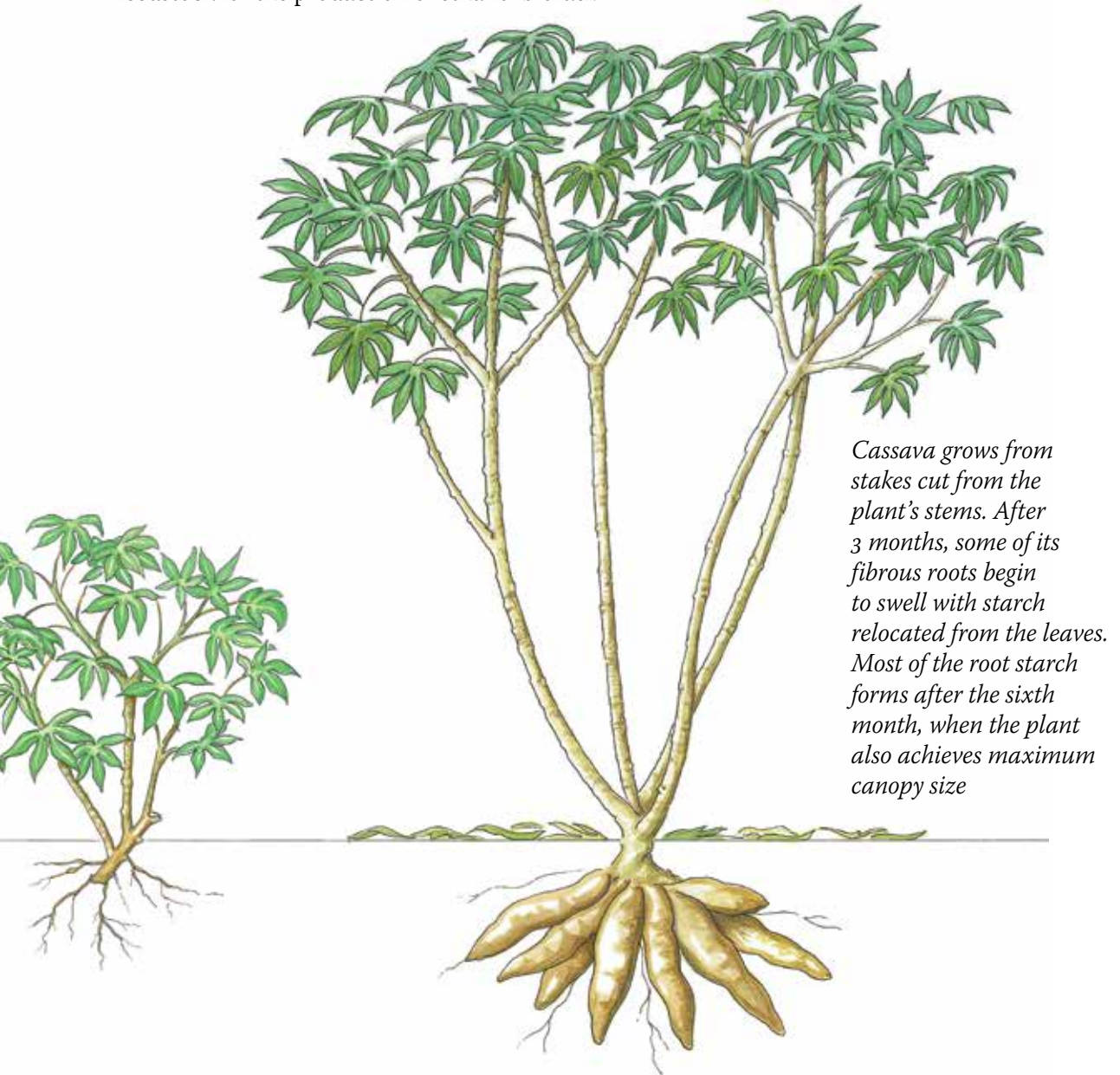
Thanks to its roots’ high starch content, cassava is a rich source of dietary energy. Its energy yield per hectare is often very high, and potentially much higher than that of cereals⁵. In many countries of sub-Saharan Africa, it is the cheapest source of calories available. In addition, the roots contain significant amounts of vitamin C, thiamine, riboflavin and niacin⁶.

Depending on the variety, they may also contain high levels of cyanogenic glycosides, especially in the outer layers⁷. Once harvested, therefore, cassava roots are peeled, then thoroughly cooked, or peeled, grated and soaked to induce fermentation in order to release the volatile cyanide gas. The mash is processed further – by drying, roasting or boiling – into coarse flour and other food products. In some countries, cassava is also grown for its leaves, which contain up to 25 percent protein, on a dry weight basis^{5, 8}. Sun-drying or cooking reduces the hydrogen cyanide to safe levels. Both leaves and roots can be fed to



farm animals, while stems can be used as firewood and a substrate for growing mushrooms.

Cassava's versatility does not end there. Its root starch can also be used in a wide array of industries, including food manufacturing, pharmaceuticals, textiles, plywood, paper and adhesives, and as feedstock for the production of ethanol biofuel.



Cassava grows from stakes cut from the plant's stems. After 3 months, some of its fibrous roots begin to swell with starch relocated from the leaves. Most of the root starch forms after the sixth month, when the plant also achieves maximum canopy size

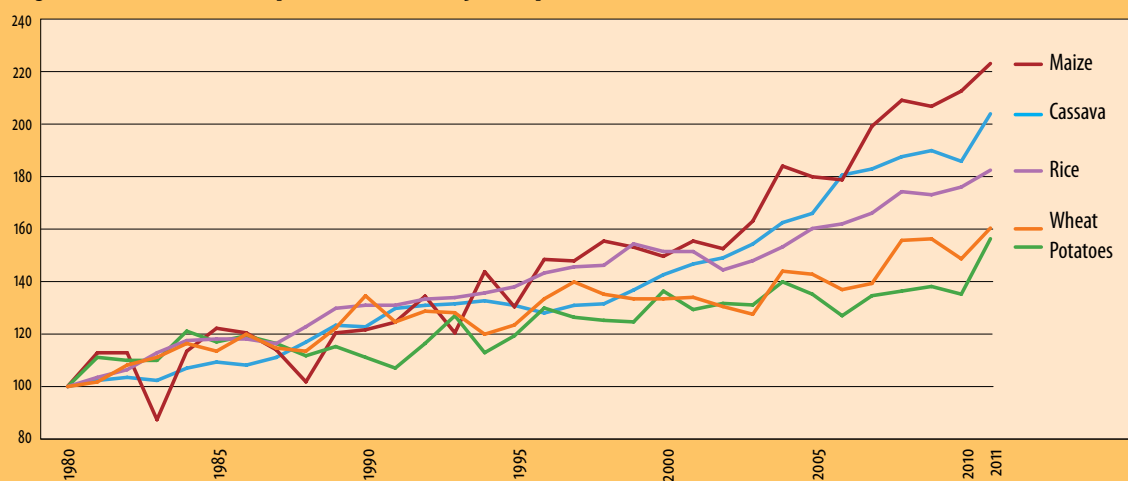
Among the family of staple food crops, cassava was long regarded as the least suited to intensification. Cassava stem cuttings are bulky and can easily transmit serious pests and diseases, and the plant's very low rate of vegetative multiplication retards the adoption of new, improved varieties. Unearthing cassava roots is labour-intensive, and the roots themselves are cumbersome to transport and highly perishable: they need to be processed within a few days of harvesting.

The Green Revolution approach to intensification, based on dwarf varieties and high inputs of agrochemicals and irrigation, dramatically boosted yields of wheat and rice, but it has proven inappropriate for cassava in rainfed areas. Partly because it is grown in developing countries, far less research and development has been devoted to cassava than to rice, maize and wheat⁹.

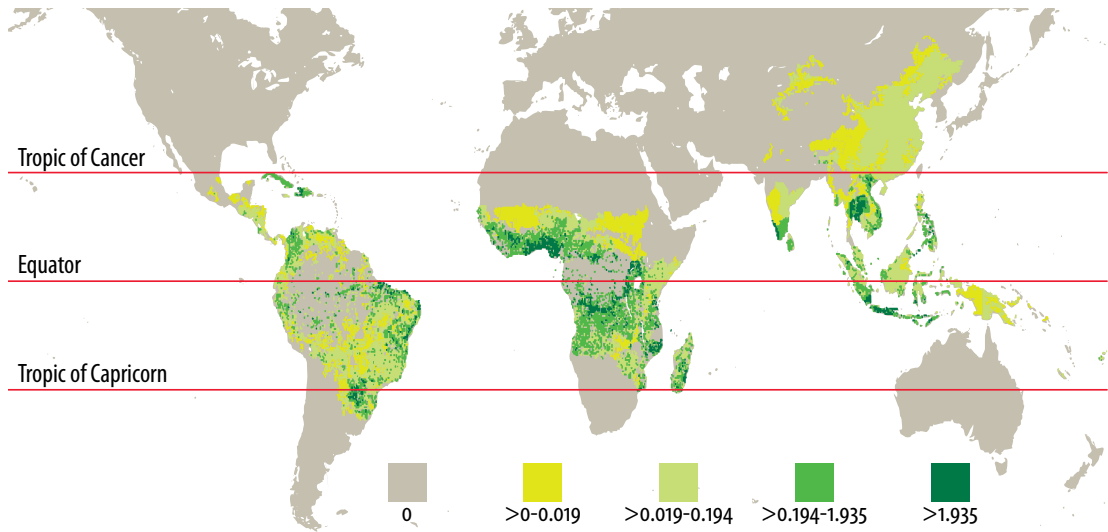
But cassava's importance in agriculture has changed dramatically. Between 1980 and 2011, the global harvested area of cassava expanded by 44 percent, from 13.6 million to 19.6 million hectares, which was the biggest percentage increase among the world's five major food crops. In that same period, world cassava production more than doubled, from 124 million to 252 million tonnes¹⁰.

Over the past decade, growth in cassava production has accelerated (Figure 1). FAO estimates put the global harvest in 2012 at more than 280 million tonnes, representing a 60 percent increase since 2000 and an annual growth rate double that of the previous two decades¹¹. Since 2000, the growth rate of cassava output in Africa has been equal to

Figure 1 **Growth in world production of major crops, 1980-2011** (index 1980=100)



Source: FAO. 2013. FAOSTAT statistical database (<http://faostat.fao.org/>).

Global cassava harvested area (ha/km²)

that of maize, while in South, Southeast and Eastern Asia the rate has been almost three times that of rice¹⁰.

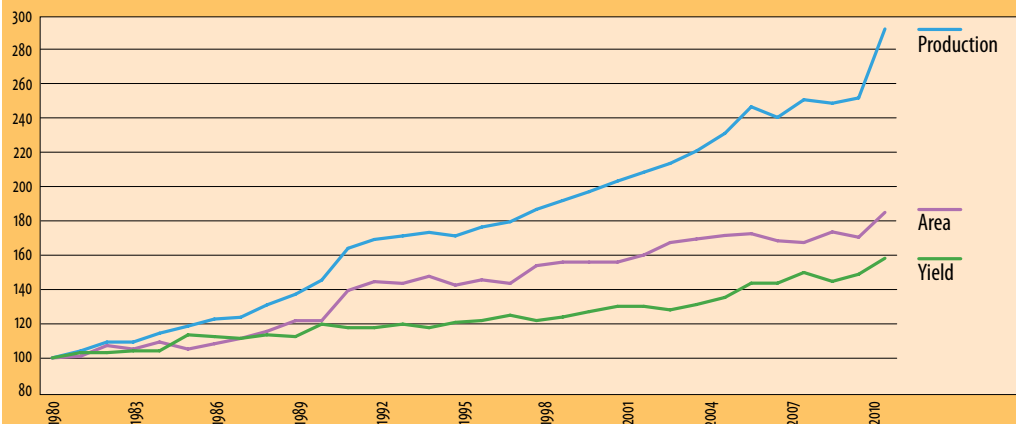
Another significant trend since the turn of the century is the higher productivity of cassava-based farming systems. Growth in production between 1980 and 2000 was due mainly to increases in the harvested area, of some 3.7 million ha; yields grew at an annual rate of just 0.6 percent. Since then, global average yields per hectare have increased by almost 1.8 percent a year, from 10.4 tonnes per ha in 2000 to 12.8 tonnes in 2011. While growth of cassava yields trailed well behind that of other major food crops in the period 1980-2000, the rate of increase over the past decade has exceeded that of potatoes, maize, rice and wheat¹⁰.

Current average yields are still far lower than cassava's potential. A study by the International Center for Tropical Agriculture (CIAT) in the 1990s estimated conservatively that – with improved crop and soil management, and the use of higher yielding varieties more resistant to drought, pests and diseases – cassava could produce an average of 23.2 tonnes of roots per ha. On the current harvested area, that amounts to more than 450 million tonnes a year.

A review of developments in the world's cassava producing regions reveals that diverse factors are driving increases in output and that growers are responding to rising demand by intensifying production.

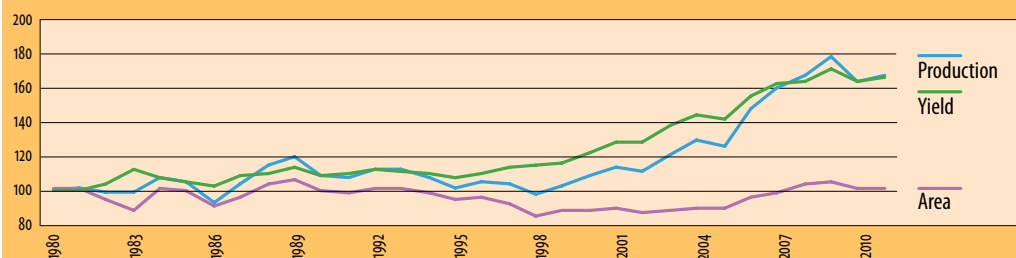
Source: Adapted from Monfreda, C., Ramankutty, N. & Foley, J.A. 2008. Farming the planet: 2. Geographic distribution of crop areas, yields, physiological types, and net primary production in the year 2000. Glob. Biogeochem. Cycles, 22: 1-19.

Figure 2 Growth in cassava production, harvested area and yield in sub-Saharan Africa, 1980-2011 Index: 1980=100



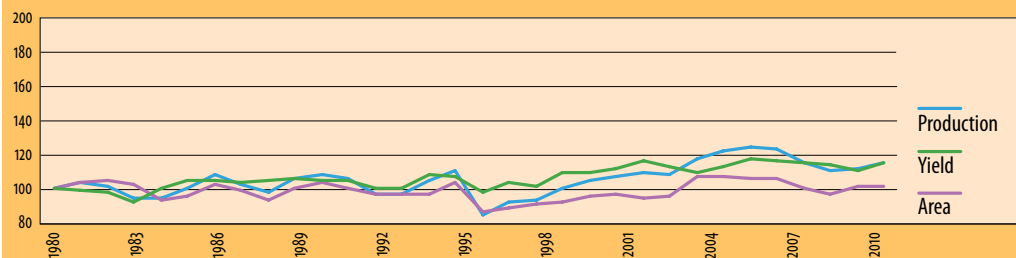
Source: Annex Tables 1.1, 1.2 and 1.3

Figure 3 Growth in cassava production, harvested area and yield in Asia, 1980-2011 Index: 1980=100



Source: Annex Tables 1.1, 1.2 and 1.3

Figure 4 Growth in cassava production, harvested area and yield in Latin America and the Caribbean, 1980-2011 Index: 1980=100



Source: Annex Tables 1.1, 1.2 and 1.3

Sub-Saharan Africa

Output of cassava has increased most markedly in sub-Saharan Africa, which harvested 140.9 million tonnes – more than half of the global harvest – in 2011. Between 1980 and 2000, production almost doubled, from 48.3 million to 95.3 million tonnes, thanks to a 56 percent increase in the harvested area and 25 percent growth in yields. Between 2000 to 2011, expansion of the harvested area slowed to 18 percent, but improvements in yields, from 8.6 tonnes to 10.8 tonnes per ha, boosted production by almost 50 percent (Figure 2).

Cassava in sub-Saharan Africa is grown mainly on small holdings by low-income farmers who make little or no use of external inputs. It is usually grown with other crops, such as maize, rice, legumes, melons, bananas and oil palm. It is still essentially a food crop – around 90 percent of harvested roots are destined for human consumption, while around 10 percent is semi-processed as on-farm animal feed¹².

Since 2000, cassava production has grown faster than the region's population, boosting the cassava food supply to almost 60 kg per capita per year. Africans' consumption of cassava is higher than that of any other staple food, including maize. Almost all of it is consumed as fresh roots or after processing into fermented flour products¹³. By some estimates, urban Nigerians consume cassava at the rate of 0.2 kg per day¹⁴.

The biggest gains in cassava production since 2000 have been in West Africa, where output rose by 60 percent, from 47 million to 76 million tonnes. Productivity has increased as countries in the subregion recognized cassava's potential as an industrial crop that could help to diversify farmers' incomes, earn foreign exchange and generate jobs¹². Growth in output was particularly strong in Nigeria and Ghana: in the space of 11 years, both countries boosted yields by 25 percent, to around 15 tonnes per ha¹⁰.

Average yields in the rest of the region remain low, at around 10 tonnes. However, thanks to more intensive production – mainly through greater use of improved varieties, mineral fertilizer and other inputs – yields have increased substantially in some countries. For example, a government programme in Malawi for the rapid multiplication of disease-free, higher-yielding planting material led to a rapid increase in cassava cultivation nationwide¹⁵. Between 1990 and 2011, average yields rose from 2.3 tonnes per ha to 21.5 tonnes, and production from 144 000 to 4.2 million tonnes¹⁰.

More recently, Rwanda has shown how intensification can produce spectacular results in a very short time. Since 2007, the country's food crop intensification programme has distributed to farmers 140 million stem cuttings of improved, disease-resistant varieties, and provided them with imported fertilizer and extension advice. As a result, yields rose from less than 6.5 tonnes in 2007 to 12.3 tonnes by 2011, and production more than tripled, from 780 000 to 2.5 million tonnes¹⁶.

Sub-Saharan Africa lags behind global trends in the development of the cassava value chain. However, new uses for cassava are emerging: in commercial livestock feed, as a partial substitute for wheat flour in bread making and as an industrial raw material. In 2012, Nigeria made a strong entry into the global cassava trade when it secured an order to supply China with 1 million tonnes of dried cassava chips¹⁰; the government recently announced further sales to China of 3.3 million tonnes in 2013¹⁷.

Asia

Cassava growers in Asia account for 30 percent of world production. Over the past three decades, their cassava output has grown by 66 percent, from 45.9 million tonnes in 1980 to 76.6 million tonnes in 2011. That growth was due almost entirely to more intensive cultivation – the harvested area in 1980 and 2011 was unchanged, at around 3.9 million ha, while average yields increased from 11.8 to 19.5 tonnes per ha in the same period (Figure 3).

As in Africa, cassava is mainly a smallholder crop that was once grown as a reserve in case of shortfalls in the rice harvest and as on-farm animal feed¹⁸. Today, most cassava is grown in the region to meet demand for dried cassava chips and cassava starch for use in commercial livestock feed and for industrial processing.

Thailand put cassava on the map of industrial uses in the 1980s, when it developed a thriving business exporting dried pellets to Europe for use in livestock feed. The country's impressive increase in cassava production, from 3.4 million tonnes in 1970 to more than 20 million tonnes in 1990, was achieved thanks to expansion of the harvested area, which grew almost seven times over; yields actually fell, from 15.3 tonnes to less than 14 tonnes per ha¹⁰.

In the 1990s, Thailand launched a major programme for the dissemination to farmers of new, higher-yielding varieties, along with improved access to mineral fertilizer and extension. Between 1990 and

2009, Thai yields rose by almost two-thirds, the harvested area shrank by 10 percent, and production reached a record 30 million tonnes.

Since 2000, Asia's cassava production has increased by 55 percent, as more countries seek to enter lucrative export markets. The region's major customer is China. Between 2000 and 2009, China's annual imports of dried cassava grew from 256 000 tonnes to more than 6 million tonnes, while imports of cassava starch more than doubled, to 1.2 million tonnes¹⁰.

Thailand dominates the export trade, shipping 6 million tonnes of dried cassava chips and starch, with a total value of US\$1.5 billion, in 2010. However, it faces increasing competition. Viet Nam has more than quadrupled cassava production, from 2 million to 8.5 million tonnes¹¹ since 2000, and exported 1 million tonnes of dried cassava in 2010. Indonesian exports also grew, from 150 000 tonnes in 2000 to 1.4 million tonnes. In Cambodia, a fledgling export trade in dried cassava, amounting to 22 000 tonnes in 2011, was recently boosted by orders from China for 1 million tonnes¹⁹.

An important new area of cassava utilization in Asia is as feedstock for the production of biofuel – one tonne of dried chips yields about 300 litres of 96 percent pure ethanol¹³. As countries seek to reduce both dependence on imported oil and greenhouse gas emissions, companies in China, Japan and the Republic of Korea are obtaining concessions for large-scale cassava plantations, mainly in Cambodia, Indonesia, Lao PDR and the Philippines, as a source of dried chips for ethanol production.

In a few countries, cassava remains first and foremost a food crop. Indonesia has the region's highest per capita cassava food supply, of 44 kg per year, well above the regional average of 6.7 kg. Cassava is also grown mainly for food in Kerala State, India, where farmers have achieved average root yields of 24 tonnes per ha, thanks to intensive production, often under irrigation²⁰.

Latin America and the Caribbean

Only 14 percent of the world's cassava, or some 34.3 million tonnes, is grown in Latin America and the Caribbean, where *Manihot esculenta* was domesticated. Between 1980 and 2011, the harvested area grew by less than 1 percent, to 2.6 million ha, while production increased by 15 percent, thanks to modest improvements in yields. Nevertheless, average annual growth in production since 2000 has been at twice the rate recorded in the previous two decades (Figure 4).

As in other tropical regions, cassava in the Americas is usually relegated to marginal areas with uncertain rainfall, acid soils, low native soil fertility, and difficult terrain. The inherent nature of cassava cultivation, especially the labour inputs required, makes it generally a smallholder crop, grown in farming systems that include other crops or animal components²¹. Production is dominated by Brazil, which harvested 24.4 million tonnes – almost three-quarters of the region's total output – in 2011, followed by Paraguay (2.4 million tonnes), Colombia (2.2 million tonnes) and Peru (1.1 million tonnes)¹⁰.

Although consumption of cassava as food has declined over the past 50 years, with the massive movement of rural populations to urban areas, it remains an important staple food especially in Colombia and northeast Brazil. FAO estimates that, regionally, about half of cassava production is used as food and half as animal feed. Cassava consumption is being promoted in Brazil by policies aimed at substituting imported cereals with domestically produced cassava flour. The government has mandated the blending of 10 percent cassava flour with wheat flour in bread, an initiative that is estimated to absorb about half of the country's cassava output¹¹.

Cassava growers in Latin America and the Caribbean typically apply few inputs, and yields – averaging 12.9 tonnes per ha – are well below potential levels. However, there has been a significant shift, beginning in the 1990s, toward larger-scale, more intensive production, especially in Brazil. While most of Brazil's cassava continues to be grown in the dry northeast, where yields average around 11 tonnes per ha²¹, intensive cultivation in the country's southern states – mainly to produce cassava flour and native starch for the food, cardboard and textile industries – has obtained yields of up to 40 tonnes²².

Brazilian production of cassava starch, processed mainly in factories in the state of Paraná, is estimated at more than 500 000 tonnes in 2011²³. Some 70 percent of the raw material is produced by smallholder farmers²⁴. To ensure a year-round supply of raw material, cassava production is mechanized, with farmers frequently cultivating cassava as a monocrop using high levels of inputs²⁴. Other countries in the region, notably Colombia, Paraguay and Venezuela, are also increasing their capacity to produce cassava starch. Compared to Asia, very little of the region's cassava output enters international trade. In fact, the biggest exporter is Costa Rica, which exported some 92 000 tonnes of dried cassava in 2010.

Although world cassava production reached record levels in 2012, for the 14th consecutive year, there remains ample room for further growth. World trade in cassava products saw a marked expansion in 2012, thanks to cassava's price advantage over maize as a source of starch. International prices of chips and starch have been remarkably stable, despite very strong demand. FAO expects continued increases in production in 2013 in sub-Saharan Africa¹¹.

Cassava's new status in agriculture is a major step forward toward realization of Global Cassava Development Strategy, adopted in 2001, after four years of consultations, by FAO, the International Fund for Agricultural Development (IFAD), public and private sector partners and 22 cassava-producing countries. The strategy recognized cassava's potential not only to meet food security needs, but also to provide an engine for rural industrial development and a source of higher incomes for producers, processors and traders²⁵.

If anything, growth in cassava production is likely to accelerate over the current decade. Once seen as the "food of the poor", cassava has emerged as a multipurpose crop for the 21st century – one that responds to the priorities of developing countries, to trends in the global economy and to the challenges of climate change. In brief:

Rural development. Policymakers in tropical countries are recognizing the huge potential of cassava to spur rural industrial development and raise rural incomes. They look to Thailand, where increases in yields over the past two decades have boosted smallholder earnings by an estimated US\$650 million and lifted many cassava growers out of poverty. In southern Brazil, cassava is a multi-million dollar industrial crop, processed in factories that employ thousands of rural people²⁴. It has been estimated that investments in cassava research and development in Africa could generate some of the highest gains in agricultural GDP²⁶.

Urban food security. A major driver of production increases will be high prices of cereals on world markets, which sparked global food price inflation in 2008. In Africa, persistent urban poverty has boosted the consumption of cassava food products as consumers seek cheaper sources of calories¹². Among FAO's recommendations to governments for holding down food prices is processing cassava into products that are marketable as instant foods with a long shelf-life²⁷. Cassava could also help improve the nutrition of low-income populations – new

biofortified varieties produce roots that are rich in vitamin A, iron and zinc.

Import substitution. Many governments have, or are considering, mandatory blending of mostly imported wheat flour with domestically produced cassava flour in bread making. Nigeria recently raised its levy on wheat flour to 100 percent, and will use revenue for a cassava bread development fund¹¹. It has also announced plans to substitute 10 percent of the maize in poultry feed with cassava grits, which will increase annual demand for cassava roots by 480 000 tonnes²⁸. In East Africa, the animal feed industry is turning to cassava, as maize and wheat become increasingly unaffordable²⁹.

Renewable energy. Global output of bio-ethanol could reach 155 billion litres by 2020, up from around 100 billion litres in 2010. Cassava currently contributes to only a small part of production, but demand from China is growing rapidly following its decision to no longer use cereals to produce biofuel. Currently, 50 percent of China's ethanol is derived from cassava roots and sweet potatoes, and in 2012 it was expected to produce 780 million litres of ethanol from 6 million tonnes of dried cassava¹³. China plans to develop cassava varieties suitable for biomass energy production in colder and drier regions of the country's north³⁰.

New industrial uses. Worldwide, cassava is the second biggest source of starch, after maize, with production estimated at 8 million tonnes a year. However, tropical countries import each year some US\$80 million worth of maize starch that could be replaced by starch from locally grown cassava¹³. In Thailand, which has earned some US\$4 billion from starch exports since 2000, scientists are developing a variety with root starch that rivals premium "waxy" maize starch^{31, 32}. A recent cassava mutation offers smaller root starch granules that reduce considerably the time and energy required for ethanol production³³.

Adaptation to climate change. Another factor that favours increased cassava production is the crop's potential to adapt well to climate change. A recent study of the impacts of climate change on major staple crops in Africa found that cassava was the least sensitive to the climatic conditions predicted in 2030, and that its suitability would actually increase in most of the 5.5 million sq km area surveyed.

Conversely, all other major food crops in the region, including maize, sorghum, millet, beans, potatoes and bananas, were expected to suffer largely negative impacts³⁴.

As market demand grows, traditional cassava cropping systems are being replaced worldwide by more intensive production. In the years ahead, the trend towards intensification – aimed at achieving higher yields on the same area of land – is expected to strengthen in all cassava-producing regions. The alternative, expanding the harvested area, is not feasible in most countries owing to a diminishing supply of arable land and the high labour requirements of cassava cultivation. Past experience has also demonstrated that opening up new areas for cassava can carry heavy environmental costs: in Thailand, expansion of the harvested area in the 1970s and 1980s led to massive deforestation²⁵.

Farmers, industry and policymakers are seeking solutions to constraints to cassava yield increases⁹. Smallholder producers in Brazil, India and Thailand have been highly successful in commercial production, obtaining yields of between 25 and 40 tonnes per ha, through more intensive farming. Although current African yields are less than half the global potential yield, root harvests of up to 40 tonnes have been obtained in on-farm trials³⁵. In Nigeria, yields could reach 25 tonnes per ha and beyond with improved varieties, agronomic practices and crop management.

Rwanda plans to boost its cassava output in 2017 from the current 2.5 million tonnes to as much as 6.1 million tonnes, by disseminating higher-yielding varieties, training farmers in improved crop management, and encouraging increased use of mineral fertilizer, pesticide and irrigation¹⁶. Supported by international donors, other African countries – including Ghana and the Democratic Republic of the Congo – have made similar plans for the commercialization of cassava, in line with the African Union’s Pan-Africa Cassava Initiative, which has identified *Manihot esculenta* as a key agricultural commodity, food security crop and “poverty fighter”³⁶.

The future of cassava is likely to see, therefore, a shift to increased monocropping on larger fields, the widespread adoption of higher-yielding genotypes that are more suited to industrialization, and higher rates of use of irrigation and agrochemicals.

In promoting programmes for intensified cassava production, policymakers should consider the lessons of the Green Revolution. Based on genetically uniform crop varieties and intensive use of tillage, irrigation, mineral fertilizer and pesticide, the Green Revolution model of agriculture produced a quantum leap in global cereal yields and average per capita food consumption. But those enormous gains in productivity were often accompanied by negative effects on agriculture's natural resource base, so serious that they jeopardize its productive potential in the future. In many countries, decades of intensive cropping have degraded fertile land and depleted groundwater, provoked pest upsurges, eroded biodiversity, and polluted air, soil and water³⁷.

Applying the same model to cassava production carries similar risks. A shift from traditional smallholder cassava farming systems – based on intercropping and periods of fallow to replenish soil nutrients³⁹ – to more intensive monocropping may simplify management and favour initially higher yields. Experience has shown, however, that it also increases the prevalence of pests and diseases, and accelerates the depletion of soil nutrient stocks^{35, 38}.

In southern Brazil, year-round demand for cassava for starch processing has led to continuous monocropping in the same field, overlapping planting dates, increasing use of genetically uniform varieties, and greater need for agrochemicals to maintain soil fertility and combat pests and diseases²⁴. In Rwanda, higher cropping densities under intensification have created pest and disease pressure that is negatively affecting yields¹⁶. As warmer conditions start to favour intensive cassava production in new areas of Africa, Asia and South America, the risk of pest and disease problems is expected to increase²⁴.

Continuous cultivation of cassava – involving at least 10 years of production on the same piece of land with less than one year of fallow between crops – is already widespread in sub-Saharan Africa, especially in non-humid and highland zones⁴⁰. In East Africa, agricultural landscapes have changed from traditional systems with an important fallow component to continuous cassava-based production³⁵.

With intensification, many of Africa's cassava growers have eliminated fallow periods altogether and are not compensating for nutrient losses by adopting soil fertility management techniques, such as cover crops and manure application. Declining levels of soil nutrients lead to falling yields, to the point where production becomes unprofitable³⁹.

In northeast Thailand, several years of cassava cultivation in upland areas led to a decline in soil fertility owing to erosion, tillage practices that removed soil cover, and the failure of farmers to incorporate residues in the soil⁴¹. In Colombia, yields of monocropped cassava dropped from 37 tonnes to 12 tonnes per ha over a period of nine years owing to soil degradation.

In Nigeria, research found that soil erosion increases when traditional mixed cropping is replaced by monoculture⁴². Moreover, traditional practices, found to be highly successful in reducing soil erosion under polyculture, are less effective when used in monoculture⁴². In trials in Viet Nam, monoculture of cassava produced yields of 19 tonnes, but resulted in severe, unsustainable soil losses to erosion of more than 100 tonnes per ha⁴³.

In 2010, FAO endorsed an ecosystem-based approach to crop production intensification, one that is both highly productive and environmentally sustainable⁴⁴. Dubbed “Save and Grow”, it calls for “greening” the Green Revolution through farming practices that draw on nature’s contributions to crop growth, such as soil organic matter, water flow regulation, pollination and bio-control of insect pests and diseases. The key principles underpinning “Save and Grow” are:

- ▶ maintaining healthy soil to enhance crop nutrition
- ▶ cultivating a wider range of crop species and varieties in associations, rotations and sequences
- ▶ using well-adapted, high-yielding varieties and good quality seed
- ▶ efficient water management that produces more crops per drop
- ▶ preventative management of insect pests, diseases and weeds.

This eco-friendly model of agriculture encourages reduced or zero-tillage in order to boost yields while restoring soil health. It controls insect pests by protecting their natural enemies rather than by spraying crops indiscriminately with pesticide. It uses mineral fertilizer sparingly, in combination with organic sources of soil nutrients³⁷.

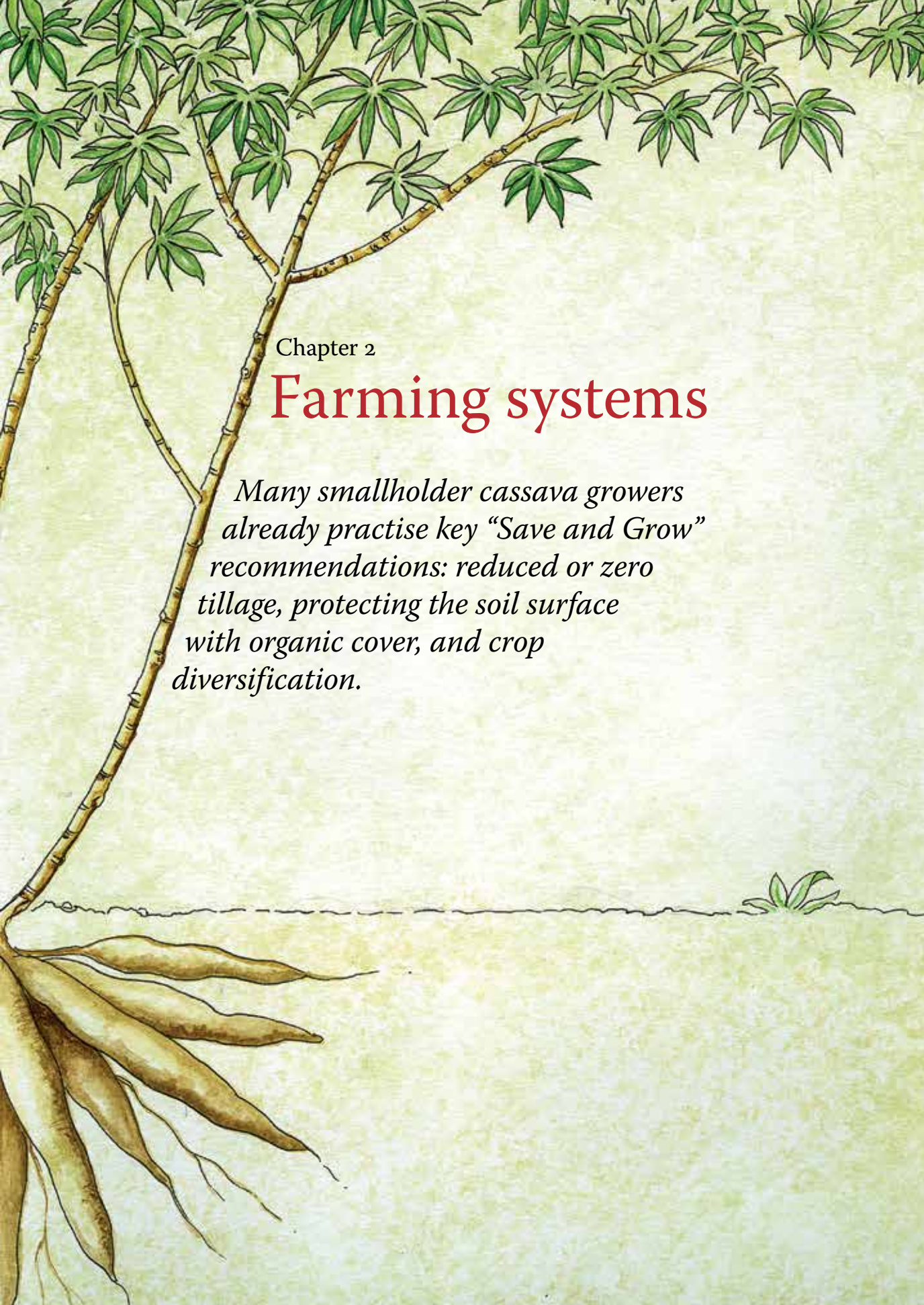
Supporting evidence from agricultural development projects in 57 developing countries has shown that more efficient use of water, reduced use of pesticide and improvements in soil health boost crop yields by around 80 percent⁴⁵. Another study concluded that farming systems that conserve ecosystem services, through conservation tillage, crop diversification, legume intensification and biological pest control, perform just as well as high-input intensive systems^{46, 47}.



With “Save and Grow”, tropical countries can avoid the risks of intensified cassava production

This guide shows how “Save and Grow” can help developing countries avoid the risks of unsustainable intensification, while realizing cassava’s potential for producing higher yields, alleviating rural poverty and contributing to national economic development. It shows, for example, how growing cassava with groundnuts produces not only high root yields but also much higher income than monocropping; how a predatory wasp has been far more effective than insecticide in defeating devastating outbreaks of cassava mealybug; and how rotating cassava with beans and sorghum restored yields where mineral fertilizer alone had failed.

Chapters 2, 3, 4, 5 and 6 present a set of adoptable and adaptable ecosystem-based practices that have enhanced cassava productivity and can serve as the cornerstone of national and regional programmes. Chapter 7 explores post-harvest uses and value addition. Chapter 8 outlines policies that facilitate sustainable intensification of cassava production, and underlines the importance – when introducing new practices or technologies – of “letting farmers decide”.



Chapter 2

Farming systems

Many smallholder cassava growers already practise key “Save and Grow” recommendations: reduced or zero tillage, protecting the soil surface with organic cover, and crop diversification.

In “Save and Grow”, farming systems are founded on three key recommendations¹. First, farmers should aim at protecting soil structure, soil organic matter and overall soil health by *limiting mechanical disturbance of the soil*. That means minimizing “conventional tillage”, the practice of ploughing, harrowing or hoeing land before every crop and during crop growth. Instead, farmers are encouraged to practise conservation tillage, which excludes operations that invert the soil and bury crop residues. Common forms of conservation tillage are strip or minimum tillage, which disturbs only the portion of the soil that is to contain the seed row or planting hole, and zero tillage, in which ploughing or hoeing are eliminated.

Along with conservation tillage, FAO recommends *maintaining a protective organic cover on the soil surface*, i.e. using crops and mulches to reduce soil erosion, conserve soil water and nutrients, and suppress weeds. Organic soil cover not only improves soil’s physical properties; it also encourages the proliferation of soil biota – including earthworms and beneficial protozoa, fungi and bacteria – that promote soil health and crop performance. In zero tillage systems, crops are planted directly through a mulch formed by the residues of previous crops or cover crops.

Third, farmers should *cultivate a wider range of plant species* in associations, sequences and rotations that may include trees, shrubs and pasture. Mixed cropping diversifies production, which helps farmers to reduce risk, respond to changes in market demand and adapt to external shocks, including climate change. Rotating or associating nutrient-demanding crops with soil-enriching legumes, and shallow-rooting crops with deep-rooting ones, maintains soil fertility and crop productivity and interrupts the transmission of crop-specific pests and diseases.

By improving levels of soil organic matter and biotic activity, reducing pest and disease pressure, reducing erosion and increasing the availability of crop water and nutrients, those three practices increase yields sustainably. They also lower production costs, mainly through savings on machinery, fossil fuel and external inputs such as irrigation, mineral fertilizer and pesticide.

To till or not to till?

Cassava needs a sufficiently loose-textured soil to facilitate initial root penetration and to allow for root thickening. It also succumbs easily to weed competition, excessive soil moisture and root rot. For those reasons, it is usually planted in soil that has been loosened and cleared of weeds by hoeing or ploughing. On degraded and unstructured soils, conventional tillage makes it easier to insert stakes in the ground and provides well-drained, aerated conditions for the root system^{2, 3}.

However, crop yields are a function not of tillage, but of soil conditions. Cassava stakes can also be planted, and can produce good yields, in soil that has not been tilled, provided that the soil is healthy, well structured and free of compaction⁴. Friable soils, high in organic matter, provide ideal conditions for zero-till cultivation². A study of smallholder cassava production in East and West Africa found that cassava was more frequently planted on seedbeds without prior land preparation than any other staple crop, except rice. Where soils had poor physical properties, farmers planted it on manually prepared mounds or ridges⁵.

Continuous conventional tillage, especially when done with heavy, tractor-mounted ploughs, harrows and rototillers, buries the soil's protective cover, kills soil biota, causes the rapid decomposition of organic matter, and degrades soil structure by pulverizing soil aggregates. Ploughing or hoeing the soil at the same depth, season after season, often leads to the formation of a hardpan, a compacted soil layer – usually found below the topsoil – that is difficult for water and roots to penetrate⁶. In such soils, some kind of mechanical loosening will be necessary for continued crop production, but at the cost of further soil degradation.

In that same soil, growing cassava without tillage may produce lower yields in the initial years. In the longer term, however, by reducing mineralization, erosion and water loss, helping to build up organic matter and maintaining soil aggregate stability and internal drainage, zero tillage promotes root functioning to the maximum possible extent. Once soil health is restored, untilled land can produce high yields and do so at a lower cost to both the farmer and the farming system's natural resource base⁷⁻¹⁰.

Currently, land is prepared for cassava in many different ways and at different intensities. Small-scale farmers in Indonesia, Viet Nam and many African countries, or wherever land is too steep for any kind of mechanization, usually use a hoe to loosen soil in the area to be planted. Since manual land preparation is labour-intensive, many farmers prepare only the planting hole itself. While that is a form of reduced tillage, it can also result in low yields if weeds are not controlled.

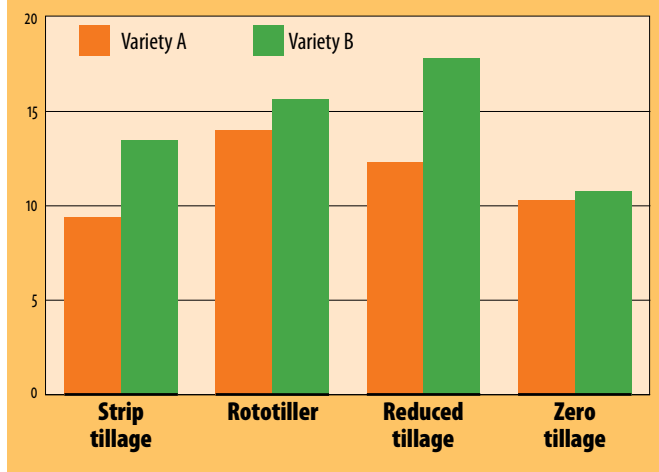
In regions where farmers cultivate larger areas of cassava, they traditionally plough the fields with oxen or water buffaloes, usually in one or two passes. In mountainous areas of Colombia, farmers use a pair of oxen pulling a simple reversible plough¹¹. In Indonesia, they plough the field with oxen, and then create planting ridges by hand, using a short-handled hoe. In Kerala State, India, farmers hoe the soil, then make individual mounds for each cassava plant, a labour intensive approach requiring more than 30 days of labour per hectare.

In countries where cassava is grown intensively on larger areas, of from 2 to 5 ha, land is usually prepared by tractor using a mouldboard or disc plough, generally followed by the use of a disc harrow and sometimes a ridger. Alternatively, the soil is loosened and residues and weeds are incorporated with a rototiller. However, this method tends to pulverize the soil and can lead to serious erosion on sloping land.

Many cassava farmers in southern Brazil practise conservation tillage. They generally grow a cover crop, such as black oats (*Avena strigosa*) or wheat, during the winter months to protect the soil surface, increase soil organic matter and suppress weeds. In the spring, before the cereal crop matures, they crush it with a tractor-drawn rolling drum, or kill it with herbicides, then plant cassava stakes with a mechanized planter directly through the mulch of the crop's residues. In Paraguay, farmers practise hand-planting of cassava without tillage using black oats or leguminous shrubs as a winter cover crop¹².

Many experiments have attempted to determine the best method of land preparation for cassava and the effectiveness of conservation tillage alternatives^{11, 13}. However, evidence of the effect of different tillage options on yields is not conclusive: the results of trials in Africa, Asia and Latin America vary from year to year and from place to place. On a gentle slope in Colombia, reduced tillage – involving the preparation by hoe of the planting holes only – resulted in the highest yields of one variety, while the use of a tractor-mounted rototiller

Figure 5 **Effect of tillage system on cassava root yield, Colombia (t/ha)**



Source: Annex Table 2.1

produced the highest yields of another variety (Figure 5). Both zero tillage and strip preparation with a hoe or rototiller produced significantly lower yields. But other trials in the same area – which compared zero tillage, ploughing with oxen, and strip tillage – found that zero tillage produced the highest yields as well as the lowest rates of soil erosion.

In a three-year experiment on a 25 per cent slope in Hainan Province, China, the highest yields, of 26 tonnes per ha, were obtained by conventional ploughing and disking. Reduced tillage of the planting holes produced slightly lower per hectare yields, of 24.6 tonnes, while zero tillage

and strip preparation produced lower yields still, of around 22.8 tonnes. However, zero and reduced tillage also resulted in the lowest rate of soil erosion, which was a major problem on the steep slopes¹⁴.

In Brazil, average cassava yields over four years of trials were 18.2 tonnes per ha on zero-tilled plots, significantly lower than the 24.7 tonnes obtained with conventional tillage¹⁵. However, in clay soil that had been previously planted with winter maize under zero tillage for four years, there were no significant differences between zero tillage and conventional tillage yields¹⁶.

In a land preparation trial conducted for four consecutive years in Thailand, the standard practice – ploughing twice with a 3-disc plough followed by a 7-disc harrow – produced the highest yields, while zero tillage consistently produced the lowest yields³. In another Thai experiment, however, tillage did not result in significant yield differences. Using a subsoiler followed by a chisel plough, researchers obtained an average root yield of some 22 tonnes per ha, compared to 20 tonnes when the land was not tilled and weeds were controlled with herbicide¹⁷.

Also in Thailand, with nitrogen fertilizer applied at the rate of 100 kg per ha, the fresh root yield of cassava grown under zero tillage reached 67 tonnes, significantly higher than the 53 tonnes obtained using conventional tillage (Figure 6). In the second year, average yields from the unprepared plots fell to 49 tonnes, slightly less than the conventional tillage yield that year of 54 tonnes¹⁷.

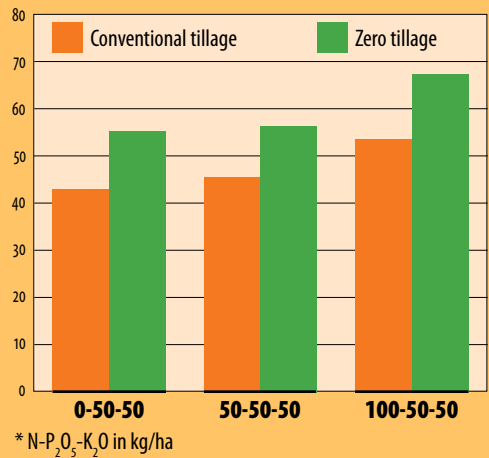
A study in Nigeria found that yields under conventional ridge tillage were up to 46 percent higher than those obtained in untilled fields¹⁸, although zero tillage was practised by the majority of local farmers. However, the trial beds were planted at the height of the rainy season in June, when levels of soil moisture were higher and soil temperatures lower, which delayed the emergence of plants in the zero-tilled plots and led to a substantial number of rotten stems¹⁸. In fact, when planted at the onset of the rainy season, in March, cassava emergence was higher under zero tillage¹⁹. Other trials in Cameroon and Nigeria have found that cassava yields were not affected by tillage^{18, 20}; in the Democratic Republic of the Congo, yields were higher in untilled than tilled oxisols, and similar in sandy loam soil, provided the field was mulched².

Finally, a recent study of an 8-year experiment in sandy loam soil in Colombia concluded that zero tillage was more effective in building up soil nutrients and conserving the soil's physical properties and, when combined with mulching of residues, produced the highest root yields, with or without mineral fertilizer (Figure 7). Weighing up the costs and benefits, the study concluded that zero tillage compared favourably with conventional tillage and, in the long term, was “an optimum system” for cassava production²¹.

Based on the evidence presented, no single method of land preparation can be described as “best for cassava”. As a general conclusion, it can be inferred that the effects of tillage on cassava yield

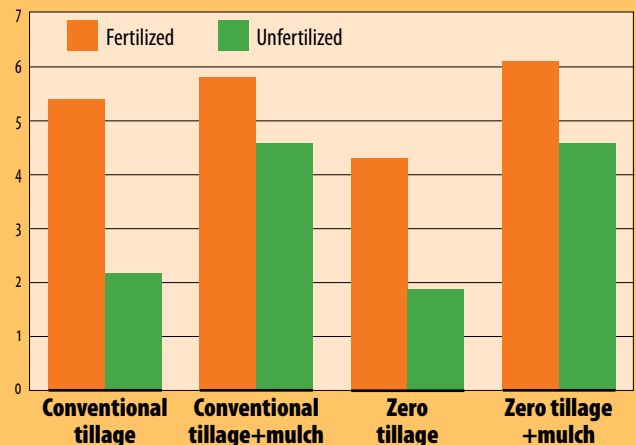
are variable from year to year and that the benefits of zero tillage in terms of erosion control are usually positive. Research also indicates that some land preparation is necessary in areas with heavy, poorly drained soils or where soils are already badly degraded. However, even in those cases, the need for tillage can be reduced through practices

Figure 6 Effect of tillage system and fertilizer* on cassava root yield, Thailand (t/ha)



Source: Annex Table 2.2

Figure 7 Cassava yield response to surface plant mulch, fertilizer and tillage, Colombia (t/ha)



Source: Annex Table 2.3

that improve soil structure, organic matter content and drainage, such as mulching².

Cassava growers should be encouraged to adopt minimum tillage and, ideally, zero tillage, especially on well-aggregated, friable soils with an adequate level of organic matter. Since yields do not depend on tillage *per se*, but on soil health, it is also recommended that, in tillage trials, changes in soil structure and organic matter under a zero-till regime be monitored closely, as those factors are likely to have a long-term positive impact on cassava yields and are good indicators of sustainability.

Even where conservation tillage produces lower yields, it offers farmers economic advantages: reduced spending on the fuel and equipment needed for conventional tillage, and – since it reduces soil erosion, conserves soil moisture and helps maintain soil health – the opportunity to produce cassava more intensively and sustainably, without the need for high levels of external inputs²². Conservation tillage will also be important as an alternative to conventional tillage in cassava-growing areas affected by climate change. Where rainfall is reduced, it will help to conserve soil moisture; where rainfall increases, it will help reduce soil erosion and improve soil structure, allowing better internal drainage²³.

Cover crops and mulching

Maintaining a continuous ground cover is another basic “Save and Grow” practice that is also essential for reaping the full benefits of conservation tillage. Ground cover is especially important in cassava production – because the initial growth of cassava is slow, the soil is exposed to the direct impact of rain during the first 2 to 3 months of its growth cycle, and the wide spacing between planted stakes favours the emergence of weeds. To protect the soil surface, reduce runoff and erosion, and inhibit weed growth, “Save and Grow” recommendations include covering the soil surface with mulch, such as crop residues, or growing cover crops (also called “live mulch”) during fallow periods or during cassava establishment. Mulching seedbeds is recommended especially when growing cassava on slopes prone to soil erosion. Cassava stakes can be planted directly through the mulch cover, with little or no land preparation²⁴.

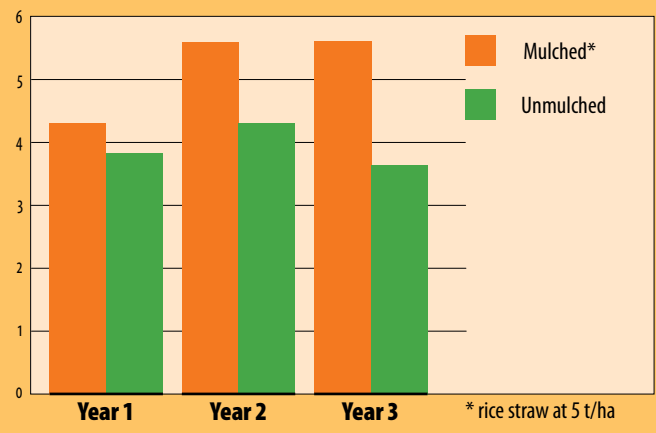
Mulch cover also serves as an insulating layer that reduces diurnal temperature variations and water evaporation, even during periods of prolonged drought. It increases the soil organic matter content and provides a favourable environment for soil micro-organisms and below-ground fauna. By improving physical soil conditions – reduced soil temperatures, higher levels of moisture, increased water infiltration capacity and lower evaporation – it favours higher yields¹⁶.

In a 3-year trial in the Democratic Republic of the Congo, the application of 5 tonnes of rice straw on late season cassava led to an increase in soil pH, organic carbon content, total nitrogen, soil-available phosphorus and soil exchangeable cations. Mulched cassava plants produced more and bigger storage roots than unmulched plants, and the dry storage root yield increased each year, from an average of 4.3 tonnes to 5.6 tonnes per ha, irrespective of the cultivar used. In the first, second and third year, yields were 17 percent, 28 percent and 58 percent higher, respectively, than those of unmulched cassava (Figure 8)²⁵.

Growing cover crops between cassava cropping cycles is regarded mainly as a soil improvement practice (see Chapter 5, *Crop nutrition*). However, it can also help reduce weed infestations. Fast-growing legumes smother many unwanted weeds that normally proliferate during cassava establishment and after the cassava harvest, thus providing weed control that is less labour-intensive than manual weeding and less expensive than spraying with herbicides (see also Chapter 6, *Pests and diseases*).

Trials have found that while perennial legumes are more effective for soil protection than commonly intercropped grain legumes, such as beans and cowpeas, highly productive perennials, such as stylo (*Stylosanthes guianensis*) competed strongly with cassava for nutrients and reduced root yields considerably. However, with less aggressive legumes, such as pinto groundnuts (*Arachis pinto*), the yield loss was less serious²⁶.

Figure 8 Effect of mulching on dry root yield of late season cassava, Democratic Republic of the Congo (t/ha)



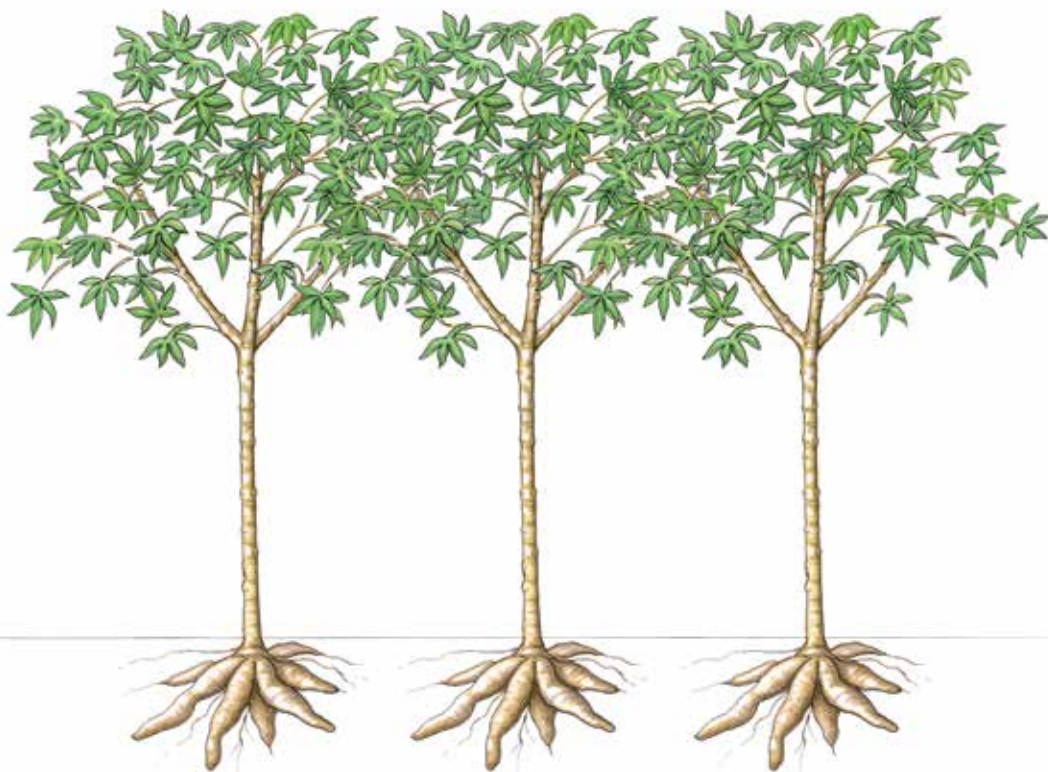
Source: Annex Table 2.4

Mixed cropping

Although cassava is widely grown as a monocrop in Thailand and southern Brazil, intercropping is practised by smallholder cassava farmers in many parts of the tropics. Subsistence growers, or those with very limited areas of land, generally plant the space between cassava rows with early maturing crops, such as maize, upland rice and various types of grain legumes, including common beans, cowpeas, mungbeans and groundnuts. The practice has many benefits – it protects the soil from the direct impact of rain, reduces soil erosion from runoff, and limits weed growth during the early stages of cassava development.

Intercropping also produces crops that can be harvested at different times during the year, increases total net income per unit area of land, and reduces the risk of total crop failure. In south-western Nigeria, for example, maize and cassava are often planted in the first of two annual rainy seasons; the maize is harvested during a short break in the rains, after which the cassava continues alone. Since the two crops have different pest and disease complexes and growth requirements, one may survive even if the other fails. Some farmers even plant a second maize crop – cassava is less risky and the maize, if it succeeds, provides a bonus²⁷.

When grown as a monocrop, cassava is usually planted with spacing of 1 m, making 10 000 plants per hectare



Growing cassava with short-duration grain legumes has an added advantage: it supplies both carbohydrates and protein, which provide the foundation of a healthy diet for the farming household. It has been estimated that one hectare of cassava intercropped with black common beans (*Phaseolus* spp.) can produce around 10 tonnes of fresh cassava roots with 30 percent starch and 600 kg of beans with 28 percent protein – enough to meet the annual requirements of five adults and leaving a surplus of about 6 tonnes of cassava for use as animal feed or for sale².

In many parts of Africa, cassava is grown with a wide range of other crops, either in a regular pattern or an irregular mixture of various crops that are continuously harvested and replanted as space becomes available. In West Africa, farmers often plant from 5 to 10 cassava stakes along the edge of large mounds, and plant crops such as maize, beans and melons in the middle of the mounds.

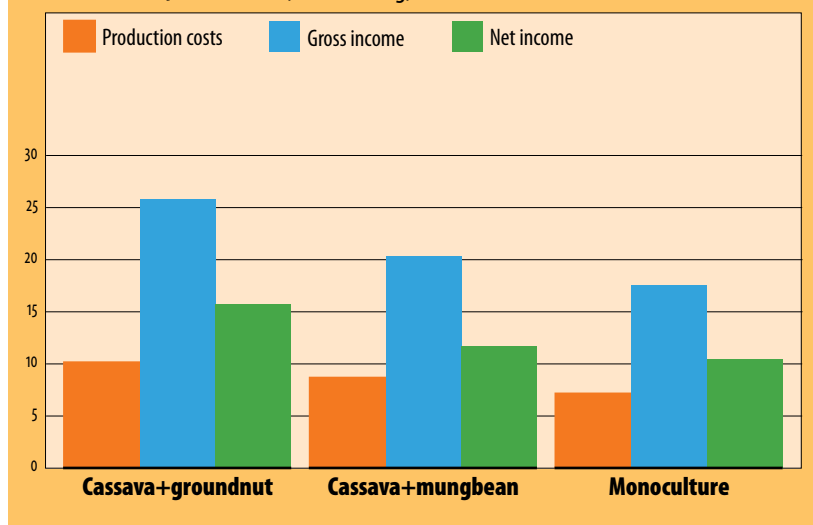
In Indonesia, upland rice is grown between the cassava rows, while maize is grown between the cassava plants in the rows themselves. Once the rice and maize are harvested, at about four months after planting, the inter-row space is replanted with grain legumes, such as soybeans and groundnuts. In some areas, the long rainy season allows the planting of a fourth intercrop, such as mungbeans, after the grain legumes have been harvested. That very intensive intercropping allows the production of up to five crops a year on a very small area of land.

Trials in Viet Nam showed that cassava intercropped with groundnuts (*Arachis hypogaea*) produced not only high root yields, of 30.7 tonnes per ha, but also much higher income than monocropping



In Indonesia, farmers plant cassava along with faster growing crops, such as maize and rice. After the cereal harvest, they plant groundnuts

Figure 9 **Production costs and income of three intercropping trials with cassava, Viet Nam** (million dong)



Source: Annex Table 2.5

(Figure 9). At 32 tonnes per ha, monoculture yields were slightly better than those of the cassava/groundnut system and production costs were almost 30 per cent lower. However, the high commercial value of the groundnut yield, of 1.5 tonnes per ha, resulted in a total net income 50 per cent higher than that of the monoculture.

In the Democratic Republic of the Congo, planting cassava with spacing of 2 m between rows and 0.5 m within the row

(instead of the usual 1 m x 1 m) allowed for two successive legume intercrops, of groundnuts and climbing beans. The crop arrangement did not affect the cassava root yield, and the extra income generated from legume sales amounted to almost US\$1 000 per ha²⁸. In India, intercropping with banana produced higher cassava root yields, while the highest net return was obtained by combining cassava with french beans or cowpeas²⁹.

In northeast Thailand, dairy farmers have developed a “food-feed” system of cassava intercropped with cowpeas. The cowpea crop produces up to 2.4 tonnes of fodder per ha, which is fed along with dried cassava leaves to their cows. While the system produces generally lower root yields, compared with monocropping, researchers found that it increased land use efficiency and resulted in higher economic returns³⁰.

Intercropping requires careful selection of the crops – and the most suitable varieties of each crop – to be planted, careful timing of planting, good fertilization, and optimum plant densities and distribution. In Nigeria, the success of maize/cassava combinations depends on the time and the rate of recovery of the cassava after the maize harvest. Research found that cassava root yields dropped from 31.6 tonnes per ha to less than 20 tonnes with high densities of maize planting and maize yields that exceeded 3.5 tonnes²⁷. In trials in Thailand, planting

cowpeas (*Vigna unguiculata*) and sword beans (*Canavalia gladiata*) at the same time as cassava, over a period of four years, resulted in lower yields than when cassava was grown alone. However, moving the planting date three weeks after that of cassava reduced competition during cassava's early growth stages, which allowed it to establish better and produce root yields exceeding those of the monocrop³¹.

The effectiveness of intercrops in reducing soil erosion depends on whether they have been able to produce enough foliage in time to protect the soil surface from rainfall. That may explain why experience with intercropping as a means of soil erosion control is mixed. Intercropping with groundnuts, pumpkins, squash or sweet corn was judged not very effective in Thailand, but growing cassava along with maize in Viet Nam and with mungbeans in Thailand was “quite effective”³².

More consistent results in reducing soil erosion have been achieved by planting cassava with protective hedgerows, or “live barriers”, a low-cost alternative to engineered soil conservation options such as contour bunds or bench terraces³³. Hedgerows filter and slow the rate of runoff and can be created using various recommended grasses, perennial legumes and other plants, or established naturally from native grasses and other species left as unhoed or unploughed strips in the field^{2, 34}. Farmers in several Asian countries protect their fields with hedgerows of vetiver grass (*Vetiveria zizanioides*), the shrub *Tephrosia candida*, the grass *Paspalum atratum* and closely-spaced pineapple. Vetiver grass, especially, is recommended for reducing severe erosion of already degraded land.

An added advantage of planting hedgerows is that, when pruned regularly, they provide *in situ* mulch, which makes these systems particularly effective in reducing erosion and less laborious than carrying mulch from elsewhere. Pineapples can be harvested and sold, while paspalum and other grasses can be cut and fed to cattle and buffaloes.

In trials in Viet Nam, monoculture of cassava without hedgerows produced yields of 19 tonnes per ha, but resulted in severe soil losses of more than 100 tonnes per ha. Intercropped with groundnuts, cassava root yields were slightly higher and soil losses fell to 65 tonnes, a big improvement but unsustainable in the long term. Cassava grown with groundnuts and vetiver hedgerows recorded the highest root yields, of 23.7 tonnes, the lowest soil losses, of 32 tonnes, and the highest net income of all the treatments tested (Figure 10).



In Thailand, intercropping cassava with cowpea (above) results in generally lower root yields, but enough cattle fodder to produce higher net income

Another type of intercropping is agroforestry, in which trees and perennial shrubs are grown along with crops. In India, cassava is grown under mature coconut palms and rubber trees³⁵. Cassava may also be planted in alleyways between rows of deep-rooting and fast-growing leguminous trees, such as *Leucaena leucocephala* and

Gliricidia sepium. The foliage is cut back regularly and the prunings are either incorporated into the soil of the alleys or – in a zero-till system – applied as mulch before the cassava is planted.

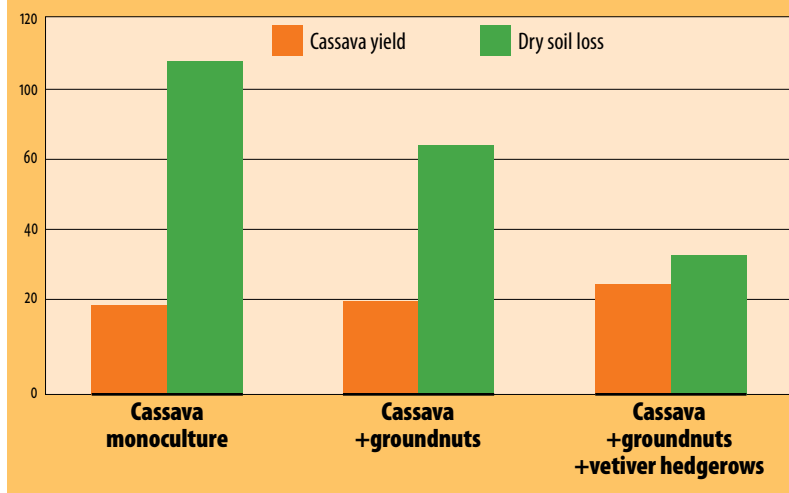
Since the trees fix large amounts of atmospheric nitrogen and their roots draw nutrients from deeper soil layers, the decomposition of prunings fertilizes the alley soil and boosts the yield of alley crops. In dryer climates, trees are deeper-rooting and thus compete less for water

and nutrients than other intercrops. In agroforestry systems with cassava, leaf cuttings from the forage legume *Flemingia macrophylla* were found to have a particularly positive effect on root yield³⁶. In Benin, a combination of mineral fertilizer and the application of 3 tonnes per ha of pigeon pea (*Cajanus cajan*) mulch led to significant root yield increases³⁷.

While cassava is rarely rotated with cereals in cassava-growing areas with poor soils and unpredictable rainfall, it is a common practice in cereal-growing areas in parts of Africa, where cassava's ample litter falls and post-harvest residues are used by farmers to maintain soil fertility. Maize yields benefit substantially from the nitrogen released by the decomposition of green, leafy cassava biomass³⁸.

In marginal areas where cassava is the main crop, it can be rotated with grain legumes, such as beans, groundnuts, mungbeans, cowpeas and soybeans, which fix atmospheric nitrogen and make it available to the successive cassava crop. In India, sequential cropping of cassava and cowpeas improved soil fertility to the point where applications of

Figure 10 **Yield and dry soil loss in response to crop management treatments, Viet Nam (t/ha)**



Source: Annex Table 2.6

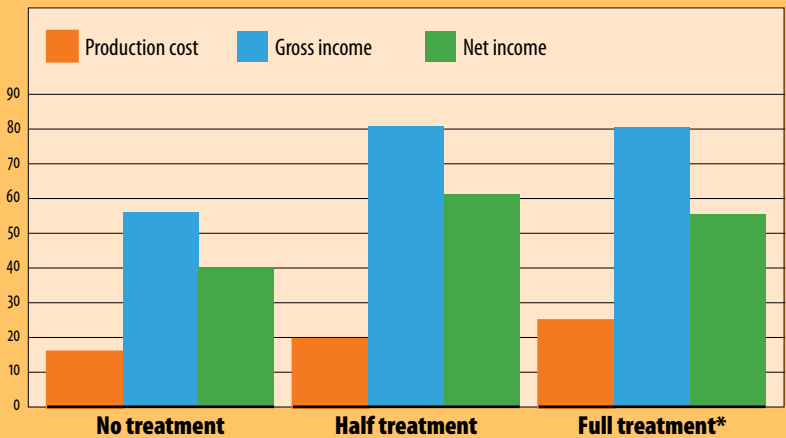
manure and mineral fertilizer could be reduced by 50 percent, with no yield loss. Thanks to savings on external inputs, income from the cowpea-cassava sequential cropping system exceeded that of production using full fertilizer treatments (Figure 11)³⁹.

A study in Colombia found that yields of mono-cropped, unfertilized cassava dropped from 37 tonnes to 12 tonnes per ha over a period of nine years. While moderate use, thereafter, of

fertilizer had no positive effect on productivity, a rotational scheme – using sunn hemp (*Crotalaria juncea*), maize, cassava, common beans, sorghum and cassava again – restored yields to 30 tonnes. Researchers concluded that soil nutrients were not deficient, but that the cassava had been unable to make use of them owing to biological soil degradation following years of continuous cassava production⁴⁰. In Thailand, a long-term experiment showed that rotating cassava yearly with groundnuts, followed by pigeon peas in the same year, contributed to a steady increase in cassava root yields, while yields under continuous cassava monocropping tended to decrease³¹.

Many smallholder cassava production systems already incorporate, to varying degrees, the three key “Save and Grow” practices of minimizing soil disturbance, using organic soil cover and improving system resilience through crop diversification and cropping sequences. Those practices provide the foundation for sustainable intensification of cassava production. However, they need to be supported by four additional “Save and Grow” practices: the use of well-adapted, high-yielding varieties and good quality planting material; efficient management of water resources; enhanced crop nutrition based on judicious use of mineral fertilizer combined with organic manures; and integrated management of insect pests, diseases and weeds. Those practices are described in the following chapters.

Figure 11 **Cost and benefit of sequential cropping with cassava and cowpea, India** ('000 Rs/ha)



* Full treatment= 26 kg/ha P + 25 tonnes/ha farmyard manure

Source: Annex Table 2.7