



SAVE AND GROW

Cassava

A GUIDE TO SUSTAINABLE PRODUCTION INTENSIFICATION



Save and Grow: Cassava
A guide to sustainable
production intensification
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Policy brief

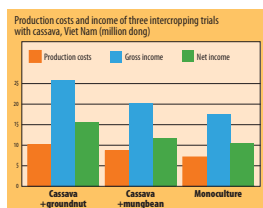
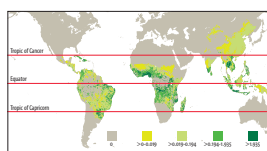
*How FAO's "Save and Grow" model
of agriculture can help make intensive
cassava farming more productive,
profitable – and sustainable*



Save and Grow: Cassava is the first in a series of guides to the practical application of FAO's ecosystem-based model of agriculture, which aims at improving productivity while conserving natural resources.

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. [page 4]



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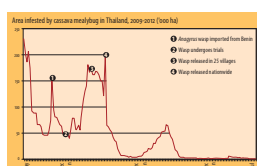
Once established, cassava can grow in areas that receive just 400 mm of average annual rainfall.



But much higher yields can be obtained with higher levels of water supply. [page 11]

The guide shows how “Save and Grow” can help cassava growers avoid the risks of intensification, while realizing the crop’s potential for producing higher yields, alleviating hunger and rural poverty and contributing to national economic development.

5 Crop nutrition. Combining ecosystem processes with judicious use of mineral fertilizer forms the basis of a sustainable crop nutrition system that produces more while using fewer external inputs. [\[page 13\]](#)



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high-tech starch gels – cassava is a truly multipurpose crop. [\[page 18\]](#)

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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 grown by smallholder farmers in more than 100 tropical and subtropical countries. Thanks to its efficient use of water and soil nutrients, and tolerance to drought and sporadic pest attacks, cassava can produce reasonable yields, using few if any inputs, in areas with poor soils and unpredictable rainfall.

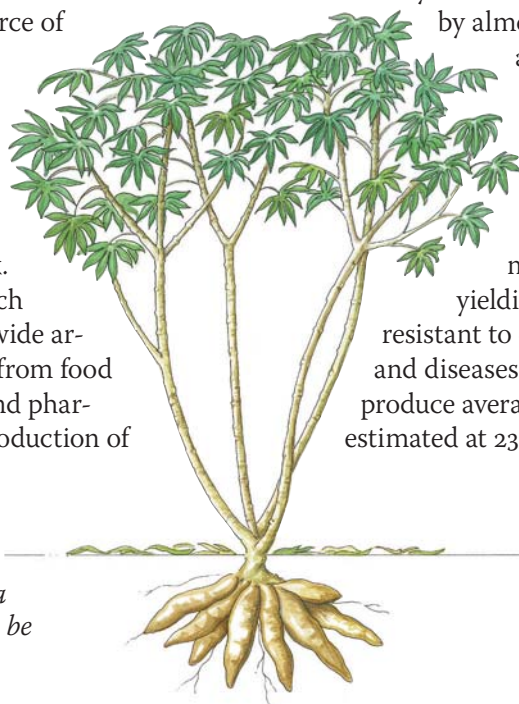
The roots of cassava are very rich in carbohydrates, which makes them an important source of dietary energy. They can be consumed fresh after cooking, processed into food products, or fed to livestock. Cassava root starch can be used in a wide array of industries, from food manufacturing and pharmaceuticals to production of

plywood, paper and bio-ethanol. In some countries, cassava is also grown for its leaves, which contain up to 25 percent protein.

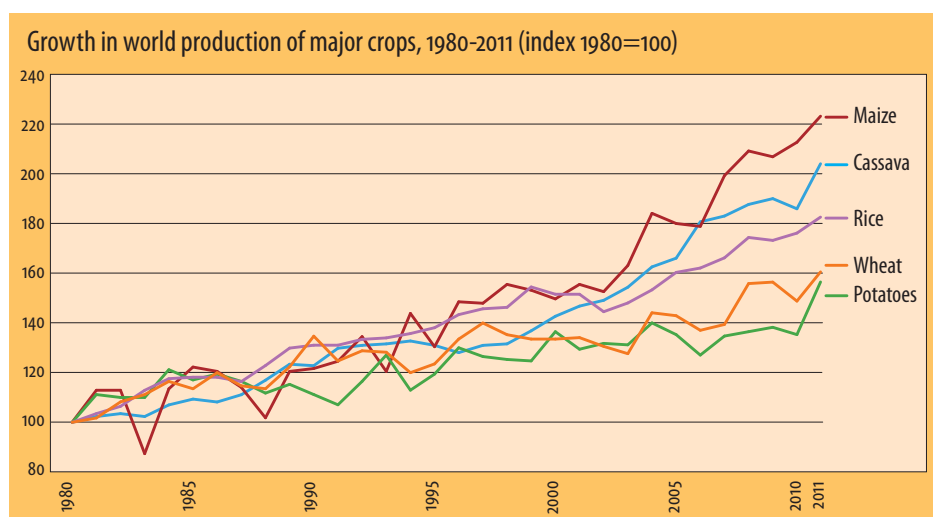
Among the world’s staple food crops, cassava was long seen as the least suited to intensification. The Green Revolution approach to intensification – based on the use of genetically uniform crop varieties, intensive tillage, irrigation, fertilizer and pesticide – has proven inappropriate for cassava in rainfed areas.

But cassava’s importance has changed dramatically. FAO estimates the global harvest in 2012 at more than 280 million tonnes, a 60 percent increase since 2000. Global average

yields have increased by almost 1.8 percent a year over the past decade, to 12.8 tonnes per hectare. With better crop and soil management, and higher yielding varieties more resistant to drought, pests and diseases, cassava could produce average root yields estimated at 23.2 tonnes.



Grown almost exclusively by low-income, smallholder farmers, cassava is one of the few staple crops that can be produced efficiently on a small scale



Between 1980 and 2011, world cassava production more than doubled, from 124 million to 252 million tonnes. Only maize output grew at a faster rate

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 developing countries’ priorities, 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.
- ▮ **Urban food security.** A major driver of production increases will be high cereal prices, which sparked global food price inflation in 2008.
- ▮ **Import substitution.** Domestically produced cassava flour can replace some of the wheat flour in bread.
- ▮ **Renewable energy.** Demand for cassava as a source of bio-ethanol is growing rapidly. Global output of bio-ethanol could reach 155 billion litres by 2020.

- ▮ **New industrial uses.** Cassava is second only to maize as a source of starch. Recent cassava mutations produce root starch that will be highly sought after by industry.
- ▮ **Adaptation to climate change.** Of the major staple crops in Africa, cassava is expected to be the least affected by climatic conditions predicted in 2030.

As market demand grows, cassava is likely to see a shift to increased monocropping on larger fields, the widespread adoption of higher-yielding genotypes, and higher rates of use of irrigation and agrochemicals. 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.

In promoting programmes for intensified cassava production, policymakers should consider the lessons of

the Green Revolution. While it led to a quantum leap in global cereal production, decades of intensive cropping have depleted the natural resources of many agro-ecosystems, jeopardizing their future productivity, and added to the greenhouse gases responsible for climate change. Applying the same model to cassava production carries similar risks.

FAO's ecosystem-based “Save and Grow” model of crop production intensification calls for “greening” the Green Revolution through farming practices that maintain healthy soil, cultivate a wider range of crop species and varieties in associations, rotations

and sequences, use well-adapted, high-yielding varieties and good quality seed, manage water efficiently to obtain more crops per drop, and control pests through integrated pest management.

This brief shows how “Save and Grow” principles can be applied to cassava production intensification. With “Save and Grow”, developing countries can avoid the risks of unsustainable intensification, while realizing cassava's potential for producing higher yields, alleviating hunger and rural poverty and contributing to national economic development.

2. Farming systems

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

FAO's “Save and Grow” farming model seeks to limit mechanical disturbance of the soil by minimizing the ploughing, harrowing or hoeing of land. Continuous conventional tillage with 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.

Crop yields are a function not of tillage, but of soil conditions. Cassava stakes can 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 compaction. In degraded soils, 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 – eliminating 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 base.

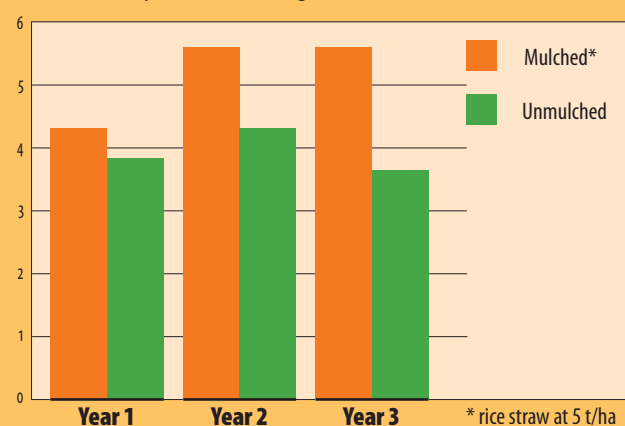
Cassava growers should be encouraged to adopt minimum tillage and, ideally, zero tillage, especially on well-aggregated, friable soils with adequate levels of organic matter. Even where conservation tillage produces lower yields, it offers farmers economic advantages: reduced spending on the fuel and equipment needed for conventional tillage, and the opportunity to produce cassava more intensively and sustainably, without the need for high levels of external inputs.

Reduced or zero 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 drainage.

Along with reduced or zero tillage, FAO recommends maintaining a protective organic cover on the soil, using crop residues and mulches, in order to protect the surface, reduce runoff and erosion, and suppress weeds.

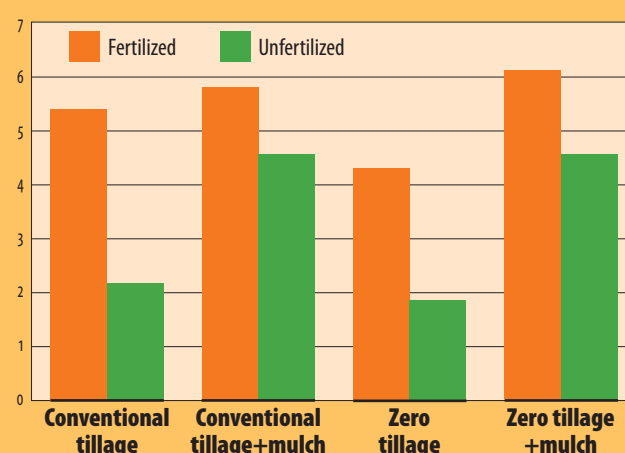
Ground cover is especially important in cassava production: because the initial growth of cassava is slow, the soil is exposed to the direct impact of rain during the first 2 to 3 months of its growth cycle, and the wide spacing between plants favours the emergence of weeds. Fast-growing

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



By improving physical soil conditions, mulch cover favours higher yields (above). Mulching helps farmers reap the full benefits of zero tillage (below)

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



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

legumes smother many unwanted weeds that normally proliferate during cassava establishment and after the cassava harvest, thus providing weed control that is less demanding than manual weeding and less expensive than spraying with herbicides.

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

In “Save and Grow”, farmers are encouraged to cultivate a wider range of plant species in associations, sequences and rotations that may include trees, shrubs and pastures. 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.



Smallholder cassava farmers in many parts of the tropics practise intercropping with early maturing crops, such as maize, upland rice and

various grain legumes. Intercropping protects the soil from the direct impact of rain, reduces soil erosion, and limits weed growth. It 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. Growing cassava with short-duration legumes also supplies both carbohydrates and protein, the foundation of a healthy diet for the farming household.

In marginal areas where cassava is the main crop, it can be rotated with grain legumes, such as groundnuts, mungbeans, cowpeas and soybeans, which fix atmospheric nitrogen and make it available to the successive cassava crop. Sequential cropping of cassava and cowpeas improves soil fertility to the point where applications of mineral fertilizer can be reduced, with no loss of yield.

3. Varieties and planting material

The full potential of cassava will not be realized until production constraints are mitigated in higher-yielding varieties, and cassava growers have reliable access to disease-free planting material.

The cassava genepool consists of the cultivated species *Manihot esculenta*, and some 100 wild species. Both wild relatives and traditional landraces are the primary sources of genes and gene combinations for new varieties.

Biotechnologists and molecular breeders have used cassava accessions in genebanks to determine which genes control specific traits. With the decreasing cost of molecular biology and biotechnology, the time is right to begin the genome-wide characterization of cassava genetic diversity and to fill gaps in germplasm collections before valuable diversity is lost.

Wild relatives of cassava could make an important contribution to the breeding of varieties suitable for low-input intensification. However, wild *Manihot* species have been poorly collected and are threatened in many of their native habitats. Action is urgently needed to create *in situ* reserves for wild *Manihot*.

The harmonization of data on genebank accessions, and more efficient data generation and dissemination, are needed to facilitate the acquisition of germplasm that could be used to augment locally available heritable variations for

cassava genetic improvement.

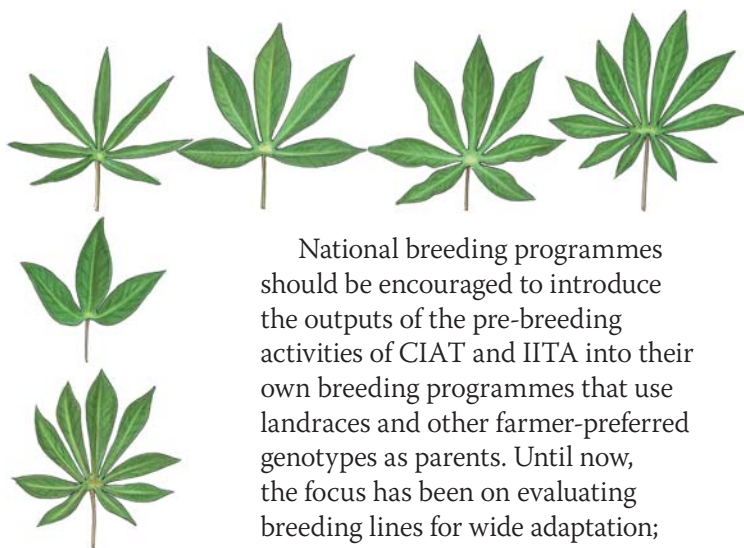
Through the International Treaty on Plant Genetic Resources for Food and Agriculture, FAO can provide a neutral platform for synergistic cooperation.

The breeding of higher-yielding varieties with resistance or tolerance to biotic and abiotic stresses has contributed to big increases in cassava yields over the past 30 years. The International Center for Tropical Agriculture (CIAT) has released clones with resistance to cassava bacterial blight and insect pests, and tolerance to root rot. In Africa, the International Institute of Tropical Agriculture (IITA) has produced improved varieties with traits such as resistance to cassava mosaic disease and green spider mites.

With climate change threatening agriculture in many parts of the world, breeding efforts will focus increasingly on “stacking” multiple traits in elite varieties. There should also be greater focus on developing locally adapted varieties that can produce very good yields for a range of end-uses, with minimal need for agrochemicals or irrigation.

Cassava roots are conical, cylindrical or irregular, and coloured cream, yellow and light to dark brown





Cassava plants have 3 to 11 smooth or winding leaf lobes, arranged spirally around the stem

National breeding programmes should be encouraged to introduce the outputs of the pre-breeding activities of CIAT and IITA into their own breeding programmes that use landraces and other farmer-preferred genotypes as parents. Until now, the focus has been on evaluating breeding lines for wide adaptation; that work must now be complemented by introgressing traits from locally adapted materials.

Farmer participation in variety trials and selection criteria needs to become a key step in the development of new varieties. Farmers' criteria must inform all stages of selection, and trials in farmers' fields should begin as early as possible in the selection process.

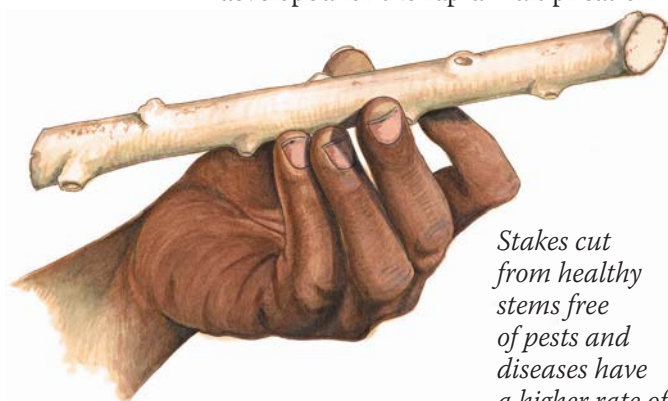
The availability and use of high quality planting materials that maintain genetic purity and are free of diseases and pathogens are crucial to intensified cassava production. Although protocols have been developed for the rapid multiplication

of cassava, few countries have a formal cassava seed system.

In the absence of such systems, cassava development programmes in Africa have used a 3-tier community-based approach for rapid multiplication. At the top level, material from breeders is multiplied on research stations and government farms to produce clean, healthy foundation seed. The secondary level involves further multiplication on farms often run by farmer groups and NGOs. Certified material is then distributed to tertiary multiplication sites in farming areas.

Elsewhere, the use of poor-quality planting material remains one of the major causes of low yields. Farmers can help to improve the situation with improved agronomic practices. They should cut stems from vigorous plants that show no symptoms of pests or diseases. Cut stems need to be stored upright in the shade, with the base of the stems resting on soil that has been loosened with a hoe and is watered regularly. Stakes cut from stems should be about 20 cm long, with 5 to 7 nodes, and soaked for 5 to 10 minutes in hot water to kill pests or disease-causing organisms that might be present.

Farmers can increase the size of their next cassava harvest by cutting stakes only from well-fertilized plants with high yields. That simple practice will markedly increase production, especially of traditional varieties that may be susceptible to pests and diseases.



Stakes cut from healthy stems free of pests and diseases have a higher rate of sprouting and produce higher root yields

4. Water management

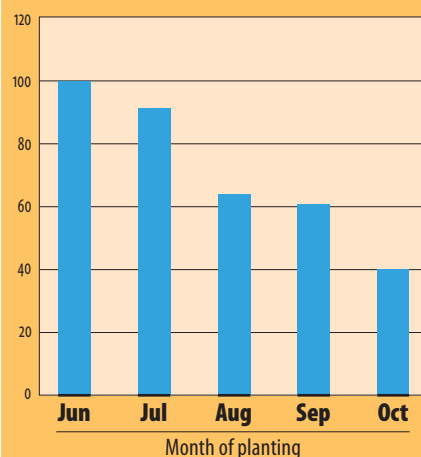
Once established, cassava can grow in areas that receive just 400 mm of average annual rainfall. But much higher yields can be obtained with higher levels of water supply.

Although cassava can withstand periods of drought, it is very sensitive to soil water deficit during the first three months after planting. Water stress at any time in that early period reduces significantly the growth of roots and shoots, and impairs subsequent development of the storage roots.

Once established, cassava can grow in areas that receive just 400 mm of average annual rainfall. But higher yields have been obtained with much higher levels of water supply. Research in Thailand indicates that maximum root yields are correlated with rainfall totalling about 1 700 mm during the fourth to eleventh month after planting. Cassava also responds well to irrigation. In trials in Nigeria, root yields increased sixfold when the quantity of water supplied by supplementary drip irrigation matched that of the season's rainfall.

In most parts of the world, cassava is almost exclusively a rainfed crop. In areas with only one rainy season per year, farmers usually plant as soon as the rains start. Delaying planting can lead to drastic yield reductions. In areas with two relatively short

Effect of planting date on root yield of late season cassava, Nigeria (%)

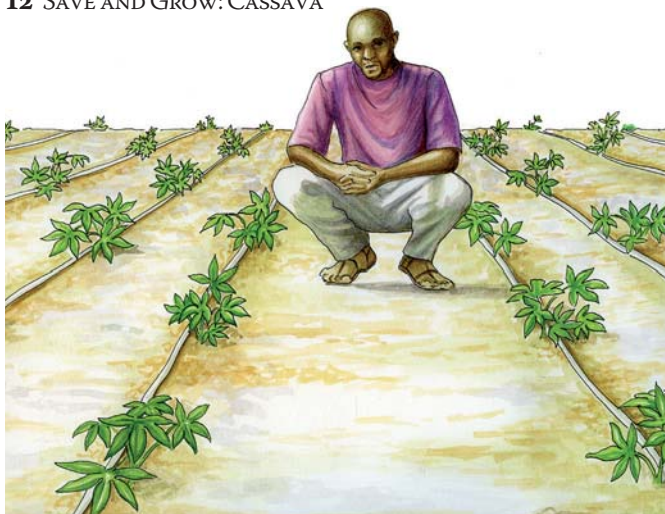


Delaying planting beyond June in southern Nigeria can lead to drastic yield reductions, of up to 60 percent

rainy seasons per year, cassava can be planted in the early or middle part of either rainy season and harvested after 10 to 14 months, preferably during the dry season.

Planting early in the rainy season will generally produce the highest yields because the plants have adequate soil moisture during the most critical part of their growth cycle. However, research has shown that yields may vary according to the variety used, the soil type, the plant's age at harvest, and the rainfall intensity and distribution during any particular year.

Planting methods need to be tailored to soil moisture conditions under rainfed production. When the soil is not well-drained and too wet owing to heavy rains, it is better to plant stakes on the top of ridges



With drip irrigation, researchers have increased root yields from 4.6 to 28 tonnes per hectare

or mounds to keep the roots above standing water.

However, where cassava is planted during dry periods, the rates of stake sprouting and plant survival are significantly higher when cassava stakes are planted on the flat, owing to the slightly higher soil moisture content of the topsoil. Stakes should be planted at a shallow depth, of 5 to 10 cm, in heavy and wet soils, but slightly deeper in light-textured and dry soils to avoid surface heat and lack of moisture.

If the first rains are intense, the risk of waterlogging is greatest in shallow soils, and in poorly drained soils compacted by heavy tilling equipment. The risk of waterlogging can be reduced with zero tillage, which improves internal drainage. Where tillage is practised, soil should be prepared when it is not too dry or too wet. If necessary, a subsoiler can be used to break up the compacted soil layer.

Planting towards the end, rather than at the beginning, of the rainy season usually results in lower yields, but it has some advantages: less weed competition and – if the crop

is harvested in the off-season – the possibility of higher market prices. Another advantage is that the late planting of cassava does not coincide with other major agricultural activities, so there is less competition for labour.

Cassava benefits from supplemental irrigation during rainless periods. Research in India found that during periods of drought, yields increased with increasing amounts of surface irrigation water applied. Full irrigation, at 100 percent of crop water requirements, doubled the root yield obtained without irrigation.

Drip irrigation makes more efficient use of water by providing small, frequent applications, which saves water while maintaining soil moisture at a level that is highly favourable to crop growth. In trials in India, drip irrigation produced about the same root yields as flood irrigation – around 60 tonnes per ha – using 50 percent less water. When the water applied through drip irrigation was equal to that used in flood irrigation, yields continued to increase substantially, to 67.3 tonnes per hectare.

Similar results were reported from experiments in south-western Nigeria. In plots under supplemental drip irrigation, yields rose sharply with increasing levels of water applied. Yield increases at low application rates were significant – irrigation that boosted the water supply by 20 percent almost doubled yields.

5. Crop nutrition

Combining ecosystem processes with judicious use of mineral fertilizer forms the basis of a sustainable crop nutrition system that produces more while using fewer external inputs.

Cassava is highly tolerant to acid soils, and has formed a symbiotic association with soil fungi that help its roots take up phosphorus and micronutrients. Since most of the absorbed nutrients are found in the stems and leaves, returning them to the soil helps maintain soil fertility for the next crop.

Its ability to produce reasonable yields on poor soils has given rise to the belief that cassava does not require, nor even respond to, mineral fertilizer. The results of extensive trials reviewed by FAO have shown, instead, that many cassava varieties benefit from fertilization. Cassava's

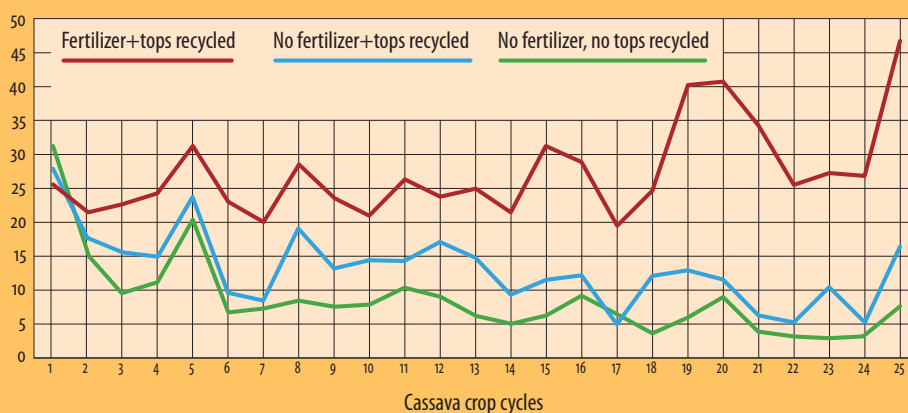
need for fertilizer is increasing, as traditional means of maintaining soil fertility are abandoned under more intensive production systems.

Cassava yields could be increased markedly if farmers had access to mineral fertilizer at a reasonable price. In the Democratic Republic of the Congo, the use of improved varieties and mineral fertilizer, led to increases in cassava root yields of 30 to 160 percent.

Initially, cassava should be fertilized with about equal amounts of nitrogen (N), phosphorus (P) and potassium (K). However, if the crop is grown continuously for many years, the N-P-K balance will need to be modified to compensate for the removal of nutrients, especially potassium, in the harvest.

That can be done using compound fertilizers that are high in K and N, and relatively low in P.

Effect of mineral fertilizer and crop residue management on cassava root yields over 25 crop cycles, Thailand (t/ha)



When no fertilizer was applied and plant tops were removed from the field, per hectare yields declined sharply in Thailand

To cut their input costs, farmers should reduce volatilization of nitrogen and losses of nutrients to runoff and erosion by always covering the applied fertilizers with soil. The supply of nitrogen fertilizer can



Tithonia diversifolia, a wild tropical sunflower, makes nutrient-rich mulch

also be optimized with urea compressed into supergranules or urea prills coated with cake made from neem seed oil. Both technologies slow considerably the nitrification of urea, reducing losses to the air and to surface water runoff.

While mineral fertilizer can help to boost yields, alone they cannot sustain crop production in the long-term on degraded land. Farmers can maintain and improve soil quality and health using a number of other “Save and Grow” measures:

- ▀ **Intercropping** with grain legumes make some nitrogen available to the cassava crop. In Nigeria, after two years of cassava-soybean intercropping, incorporation of soybean residues led to yield increases of 10 to 23 percent. Research at two locations in the Democratic Republic of the Congo found that planting four rows of groundnuts between widely spaced rows of cassava also boosted root yields.
- ▀ **Alley cropping** with fast-growing leguminous trees may also be an effective means of improving soil fertility. In Viet Nam, alley cropping with two leguminous tree species, *Leucaena leucocephala* and

Gliricidia sepium, had a marked and consistent long-term beneficial effect on cassava, both when it was fertilized and when it was not fertilized.

- ▀ **Green manuring** – i.e. mulching legume crop residues prior to planting cassava – also improves soil fertility. Effective green manures include cowpeas, groundnuts, pigeon peas and velvet beans. In Colombia, mulching native legumes led to yield increases similar to those obtained with mineral fertilizer. In the Democratic Republic of the Congo, incorporating into the soil 2.5 tonnes per ha of dry matter of the wildflower *Tithonia diversifolia* produced a higher cost-benefit ratio than use of mineral fertilizer.
- ▀ **Animal manure and compost** are good sources of organic matter, which improves soil structure, enhances water holding and cation exchange capacity, supplies micronutrients, and promotes the below-ground activity of earthworms, bacteria and fungi. In trials in Indonesia, a combination of 5 tonnes of compost with judicious use of mineral fertilizer produced higher yields than fertilizer alone.

Control of soil erosion is essential for sustainable soil fertility management. Growing cassava tends to cause more soil losses to erosion than most other crops, especially where farmers do not use cover crops or mulches to protect the soil.

“Save and Grow” practices reduce runoff and erosion significantly. One

option is minimum or zero tillage, which slows the decomposition of organic matter and maintains soil aggregate stability and internal drainage. If the land is prepared using conventional tillage, ploughing and ridging on slopes needs to be done along the contour, and contours should be planted with non-competing hedgerows of grasses or

shrub- or tree-legumes to slow water runoff and trap eroded sediments.

Research in Colombia and in several Asian countries has shown that all erosion control measures were enhanced by applying mineral fertilizer, which leads to faster soil coverage by the plant canopy.

6. Pests and diseases

Protecting cassava with pesticide is usually ineffective and hardly ever economic. A range of non-chemical measures can help farmers reduce losses while protecting the agro-ecosystem.

Like other crops, cassava is vulnerable to pests and diseases that can cause heavy yield losses. In some regions, the incidence of pests and diseases is increasing as the crop is grown more intensively over larger areas and planted throughout the year for industrial processing.

Because synthetic insecticide, fungicide and herbicide disrupt the

natural crop ecosystem balance, and can exacerbate pest and disease problems, “Save and Grow” seeks to minimize their use through integrated pest management (IPM), a plant protection strategy that enhances the biological processes and biodiversity that support crop production. A range of sustainable, non-chemical measures can help cassava growers reduce losses to insect pests and diseases.

► *Bacterial blight*, one of the most widespread of the cassava diseases, is transmitted by infected planting material and farm tools. It can be controlled by using varieties with good tolerance, soaking stakes



Friends and foes of cassava. At left, the whitefly and cassava mealybugs, often responsible for heavy yield losses. At right, two natural enemies of cassava insect pests: Coccinellidae beetles and the African lacewing



Missshapen leaves, lack of chlorophyll, mottling and wilting: symptoms of cassava mosaic disease

in hot water before planting, sterilizing tools with disinfectant, and intercropping to reduce plant-to-plant dissemination.

- *Viral diseases* are usually transmitted through infected planting material. In addition, whiteflies are vectors for viruses that cause cassava mosaic disease (CMD) and cassava brown streak disease (CBSD), which can cause total crop failure. Key recommendations for control of CMD and CBSD are strict enforcement of quarantine procedures during international exchange of germplasm, and cultural practices, especially the use of resistant or tolerant cultivars and virus-free planting material.
- *Root rots* occur mainly in poorly drained soils during intense rainy periods. In Colombia, farmers eliminated root rot by planting stakes taken from healthy mother plants, using ashes and dry leaves as a soil amendment and fertilizer, and intercropping with cowpeas. An effective biological control is immersion of stakes in a suspension of *Trichoderma viride*, a soil fungus that parasitizes other soil-borne fungi.
- *Whiteflies* are probably the most damaging insect pest in all cassava-producing regions. Although some farmers use insecticide to control whiteflies, spraying is usually ineffective. Not spraying insecticide, on the other hand, allows biological control by the whitefly's natural enemies. A two-year experiment in Cameroon found that intercropping cassava with maize and cowpeas was associated with a drop of 50 percent in the adult whitefly population and a 20 percent reduction in the incidence of cassava mosaic disease.
- *Mealybugs* feed on cassava and inject a toxin that causes leaf withering. A region-wide outbreak of mealybug in sub-Saharan Africa was brought under control with the introduction of a natural enemy from South America, *Anagyrus lopezi*, a tiny wasp that lays its eggs in the pest (the growing larvae kill their host). A serious outbreak of mealybug in Thailand in 2009 was overcome rapidly by the release of 3 million pairs of *A. lopezi* across the infested area.
- *Cassava mites* are a major pest in all cassava-producing regions. The introduction of green mites

from Latin America devastated African cassava production in the early 1970s. They were brought under control by a predatory mite introduced from Brazil, which reduced substantially the damage caused by the pest. Cassava mites can also be controlled using resistant or tolerant varieties, and by fertilizing the crop to improve plant vigour.



Some cassava pests and diseases have been accidentally introduced on plant species closely related to cassava, such as *Jatropha curcas*. Special care must be taken in moving vegetative planting material of related species between countries, and large *Jatropha* plantations should not be located in cassava-growing regions.

Cassava's slow initial growth

gives weeds a chance to emerge and compete strongly for sunlight, water and nutrients. "Save and Grow"

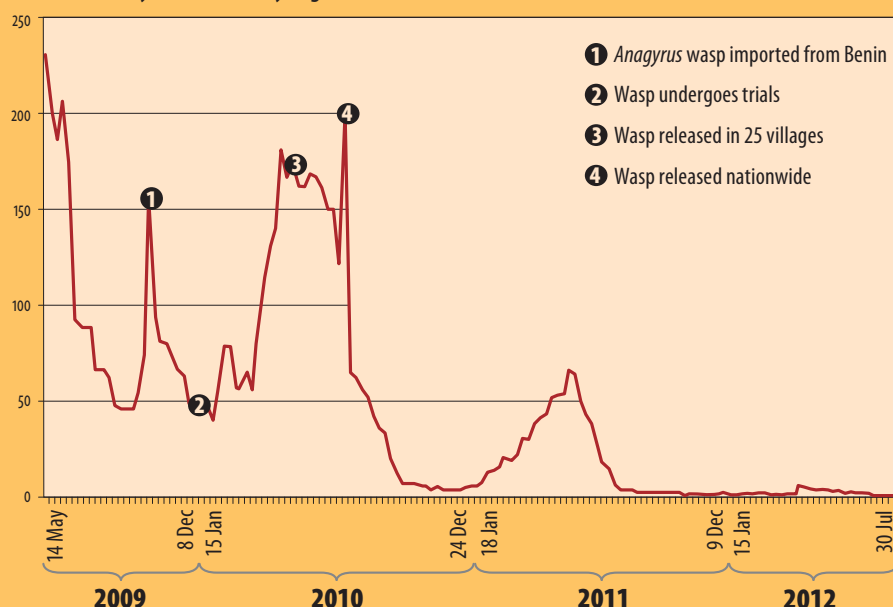
cultural practices to control weeds include encouraging vigorous early growth with fertilization and – in the dry season – drip irrigation, covering the soil with mulch, and intercropping with fast-growing, short-duration crops that can be harvested when the cassava canopy closes and weeds are shaded out.

Hand-weeding at 15, 30, 60 and 120 days after planting has helped achieve cassava root yields of 18 tonnes per ha, only 8 percent less than those obtained when weeds were controlled with herbicides.

However, herbicides are often used on larger farms or when labour is unavailable or is too expensive. Since many products are highly toxic, farmers need to exercise care in the choice of herbicide and follow the advice of local plant protection specialists. Products should be locally registered and approved, and carry clear instructions for their safe handling and use.



Area infested by cassava mealybug in Thailand, 2009–2012 ('000 ha)



Thailand's secret weapon in defeating a devastating nationwide outbreak of cassava mealybugs was the tiny wasp *Anagyrus lopezi* (above)

7. Harvest, post-harvest and value addition

Food for the household, feed for livestock, and raw material for a wide array of value-added products, from coarse flour to high-tech starch gels – cassava is a truly multipurpose crop.

Cassava roots may be harvested at any time between 6 and 18 months after planting. During food shortages, they can be harvested as needed, often one plant – or even one root – at a time. Once harvested, roots are consumed directly by the farm household, fed to livestock or sold for processing into a wide array of value-added products. However, harvested roots deteriorate rapidly and processing must begin within 48 hours.

The root is not the only part of the plant that can be put to good use. Cassava leaves can be cooked as a vegetable or used for raising silkworms. The green part of the upper stem is fed to cattle and buffaloes, and the leaf-blades to pigs and chickens. Stumps are burned as fuelwood, and woody stems are ground-up and used as substrate for growing mushrooms.

Food for direct consumption. Young cassava leaves are regularly picked and cooked for human consumption in Central Africa. The tender leaves contain up to 25 percent protein and are a valuable source of iron, calcium, and vitamins A and C. The market

value of cassava leaves in areas where they are consumed is often higher than that of the roots.

Cassava roots are washed and peeled before being boiled, steamed or roasted. In West Africa, grated roots are fermented, then roasted to produce a granulated flour called *gari*, or sun-dried, milled and mixed with water to make a stiff dough called *fufu*. In Indonesia, thinly sliced roots are fried, covered with spices and sold in local markets.

High quality cassava flour (or HQCF) is not fermented and can be used as substitute for wheat flour in bread and confectionary. Native starch extracted from the roots is used in many food products. Starch extraction can be done at almost any scale – in backyard artisanal production units and in large-scale fully mechanized factories. Many artisanal starch production units operate in Cambodia, India, Indonesia and Viet Nam, with daily output of 60 kg per worker. Semi-mechanized plants yield up to 10 tonnes a day.

Industrial uses. Modified cassava starch is produced, mainly in Asia, for use as feedstock for production of sweeteners, fructose, alcohol and monosodium glutamate, and in plywood, paper and textiles. In modern starch extraction plants, daily output is as high as 300 tonnes.



In Central Africa, tender young cassava leaves are regularly picked and cooked as a protein-rich vegetable

Increasingly, cassava is also being used for production of fuel ethanol; in 2012, China produced 780 million litres of bio-ethanol from 6 million tonnes of dried cassava. Two recent cassava mutations could expand considerably cassava's use in industry: an induced mutation with very small starch granules, which offer a faster rate of hydrolysis than other starches, and a spontaneous mutation with amylose-free starch that rivals premium "waxy" maize starch.

Animal feed. Both the roots and leaves of the cassava plant can be used as on-farm animal feed or as an ingredient in commercial animal feed. In Asia, small farmers and their

marketing partners provide large amounts of cassava chips for the animal feed export industry. Sun-dried chips are milled into a powder that can be mixed with vegetable protein sources to make a nutritious animal feed. Animals raised on cassava diets have generally good health, good disease resistance and a low mortality rate, and require few if any antibiotics in their feed.

Dry cassava leaf meal (or "cassava hay") is usually obtained by cutting the plant tops at 2.5 to 3-month intervals during the cassava growth cycle. Research has shown how supplementation with 1 to 2 kg of cassava hay per animal per day increases the milk yields of dairy cows and may enhance milk quality and storability.

Leaf silage is made from chopped leaves mixed with small amounts of cassava root meal or rice bran. Sealed in air-tight containers, the leaves ferment and after about 90 days are ready to be fed to pigs and cattle. In experiments in Viet Nam, a diet containing 15 percent ensiled cassava leaves improved the daily weight gain of pigs and reduced their feed costs by 25 percent.

8. Policies that save and grow

Sustainable intensification of cassava production calls for political commitment, investment, institutional support and a demand-driven approach to technology development.

In most countries, cassava production is labour-intensive and subsistence-oriented, with low levels of technology uptake, high production costs and post-harvest losses, and weak linkages to markets. Transforming the subsector will require the identification of profitable value chains and market preferences, as well as strategies for reducing price variability and enhancing the quality, volume and reliability of production. There is no “one-size-fits-all” set of recommendations. But it is possible to identify the key features of enabling policies and institutions for sustainable intensification of smallholder cassava production.

Promote “Save and Grow” farming approaches and practices. In many countries, low-input production systems already incorporate key “Save and Grow” practices, such as reduced tillage, the use of cover crops and mulches, and mixed cropping. Extension services will be crucial in building on those practices by ensuring access to relevant external knowledge and linking it to the wealth of knowledge held by smallholders.

Cassava growers may need incentives to manage ecosystem services such as soil conservation and protection of biodiversity.

Facilitate improvements in the input supply chain. Governments should encourage private investment in the production of inputs, and establish credit lines to enable private suppliers to organize bulk procurements that ensure their timely availability. Institutions that facilitate participation, such as farmer organizations, help to reduce the transaction costs of accessing input markets. While “smart subsidy” schemes can help smallholders to purchase fertilizer at below-market prices, group-based revolving credit funds are a more sustainable source of financing.

Control pest and disease threats. Cassava intensification programmes should promote integrated pest management, which draws on resistant cultivars, biological control agents, bio-pesticides and habitat management to protect crops. Increased international movement of cassava germplasm will require improved phytosanitary measures to ensure that planting material is free of pests and diseases. Robust detection and diagnostic methods to prevent the movement of pathogens are essential for improving quarantine security

and bringing national phytosanitary regulations into line with international trade conventions and protocols.

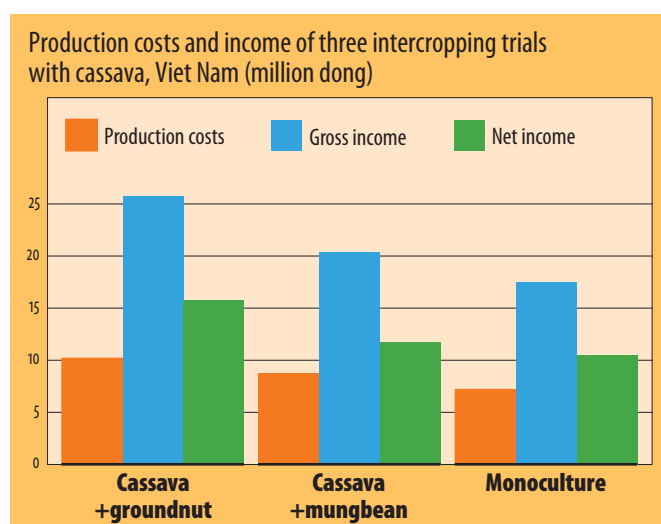
Support cassava research and technology development. Applied research can facilitate the cassava transformation by helping to develop varieties with disease- and pest-resistance, water-efficient irrigation technologies, and appropriate farm machinery. Policies should foster public-private partnerships for technology development, and link them to markets in order to facilitate the up-scaling of successful innovations. For example, Thailand's Tapioca Development Institute is working with CIAT and Kasetsart University to breed "waxy" starch cassava varieties adapted to Thai growing conditions.

Improve rural infrastructure. Investment in roads, warehousing and processing capacity in production zones will help to link cassava farmers and processors to growing markets for intermediate products that have a longer shelf life. It will also contribute to price stabilization, reduce post-harvest losses and lower transaction costs. With appropriate technology and equipment, community-level processing plants could produce high quality cassava flour, grits and chips for rural and urban-based industries, allowing growers to retain a bigger share of the value-addition.

Develop value chains and markets. Governments should promote private investment in cassava processing, and

foster associations that link growers and processors. Cassava industry stakeholders may need assistance in initiating industry-wide or activity-specific associations. Planners should link support to the cassava subsector with action to develop associated industries – for example, increasing output of high quality cassava flour will require the strengthening of links with the bakery industry.

Reduce farmers' exposure to price volatility. Guaranteeing farmers a reasonable price for



their crops will encourage them to invest in production. One approach is government subsidies. More sustainable approaches include contract farming, which helps to reduce the transaction costs of input supply and output marketing by aggregating small parcels of farmland. Governments in developing countries should also foster greater availability of crop insurance which improves farmers' capacity to bear risk.

"Save and Grow" farming practices, such as mixed cropping, generate higher net income than monoculture

9. Letting farmers decide

Incorporating sustainable natural resource management into smallholder production systems requires a shift in research and extension from “teaching” to “learning”.

Cassava growers will need to be convinced that ecosystem-based “Save and Grow” farming practices are better than those they are already using, and – very importantly – that they have short-term economic benefits. It is important, therefore, that cassava growers be involved in all stages of agricultural research and technology development, and that they test and validate practices aimed at improving the productivity and sustainability of their production systems.

Farmer participatory research (FPR) emerged in the 1990s in response to the failure of top-down agricultural research to deliver significant improvements in the well-being of low-income farmers in risk-prone environments. The difference between

FPR and the traditional “technology transfer” approach is that extension workers do not promote or recommend any particular practice or technology. Instead, they provide a menu of options that farmers can test in trials in their own fields, with help from research or extension staff.

The International Center for Tropical Agriculture has used farmer participatory research extensively in Asia for the development and transfer of cassava production technologies. With FPR, members of a farmers’ group, or farmers in a particular

village or district, diagnose the main problems encountered in cassava production and consider possible solutions.

The farmers then design and conduct trials of 3 to 5 alternative treatments, along with one traditional practice. At harvest time, all farmers in the area are invited to a field day where they view the trials and discuss the results.

During the field day, staff present the average results of the various types of trials, as well

Bringing home the harvest. Worldwide, cassava growers produced an estimated 280 million tonnes of fresh roots in 2012



as the production costs, gross income and net income of each treatment. Based on this information, farmers can select those treatments that they consider most suited to their own conditions.

An independent impact assessment found that, in Thailand, 100 percent of the farmers who participated in trials had adopted improved varieties, and 98 percent the use of mineral fertilizer. In one province of Viet Nam, improved technologies and agronomic practices boosted average per hectare root yields from 8.5 tonnes in 1994, when the trials began, to 36 tonnes in 2003.

The Asian trials have also shown clearly that farmers prefer those treatments which produce both sustainable yields and the highest net income.

Farmer field schools (or FFS) encourage a process of group-based learning, and were originally developed by FAO in the late 1980s to promote integrated pest management (IPM) in Asian rice fields. At field schools, farmers are able to deepen their knowledge of agro-ecosystem processes, and test practices that control pests and diseases and improve the sustainability of crop yields.

In Africa, the spread of new strains of the viruses causing cassava mosaic disease and, more recently, cassava brown streak disease, have served as an entry point for promoting IPM and eco-friendly production. Field schools link up with programmes that distribute disease-tolerant

cassava varieties and test them in multiplication fields. This learning-by-doing approach provides the opportunity for farmers to develop strategies to manage disease problems more effectively, while improving their cassava production practices.

In the Democratic Republic of the Congo, an FAO project trained facilitators to assist 30 field schools in Kinshasa province, where yields of cassava had been declining owing to pest attacks, diseases and soil nutrient depletion. Through training in the use of healthy planting material, mulching and intercropping, the field schools helped farmers achieve yield increases of up to 250 percent.

In Gabon, pest and disease pressure, the lack of improved varieties, and the use of inefficient farming methods kept smallholder cassava root yields below 8 tonnes per ha. Through field schools, some 750 growers improved their skills in the selection of healthy planting material. Many began using higher-yielding varieties with resistance to cassava mosaic disease, as well as improved practices, such as avoiding cultivation in wet soils and planting stakes along the contours of sloping land to limit damage from root rot. They also learned the importance of regular weeding, planting in rows and optimizing planting densities.

An evaluation in 2012 found that, thanks mainly to the use of high yielding varieties, IPM and resource-conserving cultivation practices, the farmers had increased their cassava yields threefold. In one province, yields reached 30 tonnes per hectare.



Booming demand for cassava offers millions of farmers the opportunity to intensify production, earn higher incomes and boost the food supply where it is needed most. But a shift to intensive monocropping of cassava carries risks, including an increase in pest and disease pressure, and the depletion of soil nutrients. FAO's "Save and Grow" model of agriculture can help cassava growers achieve higher levels of productivity, while conserving natural resources.

Save and Grow: Cassava
A guide to sustainable production
 intensification (FAO, 2013)



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