Cassava: Future Potential and Development Needs

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Abstract

Cassava has the potential of generating low cost calories under relatively marginal production conditions and with minimal increases in inputs. Minimal cost but high yielding production technology is recognized as the key to realizing production potential of cassava.

Important areas of research emphasis and how national and international agencies shoulder responsibility for research is presented.

Introduction

In spite of the success of the dwarf wheat and rice varieties in the developing countries since the mid-1960's, there still remains a guarded pessimism about the continuing ability of the world, and especially the developing world, to feed itself. Food production increased at similar rates of 2-3% per year, in developed and developing countries from 1961-1975 (Wortman 1976), however per capita food production in the developing countries has fallen from an annual growth rate of 0.7% in the 1960's to 0.3% in the 1970-76 period (FAO 1977). Growth rates in per capita production of cereal grains fell from 1.1 to 0.4% in the same period, despite the fact that the 1970's was the major period of expansion in area planted to the dwarf rice and wheat varieties (FAO 1977, Dalrymple 1978). Given substantial increases in per capita incomes in the developing countries, food production has not been able to keep pace with effective demand, resulting in an 86% rise in the level of grain imports into the developing market economies in the 1970-1976 period (IFPRI 1977).

Although the agricultural production of the developed world has served as a buffer for food shortfalls in developing countries, balance of payments restrictions, food distribution systems that fail to reach the most needy, and the economic and political expediency of food self-sufficiency have moved the developing world to look for its own means of meeting rising food demand, However, the ability of the developing world to move toward self-sufficiency in food staples in facing an increasing number of constraints. Land/labor ratios continue to increase and the ability of the developing countries to productively absorb more labor in the agricultural sector is becoming increasingly limited, due to relative land scarcity in much of Asia and the Near East. social and institutional constraints in Latin America, and technological constraints in Sub-Saharan Africa. Improving land productivity, especially for rainfed areas, appears essential to generate higher rates of food production. Increasing labor productivity is critical for social reasons. However, higher yield and agricultural wages are increasingly constrained by the rising prices of agricultural inputs, especially those heavily dependent on petroleum for their manufacture. Higher yields must therefore come from very efficient use of fertilizers, especially nitrogen, and petroleum based herbicides, insecticides, and fungicides.

Partly in response to the success of the miracle varieties, agriculture has been made responsible for more than self-sufficiency in the production of food. Agricultural development had been made accountable for equity as well as growth objectives. This linkage of goals, coming on the heels of the Green Revolution, was in response, to the following empirical evidence: that among the 1.9 billion people in developing market countries, 700 million lived in acute poverty, 480 to 500 million suffered from a severe degree of protein/energy malnutrition, and 300 million were either unemployed or underemployed (Schuh, 1978). A major portion of the poverty problem had its roots in the agricultural sector; emphasis was therefore put on the critical role agriculture might play in alleviating poverty.

The agricultural sector in the developing world is therefore facing the following task: (1) in order to meet market demand, food production must increase from 3.0 to 4.2% per annum (IFPRI 1977) (2) To meet minimum nutritional needs of the total population, food production will have to increase at between 5.4 to 6.3% per year (IFPRI 1977) (3) In order to affect rural employment and improve the welfare of the most needy in the rural sector, much of this increase will need to come from outside irrigated areas and much of the small farm sector will have to have access to income raising activities, (4) This increase in food supply will need to come principally from rainfed areas, will be based principally on yield increases and more effective use of marginal areas, and will require very efficient use of relatively scarce agricultural inputs. New agricultural technologies for the tropics are therefore crucial if agricultural growth and equity objectives in developing countries are to be met.

National policy planners and those who administer international agriculture programs have focused on technology generation in cereals as a primary strategy in increasing food production (for example, Wortman and Cummings (1978) and IFPRI (1978)). Based on the current importance of cereals in the national food budget, this is a sound strategy. However, this policy has tended to bias opinion toward cereals as the solution, rather than as one potential solution among many. Thus, research expenditures as percentage of total value of production in Asia in 1975 were .12% for rice, .11% for millet and sorghum, .23% for wheat, and .12% for maize; whereas for roots and tubers it was 0.03%, the lowest percentage for any commodity except bananas (Evenson 1978). The CGIAR support to cassava research in 1978 is only 2% of its total research budget whilst 5% of the calories in the food deficit countries came from cassava (CGIAR 1977). The cereal bias, particularly in the allocation of agricultural research resources, has tended to focus food policy on means of expanding the principal cereal crops. Given the current needs in agricultural development, as outlined above, a strict cereal policy is very shortsighted, as it overlooks the substantial potential of root and tuber crops. This paper will attempt to mark out the potential role o cassava in agricultural development in the tropics and the factors that are necess y for the realization of this potential.

Cassava Production Potential and Development Needs

Status quo and potential. Philipps (1974) estimates that by 1980 cassava will provide approximately 37, 12 and 7% of the calorie intake of the tropical areas of Africa, America and Asia respectively. Most of this cassava is produced on the more marginal agricultural lands with virtually no input of fertilizers, fungicides, or insecticides. Many of the cassava growing areas have a prolonged dry season (up to six months in the North East of Brazil) and yet irrigation is used only on a minimal number of farms.

Nevertheless, yields on a world average basis are close to 10 t/ha/year, which if converted to dry matter at 14% moisture, yields a figure of 4 t/ha/year. This figure compares very favorably with grain yields from unirrigated areas with a pronounced dry season where only one cereal crop per year is produced. Since cassava has received, until recently, little attention from scientists, these present yield levels are obtained using local clones and traditional agronomic practices. Current yields fall well short of the potential for the crop.

The yield potential of cassava under prime agricultural conditions is tremendous. De Vries *et al* (1967) and Coursey and Haynes (1970) in comparisons of different crops suggested that cassava was potentially one of the most efficient carbohydrate producers among the food crops. Recent data from CIAT has shown that yields of up to 28 t dry matter/ha/yr can be obtained on experimental plots under moderate radiation levels but with good rainfall distribution and high fertility (CIAT 1978). Cock (1974) and Cock *et al* (1979) have suggested that under similar conditions theoretical maximum yield is approximately 29-30 t/ha/yr of dry matter.

All these yield data and predictions are based on near ideal cassava growing conditions; however, the potential for expansion of the crop seems to lie in the more marginal agricultural areas.

The prime agricultural areas tend to specialize in higher value, export crops and grain crops, which have a long history of research on yield improvement, well developed markets, and usually a well-articulated government price policy. Cassava is as a rule just not as profitable in such areas and usually entails a higher marketing risk as well. The comparative advantage of cassava therefore usually lies in the more marginal areas, where because of its better adaptation to stress conditions vis-a-vis other alternative crops, cassava becomes one of the most profitable crops. Thus, cassava has the potential advantage of producing cheap calories from the relatively unproductive marginal areas due to its low price and its better adaptation to environmental stress and its expected low unit cost of production.

Edwards *et al* (1976) concluded that "Several features that may be associated with the special adaptation of cassava to low fertility situations, including high soil acidity have been identified". At the CIAT Quilichao site which has good rainfall distribution but very low soil fertility and a pH of 4.2 a yield of 27 t/ha was obtained with only 0.5 t/ha lime and no fertilizer nor use of fungicides or insecticides except for stake treatment costing 4 $/ha and 52 t/ha fresh roots in one year was obtained with 1 t/ha of 10:20:20 fertilizer, (Toro, pers. comm. CIAT 1978). These data suggest that cassava is particularly well adapted to give very high carbohydrate yields on the vast areas of under utilized acid infertile soils of the tropics. These soils exist to the extent of 760. 650 and 250, million hectares in Tropical America, Africa and Asia respectively and approximately half are suitable for crop or pasture production (Sanchez 1977). Apart from increasing yield on areas where cassava is presently grown there is then tremendous potential for increasing marginal land cultivation of cassava.

However cassava productivity is not just restricted by low soil fertility, but also by availability of water and losses caused by weeds, pests and diseases. Cassava does not have critical growth periods in the same manner as for example flowering in the cereals. It also has a long growth period. These factors enable cassava to endure stress and then recuperate, whether the stress be caused by either disease or pest attacks or lack of water. The most critical period is in the establishment phase when either lack of water, severity of pest attack or weed competition will severely reduce yields (Doll and

Piedrahita 1976).

Although cassava recuperates well from acute disease and pest attacks, continuous disease or pest pressure will tend to greatly reduce yields (Cock 1978). However, cassava as a long season crop, reproduced vegetatively appears to have developed as local clones with considerable field resistance to the disease and pest prevalent in the areas where it is cultivated (Lozano *et al* in press.). This leads to relatively stable yields of local clones but also means that great care will be required to ensure that new clones introduced to areas have adequate tolerance to diseases and pests. Maintenance of high levels of field resistance in improved cultivars, implies that little use of pesticides will be required to maximize yields of cassava.

The overall management of the cultivation of a crop is normally critical. Recent observations on the North Coast of Colombia in an extremely marginal area have shown that farmers, using their local variety but improved cultural practices could increase yields from 7.1 to 12.1 t/ha with minimal additional purchased inputs (4 US$/ha) (Lynam 1979). The potential of combining these improved practices with selected clones from breeding programs seems enormous.

In summary, cassava has the potential of generating large increases in low cost calories under relatively marginal production conditions and with minimal increases in inputs. Cassava is thus well tailored to the agricultural development needs of tropical countries, as outlined in the first section. What then are realistic estimates of the potential of the crop? Taking the liberty of gazing into the crystal ball, we would estimate that the following yield levels are possible without major changes in farmer production methods. Under high fertility conditions with no pronounced dry season, commercial yields (fresh roots) of more than 35 t/ha/yr should be possible; under moderately fertile conditions with up to 4 months dry season, yields of around 25-30 t/ha; and in the acid infertile soils 25-30 t/ha with no dry season and with a 3-4 months dry season, yields of 15-25 t/ha (Table 1). These estimates assume certain minimal cultural practices and moderate fertilizer dosages in acid soils. What then is required to achieve these yield levels. The means of reaching this production potential are laid out in the following section.

Research Overview

General policy. If poor soils, often with uncertain rainfall, are to be used for cassava production without modifying them with costly amendments, then the vareities and the concomittant technology developed must be well adapted to these conditions. Furthermore it is uneconomical to base control of diseases, pests and weeds on the continuous use of costly chemicals; rather, technology varieties and will have to be developed that can *per se* cope with these stress conditions. It is quite evident that it is easier to develop high yielding varieties for use with irrigation and heavy fertilizer application and to develop a technology to control weeds, insects and diseases based on chemicals, than to develop varieties that are especially adapted to give high yields under sup-optimal conditions. A minimum input technology, however, implies a heavy investment in research given the greater complexity of developing "adapted" technology It may appear paradoxical to talk on the one hand of high research investment and on the other of cheap production technology. However, minimal cost but high yielding production technology is recognized as the key to realizing the production potential of cassava. From the point of view of society it is far more efficient to invest in research than in large increases in inputs, particularly for a crop that has little history of applied research and a very high yield potential over current yield levels. The potential return of investment to agricultural research has been shown to be very high. Arndt and Ruttar (1977) present rates of return on agricultural research investment for 32 case studies. Average internal rate of return was 46%. Scobie and Posada (1977) showed that in the case of rice in Colombia the internal rate of return on research was as high as 94%. Given the lack of applied research in cassava, there is good reason to believe that, the rate of return will be high for cassava.

In certain crops, a high proportion of the research cost is assumed by the private sector. In the US, 50% of the food and nutrition research is borne by the private sector (NAS-NRC 1978). Much of the oil palm research in Malaysia has been done by the very large exporting companies that also control considerable sized plantations. These companies are sufficiently large and control such large production volumes that they can obtain a good return on substantial investment in production oriented research. Cassava is generally grown by small farmers and, except in the case of Thailand, is not a major export crop, hence, it appears unlikely that the private sector will finance cassava research on the same basis as has happened in most of the export crops such as oil palm.

New hybrid sorghum and maize varieties for the tropics have been developed by the private sector, as considerable profit can be appropriated from seed that cannot be resown in succeeding years. Return to research investment is guaranteed as a result of continuous sale of newseed of the same variety over several years. In the case of cassava, farmers produce their own "seed" and when they change varieties they only require a small amount of "seed" on a one shot basis which they themselves multiply. There are few incentives for the private sector to become actively involved in the development of new cassava varieties and to form a "seed" industry.

The private sector has also been heavily involved in the development of chemicals for use in agriculture. If cassava is to be produced with minimal chemical inputs, as was suggested earlier in this paper, then it is unlikely that the private sector will perceive a sufficiently large potential market to involve itself specifically in cassava. The two areas of potential input use in cassava, fertilizers and herbicides, imply a potential market for these inputs when cassava starts to be produced on a more commercial basis. Again this will require little cassava-specific research but rather investment in marketing It is however, the author's opinion that the private sector may become interested in two areas of development: fertilizers and herbicides. Cassava is at present grown with minimal fertilizer applications and indeed it has been shown to have relatively low nutrient requirements (Edwards *et al* 1976, Cock and Howeler 1979). Yields do however increase substantially with fertilizer application on the acid infertile soils of the tropics (CIAT 1975, 76, 77, 78) and hence there is a possibility of increased fertilizer use. In addition cassava has a reputation for exhausting the soil; this reputation is somewhat underserved because cassava is frequently grown as the last crop in a rotation on soils so depleted that cassava is one of the few crops that will still produce on them. If cassava is to be produced continuously on these depleted soilsthen fertilizer, albeit not very high level, will have to be applied. These observations indicate that some interest may be taken by the fertilizer producers in research and development in fertilizer in cassava.

Weed control is the major labor using activity in cassava (Diaz and Andersen 1977) and it is probable that cassava acreage may be limited in many areas by the peak labor demand at weeding time. The use of herbicide offers a method of resolving this problem and thus there may be interest in developing herbicide application for cassava by the private sector.

The main research effort for cassava will however have to be financed by the public sector. In the following section we will try to describe important areas of research emphasis and how national and international agencies can divide the responsibility for this work. Two international centers CIAT and IITA are involved in intensive cassava research, CIAT concentrates on problems related to production in the Americas and Asia and IITA in Africa. The two international centers are engaged in developing improved varieties and simple agronomic practices to increase the productivity of cassava. The work of these two institutes in no way negates the need for strong national research efforts as it is most unlikely that the technology developed by these two centers will be directly applicable to farmers fields in every country. The centers will develop improved germplasm and agronomic practices in general terms and these will need to be adapted and validated under local conditions by the national agencies.

Research areas. Given that the principal research strategy should concentrate on developing a cassava technology adapted to more marginal conditions, and that under such conditions in order that risk is minimized, and an adequate return on input investment is insured and adaptation is maximized the technology should be based on minimal inout levels, and given that this research is most likely carried out in the public sector, the next logical step is to define the specific areas where research would make the greatest potential impact. We consider the four following areas to be most vital in order to meet the above objectives:

Varietal improvement. The options that exist for improving cassava productivity are numerous; however, given the restraints on technology design for suboptimal conditions, one option becomes strikingly appropriate, that is plant breeding. A variety that was resistant to all diseases and pests and had high yield potential under stress conditions, combined with low fertilizer and water requirements would be the simplest form of improved technology. However, the rate of breeding progress is generally inversely proportional to the number of breeding objectives; hence, objectives will have to be carefully selected according to which are considered likely to contribute the greatest increment in eventual national yields.

The international centers are expected to produce high yielding varieties resistant to major diseases and pests. These lines may on occasion be released directly as varieties for farmers after testing under local conditions; however, it is probable that they will also be used as parents in national programs where particular local requirements can be added. In addition it is expected that as national agencies produce new clones these will be interchanged. A Brazilian line, sent by CIAT to Cuba is at present undergoing pre-release trials and the most widely grown line in Thailand was probably obtained from Malaysia some years ago. It is envisaged that in the future a close network of varietal improvement programs in national and international centers will interchange promising lines. This is now much more feasible than a few years ago because tissue culture techniques make germplasm exchange much safer, from the quarantine standpoint, than the traditional interchange of cuttings.

Pest management. The incidence and severity of disease and pest attacks vary enormously from region to region. Cassava is traditionally thought of as highly tolerant of diseases and pests, nevertheless as production areas expands outside traditional areas and cultivation methods become more intensive, disease and pest severity will almost certainly increase. Hence adequate pest management systems must be developed. As a result of cassava protection workshop Thurston (1978) concluded that "Integrated pest control systems for cassava should place emphasis on combinations of three fundamental tactics of (a) host plant resistance (b) biological control and (c) cultural controls. The use of chemical pesticides and similar control measures should be resorted to only as a supplemental adjunct to the other three. It should be noted that this is not necessarily the case for weeds. The use of herbicides should be integrated with other control measures in the event they are required". In addition the authors suggest that due to the regional variability in damage caused by pests the final resolution of pest problems is highly dependent on some tailoring of pest resistance, breeding and control techniques to local environmental conditions.

Agronomic practices. Recent experiences by the second author suggest that small farmers under very unfavorable conditions, both agronomic and socio-economic, in the North Coast of Colombia can increase their yields by 70% through the use of simple improved agronomic practices that require extremely limited inputs (CIAT 1978, 1979). It is also interesting to note that in Kerala, India, average yields on the acid infertile soils of the area are among the highest in Asia and that this is probably due to good agronomic practices based on many years of experimentation at the Central Tuber Crops Research Institute. Although certain basic principles may be accepted on a world wide basis as "good agronomic practices" the specific details are bound to be very location specific. Rather simple agronomic research on such factors as fertilization, plant population, weed control, time of planting and harvest and crop rotation offer tremendous opportunities to develop agricultural systems capable of greatly increasing cassava production in different areas. The development of these individual systems must be done by the national or local agencies.

Multiple cropping. The authors estimate that about 40% of the world's cassava is grown in mixed cropping systems; however, up to the present only a minimal proportion of the total cassava research budget has been spent on mixed cropping. Cassava is ideally suited for intercropping with short-season crops, given its slow early development and recuperative ability later in the cropping season. The possible advantage of mixed cropping from an agronomic stand point are several; disease and pest incidence tends to decline, weed control need not be so intense, and crop fertility can be maintained by use of legumes. From an economic standpoint, cassava cultivation suffers from the problem of a long period between planting and obtaining income. By mixed cropping with short season crops the farmer obtains earlier income thus relieving to a certain extent this cash flow problems. In addition, inter-cropping with grain legumes can produce protein thus compensating for the very low protein content of cassava particularly in subsistence systems. It is likely that traditional multiple cropping practices can be much improved in terms of productivity.

Transfer of Technology Requirements. Not only is it necessary to develop more productive technology but also to ensure that it is adopted by the farmers. In order that this occurs, the farmers must be aware of the new technology and also have access to the required inputs. The new technology developed, if it results from the type of research outlined in the previous section, will be based on improved varieties, improved agronomic practices, integrated pest control and improved weed control. Furthermore, in certain areas, mixed culture rather than monoculture will be used.

Bunting (1979) states that "Where an innovation offered is profitable and practicable, and meets the needs and possibilities of the producers, it will spread with little or no official communication, ...". This conclusion has really only applied to the adoption of new crops, especially highly profitable cash crops, and in certain instances to the adoption of new varieties. Bunting (1979) thus goes on to recognize that extension will be necessary" . . . . where new and effective procedures or techniques have to be taught". Extension is thus required where new technology is based on improvements in farmer management and will be most effective where the technology is relatively simple and appropriate to the socio-economic and agronomic constraints faced by the farmer.

In the case of improved cassava technology new varieties will be a principal component. These to a large extent will sell themselves, as there is evidence to suggest that while commercial cassava farmers usually plant a small number of principal varieties, they may as well maintain other varieties under evaluation for potential replacement of the principal variety or for specialized purposes. Although the new varieties may not need much extension for their adoption it should be noted that this will be slow to occur due to the following reasons. Cassava tends to be grown in small isolated lots so that communication between farmers maybe slow; the yield of cassava is only visible at harvest so that the chancesof observing the yield potential of a new line are minimized; the crop cycle is long and the multiplication rate using traditional propagation systems is slow and there is little likelihood of a seed industry developing with salesmen promoting the spread of the new varieties. Hence although extension may not be essential for the spread of new varieties it will ensure more rapid adoption.

As has been demonstrated, cassava responds very well to improved management. This response will probably be even greater for improved varieties. Thus, to increase yields to a level approximating their potential will require extension. This suggests then that the old adage that good technology sells itself is true only up to a certain point in the case of cassava. It appears to the authors that there is a further factor particular to cassava working against the previously stated adage. The empirical support for this adage rests largely on diffusion of technology in irrigated areas, which are by their nature highly concentrated and in which cooperation is a necessary fact of life. Cassava is generally grown in very poor areas where communication between farmers is limited by lack of infrastructure, particularly in slash and burn systems. Moreover, cassava is usually grown in small, widely separated plots, limiting diffusion by field observation. All these factors point to a heavy involvement of extension services if the yield potential of the new technology is to be realized.

A major role in extension is often played by commercial companies who provide free advice on the best methods of producing high yields with their particular products whether they be seeds, fungicides, insecticides, herbicides or fertilizers. As has been pointed out earlier, it is unlikely that commercial houses will interest themselves in cassava. This conclusion may even apply to fertilizer and herbicides in that the poor infrastructure characteristic of cassava areas, the wide spread distribution of cassava producers, and the relatively low level of utilization by each farmer will probably cause marketing costs to be so high as to make the development of a distribution network unprofitable. The net result of this is that if cassava yields are to increase, then initially the extension will have to be done by the public sector. Once the new technology is proven it is possible that vertically integrated agro-industry producing cassava for starch, animal feed or alcohol may provide extension services to the large producers. Nevertheless extension to the small farmer will have to be done by the public sector.

Thus, even though the improved technology is principally based on new varieties, it requires minimal increases in purchased inputs, and is in most instances based on a very simple package; public investment in extension and input distribution channels will be required if the full potential of the technology is to be realized. Investment is particularly essential for seed multiplication facilities to rapidly reproduce foundation seed. In the case of seed and input requirements, such services while they should be provided by the public sector need not be subsidized. Seed production facilities are relatively inexpensive (Cock, Wholey, Lozano and Toro 1974) and prices to farmers should cover production costs. For example, farmers in Colombia pay up to 4 US$ per 100 cuttings of promising clones. In the case of input distribution channels, farmer prices should reflect actual costs, though investment in distribution channels as well as extension services appear to be justified on the basis of potential social benefits. These benefits derive from the potential expansion in the end utilization of cassava. We thus turn in the next section to an analysis of the potential markets for cassava and the technology needed to develop these markets.

Utilization of Cassava: Potential and Development Needs

Status quo and potential. There is a duality between new cassava technology and the expansion and diversification of markets for cassava or cassava derived products. On the one hand, expansion in demand is necessary in order to absorb the potential increases from yield increasing technology. Since this yield increase is potentially so large, increased demand in traditional markets due to the expected price drop would still not be sufficient to maintain all farmer producers at the same area of production. On the other hand, in order that cassava enter these alternative markets, prices have to be much lower than current prices. Therefore, cost-lowering technology is a necessary element in making cassava competititve with most substitutes in these markets.

What are the principal current uses of cassava? What are the potential markets and the growth potential of these markets which cassava might serve if competitively priced? What are the technical problems (and therefore research areas) that need to be solved so that cassava becomes perfectly substitutable with existing alternatives? We briefly survey these questions in this section, implicitly accepting the basic hypothesis that research on cassava utilization and investment in alternative markets for cassava are as necessary as new production technology in realizing the full potential social benefits of the crop.

Human food. Apart from the exceptional case of Thailand, most of the world's cassava is currently used as human food. Moreover, the major portion of cassava produced for human food is consumed in the rural areas within or near the production centers. The advantage of cassava as a subsistence crop have been well documented, especially the high calorie production per area of land or per labor input, the relatively stable yields, and the long potential harvest period.

The consumption of cassava is normally much greater in rural areas near production centers than in the urban areas, and there tends to be a greater proportion consumed as processed product rather than the preferred fresh product in the urban areas. In Brazil, average per capita consumption of fresh cassava is 24.7 kg in rural areas and only 3.0 kg in urban areas, while cassava flour consumption is 38.3 kg in rural and 11.6 kg in the urban areas (Getulio Vargas Foundation 1970).

Fresh cassava is highly perishable and very bulky to transport and hence the marketing margin is often 75-100% over the farm level price. In addition cassava on arrival at the urban markets has often already started to deteriorate so that consumers are forced not only to buy a lower quality product but also to either eat it immediately after purchase or store it in often unavailable refrigerated space. In addition, high starch content is normally associated with better quality but shorter shelf life as a result, products for the urban market are likely to select varieties or clones that have lower starch content and hence longer shelf life. The importance of quality is highlighted by a price differential of 40-50% for good quality cassava in the Bogota market. Thus due to the high perishability of cassava the urban price is high, the quality is low and the consumer without excess refrigeration storage space will not eat cassava on a daily basis. It would appear *prima facie* that by improving shelf life of cassava, consumer price could be reduced (assuming a downward adjustment in marketing margin), quality improved and demand increased in the urban areas.

Considerable potential as well exists for increasing the demand for processed cassava. Outside of Brazil, West Africa, and Indonesia (countries which have the highest per capita consumption levels for cassava), most cassava is marketed in fresh form. There appears little reason to doubt that processed cassava could not be a cheap urban calorie source in the other tropical countries. Promotion of processed cassava could extend as far as the use of cassava flour to replace imported cereal based flours. Since every major region of the tropics is a net importer of wheat, there is obviously some scope for achieving a greater degree of self-sufficiency in this area. Cassava flour can be a partial replacement for wheat flour at levels up to 10% with minimal changes in bread quality. Supplementation with soya flour can ensure a more nutritious product. However, the economic advantages depend on a cheap cassava flour relative to the imported flour.

If marketing margins can be reduced and per-unit farm production costs lowered with new technology, cassava will have a tremendous potential for supplying cheap calories to urban food markets. The stable supply of a cheap calorie source to urban markets has a number of implications for national food and nutrition policies. Two points are relevant in this regard. First, calorie deficits are being recognized as the major form of malnutrition in LDC's (Hegstead 1978). Second, the recognition that food commodities can have differential impacts on the nutritional status of vulnerable groups within the population (Pinstrup Andresen *et al* 1976 and Timmer 1979). Supply shifts in carbohydrate staples, and the resultant declines in relative prices, appear to benefit lower income groups more than supply shifts in other crops. As Timmer and Aldeman (1979). point out, "A differential price policy (or technology policy) targets the nutritional impact without the enforcement costs and packages of programs using more preferred foods. The policy is self-enforcing because the poor eat staples no longer attractive to higher income groups." Timmer and Alderman (1979) go on to show that prices for cassava in Indonesia will benefit the poor more than the rest of the population, i.e. income elasticities for cassava are very high in the low income, group own price elasticity very elastic, and the cross price elasticity with rice very high implying high substitution with changes in relative prices (Table II). Thus although rice is the preferred staple, the poor will readily shift to cassava with changes in relative prices. Given that Indonesia is a periodic importer of rice, that rice prices vary substantially depending on the quantity harvested, and that it is relatively costly to expand rice production, a policy which promotes a continuous supply of cheap cassava will have substantial nutritional benefits among those mose vulnerable to rising food prices.

Promoting cassava as a cheap calorie source has caused some concern among nutritionists since it contains few other food nutrients. There has been some concern about potential linkages between HCN and goiter and potential cretinism. On the last, point, studies have linked the consumption of cassava with increases in the excretion of iodine (Delange *et al.* 1976). However, the toxic effect of cassava in producing goiter has only been reported among populations that consume very large portions of cassava and whose diet is already deficient in iodine and sulphur amino acids. Obviously, in such populations it is costly to change the local staple and iodized salt is the most practical intervention. Outside of such populations, there is no evidence to suggest that there is a problem; in Paraguay and Brazil per capita consumption is greater than 100 kg/yr and there are no reports of toxicity problems. On the former point, given that calorie deficits are the principal type of malnutrition, a cheap calorie source is the most efficient instrument in improving calorie consumption among vulnerable groups and increased calorie consumption will increase the nutritional impact of existing protein in the diet (Hegstead 1978). Thus, it is rare to find in populations with high cassava consumption, a protein deficiency problem (Goering 1979). Lactating mothers and weaned children will as always exhibit particular vulnerability. In summary, there is little evidence to support a deterioration in nutritional status with increased cassava consumption and a lot of evidence to suggest a large improvement.

Animal feed. Cassava can be used as a principal energy component in diets for pigs, poultry and cattle. The experience in Europe, which in 1978 imported six million tons of dried cassava from Thailand, for use in animal diets demonstrates the feasibility of using cassava in animal feed on a massive scale. The main technical problem encountered in this sector has been with product quality; however, it is considered relatively simple to improve the quality of the dried product with improved technology and economic incentives. The Thai/Europe case is not likely to repeat itself as firstly Thailand is one of the few developing market countries that is a net food exporter and secondly because the European Economic Community is becoming increasingly unwilling to accept Thai cassava under specially low tariff rates.

Nevertheless, a rapidly growing market for feed concentrates now exists in the developing world. The transfer of poultry technology from the developed countries to the LDC's has resulted in a substantial fall in the relative price of poultry. Over a 5% annual growth rate in expected demand for poultry in the LDC's is predicted through 1985 (FAO, 1978). Demand is also strong for pork. Since the major component of the improved production technology for poultry, and for pigs, are the feed concentrates, this increasing demand has resulted in rapidly expanded demand for feedgrains, particularly maize and sorghum. Domestic production has not been sufficient in most LDC's, resulting in imports, As well in countries where maize is a food staple, rising demand has caused upward pressure on prices, to the detriment of the diet of lower income groups. Cassava offers the potential for self-sufficiency in tropical production of energy sources for animal feeds. Since the price for cassava to be competitive in this market needs to be much lower than current prices, there will as well be a direct benefit to consumers of cassava. However, to make the point again, such a price depends on the availability of new technology.

Alcohol. The increase in the price of oil over the last few years has created a tremendous interest in alcohol from biomass as an oil substitute. Brazil has taken the lead and has now an operational plant using cassava as the source of biomass. Active interest is now being shown by Colombia, Thailand, the Philippines and Australia in the use of cassava as a source of alcohol. Cassava is a particularly attractive possibility as it can be grown in marginal agricultural areas and as such will not displace food crops, as might well be the case with production of alternatives such as sugarcane. One of the major problems at present is the high energy requirement of the distilleries that make the total net energy gain very small unless the stems are used as a heat source or other technological break-throughs reduce the distillation requirement.

Implementation

Human food. The major problem with fresh cassava consumption is the extreme perishability of the product and possible toxicity problems due to high HCN content. The latter problem should be resolved by breeding for low cyanide content. It appears difficult to breed for high quality (high starch content) varieties and at the same time obtain lines with a long shelf life; however recent research has shown that relatively simple storage methods based on fungicidal treatments and packaging in polyetylene bags enable cassava to be stored for up to 2 months after harvest (Lozano *et al* 1978). More research is required so as to ensure lack of toxic fungicidal residues and also to obtain consistently good quality of the stored roots. This research will have to be done by the public sector.

Improvement of traditional processing methods may be possible. In the case of Gari considerable interest has been shown on the part of manufacturers of food processing equipment. It is probable that any further developments will come from the private sector. In the case of substituting wheat flour much is already known and the main obstacles to adoption seem to be economic rather than technical.

Animal food. Research on cassava as an animal feed was recently reviewed by Nestel and Graham (1978). The main and most urgent needs for research are in the areas of feeding systems and methods of drying the cassava before incorporation into balanced diets. Recently considerable advances in drying methodology have been made (Thanh and Lohani 1979), Best 1979), however, technology for drying in areas with high humidity still need to be developed. These techniques are not likely to be very location specific and can be developed by such institutes as the Asian Institute of Technology, Tropical Products Institute and CIAT.

Alcohol. Techniques have already been developed, by private industry, for production of alcohol from starch. It is likely that private industry will continue to improve these techniques. The main technological barrier that exists appears to be to lower the energy requirements for distillation or use the cassava stems as an energy source for this process. McCann and Prince (1978) suggest that alcohol tolerant yeasts that increase the ethanol content of the fermentation liquor from 6 to 12% would reduce steam requirements by 30% and that thermophilic fermentation of wastes (stems and fibrous wastes) can produce a methane carbon dioxide gas mixture suitable for firing boilers. Energy requirements could probably be further reduced either by vacum distillation or use of molecular filters to separate the alcohol from the water. If alcohol/water mixtures are used rather than alcohol/petrol mixtures then the alcohol need not anhydrous. High compression ratio engines (14:1) can run on alcohol with 10% water with no decrease in power per unit alcohol consumed (Stumpf 1978). Use of these mixtures could further reduce the energy required for distillation. Further research is needed to develop these techniques so that they are commercially viable.

Policy

The social benefits to increased cassava production appear to be great, including reduced grain imports, improved self sufficiency in food and potential energy, improved nutritional status of low income groups, and more productive use of underutilized land and labor resources in the agricultural sector. What then is required in terms of government .policy to. achieve these benefits? First, governments must invest heavily in research to develop, new low cost production technology. When the new cassava technology is ready, further investment would be required in cassava extension and overall government policy should be directed to dismantle the wide range of policies applied to the cereal grains that tend to subsidize imported grains against cassava and home cereal production. In the post-war period as LDC's have evolved from a net export or self-sufficient position, these countries have erected a policy structure designed either to maintain low urban food prices through usually concessional grain imports or to promote self sufficiency in grain production, especially wheat, through critically high support prices or subsidized input and credit schemes. Support prices for grains will tend to also support the price of cassava however, subsidies (particularly input subsidies) to the grains will militate against cassava. The bias of governments toward manipulating agriculture through subsidized grain policies will potentially jeopardize economic incentives for the increased production and utilization of cassava.

Nevertheless, prescribing that expansion in cassava should be free of any market intervention implies that cassava prices will have to be high enough to make production expansion profitable and low enough to make it competitive with substitutes in the respective markets. Cost reducing production technology is essential to achieve this market price balance. Table 1 in the production section summarized what we consider to be feasible yields for cassava. We now ask the question as to whether these yields are compatible with farmer profitability and market competitive-ness.

In order to evaluate the competitiveness of cassava it is necessary to estimate production costs using the new technology and also the yield levels that might be obtained. In terms of production costs we have made the following assumptions (1) a return to land and management of 500 US $/ha on prime land and 100 US $/ha on marginal land (2) chemical use would be 4 $/ha for stake treatment and on marginal land 150 US $/ha for fertilizers while on prime land only 75 US $/ha would be required. It is assumed that phosphorous can largely be applied in cheap forms such as rock phosphate. A further cost of 50 US $/ha is allowed for chemical weed control, however, if labor is low priced this could be replaced by manual weed control. (3) A labor requirement of 70 mandays per hectare is envisaged; this is somewhat lower than the estimates of Diaz and Pinstrup Andersen (1977) but is in line with data of Philipps (1974), considering the use of chemical weed control. (4) Land preparation was assumed to cost 50 US $/ha. (5) It is assumed that labor rates are lower in marginal areas than in prime land areas. These assumptions lead to production cost estimates shown in Table III for two different yield levels and two labor rates for both marginal and prime land.

In addition to estimating production costs, the possibilities for substitution for various products are estimated according to the following assumptions. In order to compare cassava and rice a value of cassava at 14% moisture of 80% of milled rice is used, and a marketing margin for cassava of 40% To convert fresh cassava to cassava at 14% moisture, a factor of 2.5 to 1 is used.

Starch processing costs were estimated from data of (Buckle *et al* 1978) for small rural factories of 50$ per ton of starch produced with an efficient extraction rate of 25%. Larger plants would lower cost per ton and increase extraction rates.

The cost of production of pellets for animal feed are based on data from Thailand (Philipps, 1978). The Thai industry is very efficient and we have raised the figures somewhat to the level of 20 US $/ton. One ton of fresh cassava is assumed to give 0.4 of pellets at 14% moisture (Best 1979) at a value of 80% of that of feed sorghum or maize.

Alcohol production costs are taken as 0.15 $/ltr (see Bull and Batstone 1978, Milfont 1978, and Philipps 1978). One ton of cassava produces 170 ltr of alcohol (see Meneses 1978, Mc Cann and Prince 1978).

These data have been used to estimate the price of competing products at which cassava will enter the market as a substitute (Table IV). It can immediately be seen that the yield of cassava and labor rates are of critical importance in determining the ability of cassava to compete. However it can clearly be seen that cassava can readily compete with milled rice at yield levels of 15 t/ha and 30 t/ha on marginal land and prime land respectively even with relatively high labor rates. In order to enter the starch and animal feed markets it appears that higher yields will be required; however if labor rates are low (2 $/day and 4$ on marginal and prime land respectively) even low yields are in the areas where they maybe competitive especially if present trends in grain prices continue. In the case of petrol substitution it appears that cassava is now becoming competitive and it is likely that as prices further increase it will become a viable alternative to imported petroleum products.

From these rather speculative data we conclude that if yields of 15 and 30 t/ha can be obtained on marginal and prime lands respectively then cassava immdeiately becomes an attractive staple to replace or complement such cereals as rice in the human diet. If as a result of a concerted research and extension effort primarily from the public sector, yields can be further raised to 25 t/ha and 40 t/ha on marginal and prime land respectively, then cassava can become a basic energy source for animal feed and as a petroleum substitute.

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Table 1. Potential commercial yields of cassava under different conditions with good management and improved varieties. Note: Improved varieties are not yet available for all conditions.

Temperature	Rainfall	Months to Harvest	Soil fertility	Fungicides and Insecticides	Herbicides	Fertilizer	Yield
22 – 28°C	1000+ mm well distributed	10-12	High	stake treatment	Optional	to maintain fertility	35 + t/ha
22 – 28°C	1000+ mm 3-4 months dry period	10-12	High	stake treatment	Optional	to maintain fertility	30-35 t/ha
22 – 28°C	1000+ mm well distributed	10-12	Moderate	stake treatment	Optional	to maintain fertility	30-35 t/ha
22 – 28°C	1000+ mm 3-4 months dry period	10-12	Moderate	stake treatment	Optional	to maintain fertility	25-30 t/ha
22 – 28°C	1000+ mm well distributed	10-12	Acid infertile	stake treatment (+ zinc)	Optional	75:150:100 NPK 0.5 t/ha limes	20-25 t/ha
22 – 28°C	1000+ mm 3-4 months	10-12	Acid	stake treatment (+ zinc)	Optional	75:150:100 NPK 0.5 t/ha lime	15-20 t/ha

Table 2. Income and price elasticities of demand for food with special reference to cassava in Indonesia

		Income Class				
		1 Low	2 Low-Mid	3 High Mid	4 High	Average
Income Elasticities						
Rice:	Urban	1.436	1.100	0.794	0.121	0.527
	Rural	1.677	1.297	0.987	0.455	0.952
Cassava:	Urban	0.835	0.524	0.231	-0.401	-0.010
	Rural	1.037	0.674	0.383	-0.116	-0.350
Calories 1/ :	Urban	0.660	0.525	0.398	0.122	0.288
	Rural	0.783	0.628	0.501	0.283	0.486
Price Elasticities						
Cassava		-1.281	-0.818	-0.943	-0.800	-0.804
Cross price elasticities						
Cassava with Rice		0.996	0.709	0.787	0.685	0.765

1/ Calories from rice, shelled maize and fresh cassava only.

Table 3. Production costs ($/ton) of cassava at different labour rates on marginal and prime land at different yield levels. (See text for explanation)

	Marginal Land		Prime Land	
Daily labour rate (US$)	2	4	4	6
Yield level 15 t/ha	33	42	/	/
Yield level 25 t/ha	20	25	/	/
Yield level 30 t/ha	/	/	32	37
Yield level 40 t/ha	/	/	24	28

Table 4. Estimated price of competing products at which cassava can enter markets as a substitute, at different yield levels and with different daily wage rates on marginal and prime land. (See text for explanation)

Products to be substituted	Daily Wage rate (US $)	Marginal Land Yield		Prime Land Yield	
		15 t/ha	25 t/ha	30 t/ha	40 t/ha
Milled rice	2	145	88	/	/
($/ton)	4	185	110	141	106
	6	/	/	163	123
Starch	2	182	130	/	/
($/ton)	4	218	150	178	146
	6	/	/	198	162
Sorghum or maize	2	128	88	/	/
(for animal feed)	4	156	103	125	100
($/ton)	6	/	/	141	112
Gasoline	2	0.34	0.27	/	/
(US $/ltr.)	4	0.40	0.30	0.34	0.29
	6	/	/	0.37	0.31