A detailed illustration of a cassava tree. The tree has a slender, light-brown trunk that branches out into several smaller stems. The leaves are green and have a characteristic three-lobed shape. The root system is shown below the ground line, consisting of several thick, elongated, light-brown tubers. The background is a light, textured greenish-yellow.

Chapter 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.*

One of the major positive attributes of cassava is that it does not have a specific harvesting period. Roots may be harvested any time between six months and two years after planting. During periods of food shortage, they can be harvested whenever needed, often one plant – or even one root – at a time. For human consumption, harvesting usually takes place at about 8 to 10 months; for industrial uses, a longer growing period generally produces a higher root and starch yield. Once harvested, roots can be consumed directly by the farm household, fed to livestock or sold for processing into a wide array of value-added products, ranging from coarse flour to high-tech modified starch gels.

The root is not the only part of the plant that can be put to good use. In Africa, cassava leaves are cooked as a vegetable. In many countries, the green part of the upper stem, including leaves and petioles, are fed to cattle and buffaloes, while the leaf-blades are fed to pigs and chickens. In China, Thailand and Viet Nam, fresh leaves are used for raising silkworms. Stumps are burned as fuelwood, and woody stems are ground-up and used as a substrate for growing mushrooms.



Harvesting roots and plant tops

Cassava roots are generally harvested by cutting off the stems about 20 cm above ground, then lifting the whole root system out of the ground by pulling on the stump. If the soil is too hard or the roots are too deep, it may be necessary to dig around the roots with a hoe, spade or pick to remove the soil, avoiding damage to the roots in the process.

To harvest their cassava, Thai farmers have developed a metal tool that is attached to a pole and used as a lever. It works best in loose or light-textured soils. In heavier soils, which can become very hard in the dry season, a harvesting blade attached to a tractor is sometimes used. The blade cuts through the soil just below the roots and the forward movement of the tractor pushes the root clumps to the surface. The roots are then cut from the stump and placed in baskets or sacks for transport.

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

The harvest of large cassava fields is often done by middlemen who employ teams of workers and use trucks to transport the roots to markets or processing plants. In Viet Nam, roots are often carried home in two baskets hanging on a shoulder pole; in Lao PDR, farmers use bamboo shoulder baskets. In China, the harvested roots are generally transported in a wagon attached to a 2-wheel tractor, while in Thailand, many farmers use a small agricultural truck.

After the root harvest, plant tops are often left to dry on the ground and later incorporated in the soil to help maintain its fertility (see Chapter 5, *Crop nutrition*). However, farmers can greatly increase the total amount of cassava foliage available for feeding to animals by cutting the green tops every 2.5 to 3 months during the plant's growth cycle. After each pruning, the remaining stems will sprout again and produce another crop of leaves within 2 to 3 months. For maximum foliage production, cassava stakes should be planted with closer spacing, of about 60 x 60 cm.

Young leaves harvested at regular intervals during the cassava growth cycle tend to have a higher protein and lower fibre content than those collected at the final root harvest, when plants are normally 11 to 12 months old. The younger leaves are more palatable and provide a higher quality feed. Similarly, leaf meal containing only leaf-blades has a higher protein and lower fibre content than meal that also contains petioles and green stems.

In an experiment in Thailand, total dry leaf yield was 710 kg per ha when leaves were harvested only at the time of root harvest, at 11.5 months after planting (Annex table 7.1). But the yield increased to 2.6 tonnes when leaves were cut five times during the same period. The total leaf protein yield also increased, from 170 kg with only one leaf harvest to 650 kg, similar to a good crop of soybeans^{1, 2}. However, as the frequency of leaf cutting increased, the final root yield dropped, from around 40 tonnes per ha when leaves were harvested only at the time of the root harvest, to less than 25 tonnes when leaves were harvested a total of five times². Depending on the cost of labour and the relative prices of fresh roots and dry leaves, this system may or may not be economic.

Harvesting the plant tops 4 or 5 times during a one-year growth cycle also removes a large amount of nutrients – especially nitrogen – from the field, and would not be sustainable without the application of large amounts of mineral fertilizer to maintain soil fertility.

Post-harvest uses and value addition

Food for direct consumption

Young cassava leaves are regularly picked and cooked for human consumption in several African countries, notably Cameroon, the Democratic Republic of the Congo, Liberia and the United Republic of Tanzania. The tender leaves contain up to 25 percent protein, on a dry matter basis, and are a valuable source of iron, calcium, and vitamins A and C³. The essential amino acid content of cassava leaf protein is similar to that found in a hen's egg. The market value of cassava leaves



in areas where they are consumed is often higher than that of the roots, indicating that their sale contributes significantly to farm household incomes⁴.

Cassava leaves are prepared by removing the hard petioles, then pounding the blades and young petioles with a pestle and mortar, and boiling the resulting pulp for about 30 to 60 minutes. That process eliminates cyanogens and makes the leaves safe to eat. However, prolonged boiling also results in considerable loss of vitamin C⁵.

Cassava roots deteriorate rapidly and must be processed within a few days of harvesting. In many parts of Brazil, fresh roots are grated and the liquid, which contains much of the roots' cyanide content, is pressed out. The semi-dry mash is then roasted to produce *farinha*, a coarse flour that is spread on many Brazilian dishes. In Africa, grated roots are fermented before being roasted on a hot plate to produce a granulated flour called *gari*, or sun-dried and milled into flour, which is mixed with water to produce a stiff dough called *fufu*.

Steaming is used in Côte d'Ivoire and Benin to make another granulated cassava product, called *attiéké*. In the Democratic Republic of the Congo, pounded cassava flesh is wrapped in banana leaves and

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

steamed for several hours to make cassava bread or sticks, called *chick-wangue* or *kwanga*, which are served with soups, stews and sauces.

In Indonesia, peeled roots are sliced lengthwise then sun-dried. The dry chunks, called *gaplek*, are then stored or sold in market stalls. When needed, *gaplek* is pounded into flour, which is swirled around with a little water to produce small granules the size of rice grains. The granules, called *tiwul*, are steamed, either separately or together with rice, and eaten as a “rice extender” when there is not enough rice to feed the family. Another popular snack in Indonesia, called *krepek*, is made by washing peeled roots and thinly slicing them with a hand- or electric slicer. The slices are placed in cold water, drained and then fried in hot oil for a few minutes. Once cooked, they are covered with a mixture of hot or sweet spices and sold in small plastic bags by hawkers or in local markets.

High quality cassava flour (HQCF) is cassava flour that has not been fermented and can be used as an alternative to wheat flour and other starches in bread and confectionary. The processing of cassava roots into HQCF involves peeling, washing, grating, pressing, disintegration, sifting, drying, milling, screening, packaging and storage.

Although markets for unfermented high quality cassava flour are emerging in sub-Saharan Africa, the challenge is linking them to large numbers of small-scale growers whose output is highly variable in quality. Where the value chain is relatively well established (for example, in Nigeria and Ghana), artificial dryers capable of processing 1 to 3 tonnes of HQCF per day could help to locate intermediary processing closer to the sources of fresh cassava roots. Processors could also provide intermediate bulking, aggregation and transportation services, and ensure acceptable quality of products to be delivered to the end-use market⁶.

Native starch is extracted from cassava roots in some countries, mainly in Asia, and used in food products. If properly extracted, cassava starch is pure white, with low levels of fat and proteins and a non-cereal taste, which is desirable in many food products⁷. Starch extraction can be done at almost any scale – in backyard artisanal production units and large-scale fully mechanized factories. Many artisanal starch production units still operate in Cambodia, India, Indonesia and Viet Nam. In backyard processing, cassava roots are hand-peeled, washed, grated and mixed with water. The starch water is passed through a cloth sieve to remove the fibre, and the suspended starch is then left to settle in tanks or flow channels. After the surface

liquid is siphoned off, the wet starch is collected, crushed and spread out on bamboo mats or on concrete floors for sun-drying. In artisanal production systems, daily starch output ranges from 50 to 60 kg of starch per worker, while semi-mechanized processing can yield up to 10 tonnes a day⁸.

In some parts of Colombia, wet starch is left to ferment for a few days before being sun-dried. This produces sour starch, which is the main ingredient in buns called *pan de bono*. In Tamil Nadu State, India, wet starch is collected, crushed and then shaken on a hemp cloth to form small starch balls, which are sieved and steamed for a few minutes to form tapioca pearls. In Indonesia, cassava starch is mixed with shrimp paste, food colouring and water and then extruded and thinly sliced by hand. The slices are steamed on bamboo screens for 5 to 15 minutes, after which they are sun-dried on a patio floor for half a day, producing hard chips known as *krupuk*. When deep-fried, *krupuk* swell into brittle soft crackers, which are a popular snack that accompanies almost every meal.

Starch extraction produces a considerable quantity of useful residues. Root peelings can be recycled as fertilizer and animal feed. Once dried, the discarded fibre can be sold as flocculent to the mining industry, while low-density starch lost during sedimentation is used as pig feed⁸.

Industrial uses

In countries such as Thailand and China, much of the native cassava starch is further processed to make a range of modified starches, for incorporation in food products or use as feedstock for production of sweeteners, fructose, alcohol and monosodium glutamate. Along with high quality cassava flour, modified starch is also used in the manufacture of plywood, paper and textiles.

In fully mechanized starch factories in China and Thailand, cassava roots are thoroughly washed, then cut and rasped, after which the mash is mixed with water several times to release the starch granules. The “starch milk” – the water containing suspended granules – is then separated from the pulp, after which the granules are separated from the water by sedimentation or in a centrifuge. At that point, the starch requires solar or artificial drying to remove moisture before being milled, sifted and packed into 50 kg bags or one-tonne sacks. In modern, fully mechanized starch extraction plants, daily output is as high as 300 tonnes⁸.

Increasingly, cassava is also being used for production of fuel ethanol. Fresh roots or dried chips are cleaned, washed, crushed and mixed with water, heated with liquefying enzymes, then cooled with other enzymes, which convert the starch to sugars. The sugars are fermented with yeast to produce ethanol, which is concentrated through distillation and finally dehydrated in a molecular sieve to produce 99.5 percent pure anhydrous ethanol. It can be blended with gasoline to produce “gasohol” with 10 percent, 20 percent or even 85 percent ethanol. Cassava-based fuel ethanol factories are now operating, or are under construction, in Cambodia, China, Colombia, Thailand and Viet Nam. Conversion to ethanol will become one of the major uses of cassava fresh roots and dry chips in the future, especially in China⁹.

Two recent cassava mutations could expand considerably cassava’s use in industrial applications⁷. The first, an induced mutation, has very small starch granules which offer a faster rate of hydrolysis – thus reducing the cost of producing ethanol or sweeteners – than other major starches. The second, a spontaneous mutation, produces an amylose-free “waxy” starch that has great advantages when used in frozen foods. Gels made from the starch have excellent water retention during defrosting, a highly desirable characteristic for the food industry.

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. Because of their high cyanide content, however, fresh roots or leaves can be fed to animals only in very small quantities. Cassava roots are chipped or sliced, while leaves are chopped into small pieces. Before being fed to animals, the cassava pieces are spread out on a floor overnight in order to release some of the cyanide by evaporation. The root chips and leaf pieces can also be sun-dried to 12 to 14 percent moisture content, then stored for future use. Alternatively, the chopped pieces of roots and leaves can be packed tightly in plastic bags or air-tight containers and fermented to make silage (*see p. 96*). Both sun-drying and ensiling will release most of the cyanide, making those products safe as feed for pigs, cattle, buffaloes and chickens.

Dried cassava chips are produced by first washing, or at least slightly cleaning, the roots in a rotary drum to remove soil and some of the outer skin. The roots are then chipped and spread out on a concrete

floor for sun-drying, and turned regularly with a rake to promote uniform drying. Normally it takes up to four days of sun-drying to make dried chips with about 12 to 14 percent moisture content.

In Viet Nam, cassava roots are often roughly peeled and sliced by hand before sun-drying in courtyards or along roadsides. In Thailand, many farmers take their cassava to drying yards, where the roots are first dumped into the hopper of a diesel-powered chipping machine. The chipped roots are then spread over large concrete floors for sun-drying and turned over regularly by a vehicle with a large rake. After two or three days of drying, the chips are piled up by a grader and loaded in bulk onto trucks. Some are further processed into pellets, mainly for export.

Although the need for rapid chipping and drying adds to the complexity of production, small farmers in Asia and their marketing partners, who provide cassava chips for the animal feed export industry, have shown that with adequate infrastructure, smallholder produce can be dried locally and reach market chains with relatively low losses¹⁰.


Chips are usually sold directly or milled into a powder that can be mixed with other ingredients – such as soybean meal, full-fat soybeans, fishmeal or other protein sources – to make a nutritious animal feed that is usually supplemented with methionine, vitamins and minerals. When the diet is well-balanced, in terms of energy and protein, the performance of pigs is very similar to that obtained with a diet based on maize or broken rice. Cassava meal is highly digestible and naturally contaminated with lactic acid bacteria and yeast, which improve the micro-flora in the digestive tract of animals. At low levels, hydrogen cyanide in cassava feed increases the efficiency of an enzyme, lactoperoxidase, which is a natural antibiotic that kills mycotoxins in the animal's body and milk. Animals raised on cassava diets have generally good health, good disease resistance and a low mortality rate. They require few if any antibiotics in their feed¹¹.

Dry cassava leaf meal (also known as “cassava hay”) is usually obtained by cutting the plant tops at 2.5 to 3-month intervals during the cassava growth cycle. The best quality foliage meal contains a large proportion of leaves and only very young stems, and is obtained from plants or shoots that are less than three months old. After harvesting, the foliage is chopped and spread out on a concrete floor for sun-drying. The moisture content needs to be reduced from about

70 percent to 12 to 14 percent so that the foliage can be milled and stored.

Owing to its high fibre content, cassava foliage meal is suitable mainly for ruminants. 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 boosts levels of thiocyanate in the milk, which may enhance milk quality and storability. Condensed tannins in the foliage meal also reduces gastro-intestinal nematodes, indicating that the meal may act as an anti-helminthic agent¹². For non-ruminants, dry cassava foliage meal is best limited to 6 to 8 percent of the feed for growing pigs and to less than 6 percent of that for broilers. In broilers, the inclusion of cassava foliage meal is useful mainly as a natural pigments – the high content of xanthophyll pigments (500-600 mg/kg) improves the pigmentation of skin in broilers and that of egg yolks¹³.

Leaf silage is made by mixing chopped leaves with 0.5 percent salt and 5 to 10 percent cassava root meal or rice bran, and then placing the mixture in large plastic bags or air-tight containers. The leaves are compacted to expel all air and the bags are sealed. Under these anaerobic conditions, the leaves start to ferment, resulting in a sharp drop in pH, as well as in cyanide content. After about 90 days of fermentation, the silage is ready to be fed to animals, usually pigs and cattle. The silage can be stored in tightly sealed bags for at least five months without spoiling. The ensiled leaves contain about 21 percent crude protein and 12 percent crude fibre. They also contain 200 ppm hydrogen cyanide, compared to more than 700 ppm before ensiling. In experiments conducted in Viet Nam, a diet containing 15 percent ensiled cassava leaves improved the daily weight gain of pigs and reduced their feed cost by 25 percent¹⁴.

A detailed illustration of a cassava tree. The tree has a thick, brown, textured trunk that branches out into several thinner, lighter brown branches. The leaves are green and have a characteristic three-lobed shape. The roots are thick, brown, and fibrous, extending downwards from the base of the trunk. The background is a light, textured greenish-yellow color.

Chapter 8

The way forward

Governments need to encourage smallholders' participation in a sustainable cassava development agenda, and support research and extension approaches that "let farmers decide".

This guide has presented a range of science-based “Save and Grow” farming practices that will contribute to the sustainable intensification of cassava production. They provide the basis for competitive, profitable production systems that boost productivity per unit of input, while protecting and nurturing the agro-ecosystem.

However, those recommendations will have little impact unless they are incorporated in large-scale agricultural development programmes and are widely adopted by farmers. For that to happen, governments will need to make policies that encourage the participation of all stakeholders, and particularly smallholder producers, in a sustainable cassava development agenda. Successful adoption of “Save and Grow” will also depend on farmers’ understanding of agro-ecosystem functions and on their capacity to make wise technology choices. That will require significant strengthening of extension services and innovative approaches to the transfer of knowledge and technologies¹.

Policies for sustainable intensification

Smallholder farmers raise crops and livestock primarily to feed their families and to earn enough income from sales to cover expenses, such as education and health care. They often have a short planning horizon, focused on satisfying their immediate needs, rather than ensuring the long-term sustainability of their farming enterprise. Farmers need to become aware that some of their current practices jeopardize their natural resource base and, with it, their future productivity, income, livelihood and food security.

Locally, negative impacts of unsustainable crop production include the erosion, compaction and nutrient depletion of soil, the loss of natural habitats and natural enemies of pests, and the risks posed to farmers’ health by the excessive use of pesticide. Other farming practices have off-farm impacts which, while not harming the farmer directly, are nevertheless of serious concern to society at large. Those “negative externalities” range from nitrate pollution of waterways and flooding of downstream areas, to pesticide residues in food and the greenhouse gas emissions responsible for climate change.

Like most people, farmers are usually reluctant to spend time and money solving problems that do not directly affect them. The

challenge facing cassava-producing countries, therefore, is to set policies and create an institutional environment that facilitate sustainable intensification of cassava production, while expanding market opportunities for small-scale cassava growers.

Policymakers should begin with an analysis of the current state of the cassava subsector. In most countries, cassava production is still labour-intensive and largely subsistence-oriented, with low levels of technology uptake, high production and post-harvest losses, and weak linkages to markets.

Transforming the subsector, in a way that ensures food security, income generation and economic diversification, requires the identification of profitable value chains and market preferences, strategies for reducing price variability on the demand side, and options for enhancing the quality, volume and reliability of production on the supply side. Improving market access and competitiveness will require vertical and horizontal coordination, strategic market-led research, and mechanisms for stimulating innovation and sharing knowledge, including farmers' practical know-how. As policymakers encourage higher levels of value addition, a major effort will be needed to integrate small-scale growers into the cassava marketing chain.

While there is no "one-size-fits-all" set of recommendations, 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.

Cassava growers should be encouraged to phase out slash-and-burn production, and cultivate smaller areas of flat and more fertile land nearer to their homes, transport and markets. Continuous production on the same land will help to reduce forest clearing, the annual burning of vegetation (which emits large amounts of carbon dioxide into the atmosphere), and the drudgery of carrying heavy loads of cassava roots over long distances. The steeper land can be returned to forest vegetation or used for perennial fruit trees, rubber or coffee.

To be sustainable, however, intensive systems of cassava production need to use good quality planting material and ecosystem-based approaches to soil fertility management and to insect pest, disease and weed control. In many countries, low-input cassava production systems already incorporate key "Save and Grow" practices, such as reduced or zero tillage, the use of cover crops and mulches, and mixed

cropping. Extension and advisory services – organized by the public sector, the private sector or NGOs – will be crucial in improving those practices by ensuring access to relevant external knowledge and linking it to the wealth of knowledge held by smallholders themselves. Participatory extension approaches will be needed to support farmers in testing and adapting technologies. New channels of communication, including radio, mobile phones and the Internet, can help to reduce the transaction costs of extension.

Cassava growers may also need incentives – for example, payments for environmental services – to adopt new farming practices and to manage other ecosystem services besides food production, such as soil conservation and protection of biodiversity. Adoption of integrated pest management can be promoted by removing “perverse subsidies” on synthetic pesticides, regulating their sale, and providing incentives for local production of biopesticides and insectaries for natural predators.

Facilitate improvements in the input supply chain. Disposable household income is too low to allow many small-scale farmers to move from low-input/low-output production to more intensive cultivation of cassava. Action is needed, therefore, to make improved planting material, mineral fertilizer and other inputs more affordable to smallholders. Governments should encourage private investment in the production of inputs, and establish credit lines to enable private suppliers to organize bulk procurements that ensure the availability of inputs in time for planting. Where necessary, the quality of inputs should be routinely tested to prevent the sale of bogus products. To avoid the inappropriate use, wastage and negative environmental impacts of mineral fertilizer, its distribution should be accompanied by training and extension advice.

Institutions that facilitate participation – such as farmer groups, community organizations and development NGOs – can also help to reduce the transaction costs of accessing input markets, while “smart subsidy” voucher schemes could be introduced to allow smallholders to purchase fertilizer and planting material at below-market prices. Although subsidies are attractive to smallholders, they can create dependency; in the long-term, group-based revolving credit funds will be a more sustainable source of financing. Once cassava growers see how fertilizer and improved varieties can help to increase their yields and income, they will want to buy more – and will have the financial

means to do so. That, in turn, stimulates competition, which lowers prices and makes inputs more affordable.

Control pest and disease threats with resistant varieties and strict quarantine regulations. As cassava production is intensified, continual cropping risks provoking an upsurge in pests and diseases, which are already one of the most serious constraints to increased productivity. Rather than resorting to chemical pesticide, cassava intensification programmes should promote integrated pest management, which draws on resistant cultivars, biological control agents, bio-pesticides and habitat management to protect crops, conserve biodiversity and safeguard the environment and human health. All germplasm and varieties deployed should be resistant to the predominant pathogen populations present in each specific country, agro-ecozone and farming system. In the absence of a formal seed supply, quality planting material should be made available to growers through community systems of multiplication and distribution.

With increased international movement and exchange of cassava germplasm, improved phytosanitary measures will be needed to ensure that planting material is free of pests and diseases. Sensitive and 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. The transfer of cassava germplasm should be carefully planned in consultation with quarantine authorities and should be in amounts that allow adequate testing. Cassava germplasm should only be moved as seed, pathogen-tested *in vitro* material, or as cuttings from re-established pathogen-tested *in vitro* material that has been grown under containment².

Support cassava research and technology development. Applied agricultural research can facilitate the transformation of cassava cropping systems by helping to develop varieties with disease- and pest-resistance and more desirable commercial traits, water-efficient irrigation technologies, and appropriate farm machinery, especially for land preparation, planting and harvesting. Policies should help to 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, which was set up with government funding but operates

as an independent non-profit organization, is working with CIAT and Kasetsart University to breed “waxy” starch cassava varieties adapted to Thai growing conditions. The Latin American and Caribbean Consortium to Support Cassava Research and Development (CLAYUCA) is a regional network of public and private entities that plans and coordinates research for the cassava subsector. Acting as a facilitator of public/private alliances, CLAYUCA fosters sustainable cassava production intensification and improved access to elite genetic material. Among recent achievements is a small-scale, low-cost technology, easily operated and managed by smallholder farmers, for local production of ethanol from cassava.

Improve rural infrastructure. Good physical infrastructure is essential for the smooth operation of the cassava value chain, especially considering the need to process the roots within 48 hours of harvesting. The poor state of rural roads in many countries not only limits farmers’ access to inputs and financial services – it also severely restricts their access to markets. The lack of storage and processing infrastructure leads to high post-harvest losses, undermines market development and discourages all stakeholders in the value chain from producing and supplying quality-differentiated products with desirable market traits.

Investment in road networks and in warehousing and processing capacity in production zones will help to link small-scale cassava farmers and processors to growth markets for intermediate cassava products that have a longer shelf life. It will also contribute to price stabilization, reduction of 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 cassava growers to retain a bigger share of the value-addition. There is a need to develop models for community-level bulking and grading that can assure regular supply to potentially large urban markets. Since mechanical drying powered by fossil fuels has often proven to be uneconomic in isolated rural areas, processing power based on a combination of solar energy, fossil fuel and biomass sources should be considered.

Develop value chains and markets in order to boost demand and increase returns to producers. Initially, those markets will be local ones for fresh roots or leaves, or small-scale processors of fermented

flour or low-quality starch. As markets develop and demand grows, farmers have an incentive to grow more by intensifying production. An increased supply of raw material provides an incentive to processors to expand capacity and modernize their factories, which stimulates further production increases, driving an upward spiral of rural development. Examples of successful market development include the rapid growth in Thailand of the production of dried cassava chips and, more recently, of fuel ethanol for domestic markets and export.

Governments should promote private investment in cassava processing plants, and foster associations that link cassava growers and processors, such as the Thai Tapioca Starch Association and Nigeria's Cassava Market and Trade Development Corporation. Cassava industry stakeholders may need assistance in initiating industry-wide or activity-specific associations that can help enterprises of different sizes to work together. An active industry association can foster cooperation among value chain participants, promote grading standards, share market information, and lobby governments to support cassava subsector development. Industry clusters – market-driven, private sector-oriented groups or enterprises – can be formed around such associations to define the measures and activities needed to improve productivity and to make the value chain work efficiently.

Planners will need to link support to the cassava subsector with action to develop associated industries. For example, development of cassava as a feed resource should exploit complementarities with livestock and poultry enterprises; increasing output of high quality cassava flour will require the strengthening of links with the bakery industry.

Reduce farmers' exposure to price volatility. For people whose livelihood depends mainly on agriculture, volatility in output prices means fluctuations in income and greater risk. Guaranteeing farmers a reasonable price for their crops will encourage them to invest in production. One approach is subsidies, such as the Thai Government's national "pledging scheme", which set aside in 2012 some US\$1.43 billion for purchasing roots from cassava growers³. 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. Large scale processors not only ensure an agreed price to farmers but also provide technical services in return for growers' commitment to deliver all or a significant portion of

production. In the Philippines, for example, one of the country's leading food manufacturers offers supply contracts to farmers' cooperatives that can consolidate at least 20 ha of land for cassava production. It provides start-up technical advice, a guaranteed floor price, and a marketing agreement that covers product quality, volumes and a delivery schedule⁴.

Governments in developing countries should foster greater availability of crop insurance which, while it does not eliminate risk, does mitigate losses caused by adverse weather and similar events, thus improving risk-bearing capacity and encouraging investment in production. While common in industrialized countries, crop insurance is very limited in the developing world and particularly so for smallholder crops such as cassava.

Letting farmers decide

Farmers will need to be convinced that “Save and Grow” practices are better than those they are using already and – very importantly – that they have short-term economic benefits. Not all recommended practices are equally useful, nor are they universally applicable. Farmers are interested only in those practices that fit well with their cropping systems and ways of farming. Practices that may have been effective during trials on experimental stations may not perform nearly as well under farmers' local conditions.

Since most technologies have advantages and disadvantages, trade-offs need to be made. That can best be done by farmers themselves, rather than by researchers or extensionists. It is important, therefore, that cassava growers be involved in all stages of agricultural research and technology development, and are empowered to test and validate, in their own fields, practices aimed at improving the sustainability of cassava production. By shifting the extension paradigm from “teaching” to “learning”, two methodologies – farmer participatory research (FPR) and farmer field schools (FFS) – have proven highly effective in incorporating sustainable natural resource management into smallholder production systems.

Farmer participatory research 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 more 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 simple trials in their own fields, with help from research or extension staff⁵.

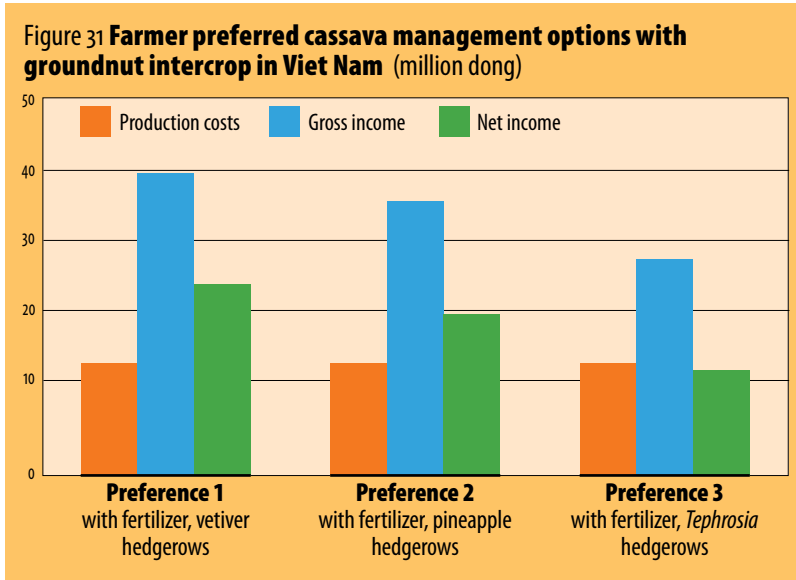
CIAT has used farmer participatory research extensively in Asia for the development and transfer of cassava production technologies. Its FPR programme involved farmers in 99 villages in China, Thailand and Viet Nam, who conducted more than 1 150 trials, mostly of improved varieties, fertilization, erosion control, plant spacing, green manuring and the use of cassava roots and leaves as animal feed.

With FPR, members of a farmers’ group, or farmers in a particular village or district, first diagnose the main problems encountered in cassava production and, with assistance from research and extension staff, consider possible solutions. From this diagnosis, they decide on specific topics for their trials. Whenever possible, the farmers visit experimental stations or other villages to view similar trials, or confer with farmers who have already adopted the practices being tested.

They then select 3 to 5 alternative treatments, along with one traditional practice, to test in simple, unreplicated FPR trials in their own fields. If all farmers in the area use the same treatments in one type of trial, each trial can be considered a replication, and the results can be averaged over those replications. That improves confidence in the results obtained.

The next step is for the farmers to design and conduct the trials, with help from research or extension staff. The farmers manage the trials themselves, while staff may visit occasionally to discuss progress and help solve problems. Finally, at harvest time, all farmers in the area, and from neighbouring areas if possible, 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 as the production costs, gross income and net income of each treatment. Based on this information, farmers can select those varieties or practices that they consider most suited to their own conditions.

The FPR approach has been highly successful. An independent impact assessment in 2003 found that, in Thailand, all of the farmers who had directly participated in trials had adopted improved varieties, 98 percent the use of mineral fertilizer, and 80 percent soil conservation practices to control erosion. In Viet Nam, the adoption rates were



Source: Annex Table 8.1

82 percent, 80 percent and 71 percent, respectively⁶. 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 Vietnamese trials, and Asian trials in general, have shown clearly that farmers prefer treatments which produce both sustainable yields and the highest net income (Figure 31).

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

The application of FFS to cassava began in Africa in the late 1990s. The spread of new strains of the viruses causing cassava mosaic disease and, more recently, cassava brown streak disease, has 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 percent⁷.

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 on wet soils and planting stakes along the contours of sloping land in order to limit damage from root rot. They also learned the importance of regular weeding, eliminating diseased plants, planting in rows and optimizing planting densities.

An evaluation in 2012 found that, thanks mainly to the use of high-yielding varieties, integrated pest management and resource-conserving cultivation practices, the farmers had increased their cassava yields threefold. In one province, yields reached 30 tonnes per hectare⁸.