Discours de Monsieur le Ministre de la Recherche Scientifique lors de l'ouverture du 11ème symposium de la Société Internationale des Plantes à Racines et Tubercules-Branche Africaines (ISTRC-AB) Kinshasa, 4-8 octobre 2010

Excellence Monsieur le Ministre de l'Agriculture,
Monsieur le Représentant de l'USAID,
Monsieur le Représentant de la FAO,
Monsieur le Représentant de l'IITA,
Mesdames et Messieurs,
Distingués Invités,

C'est un grand privilège et honneur d'être invité à inaugurer l'ouverture de ce forum qui réunit des scientifiques et des acteurs de developpement de haute renommée, j'ai cité le 11ème Symposium triennal de la Société Internationale pour les Plantes à Racines et Tubercules Tropicales-Direction Afrique.

En accueillant cette réunion au cours cette année cinquantenaire des indépendances de la plupart des pays africains dont la République Démocratique du Congo, notre pays s'est vu grandement honorer par la Direction Africaine de cette Société. En fait, ceci n'est pas une première expérience pour notre pays, car déjà en décembre 1989, soit vingt-une années passées, la République Démocratique du Congo, alors République du Zaïre, abritait le 4ème Symposium triennal de la Direction Afrique de la Société Internationale pour les Plantes à Racines et Tubercules Tropicales.

En effet, la valeur de l'élite scientifique réunie pour échanger et discuter sur différents aspects des plantes à racines et tubercules montre à suffisance l'intérêt et l'importance accordés à ces cultures pourvoyeuses des nourritures et génératrices des revenus aux communautés habitant l'Afrique Subsaharienne et les origines diverses des délégués rassurent combien ce symposium est aussi important.

Les plantes à racines et tubercules constituent la source importante des calories et interviennent quotidiennement dans le repas des populations congolaises et couvrent les plus grandes superficies des terres cultivables dans cette partie du continent Africain.

Mesdames et Messieurs,
Distingués Invités,

Il est inutile de vous rappeler que l'agriculture constitue le secteur susceptible d'accélérer la croissance économique et d'atteindre une bonne majorité des populations et que la recherche agronomique constitue alors le moteur pour la relance d'une agriculture capable de répondre aux besoins de l'humanité. A ce titre, le Gouvernement de la République entreprend des efforts à travers l'Institut National pour l'Etude et la Recherche Agronomiques (INERA) avec la collaboration des centres internationaux de recherche partenaires tels que l'Institut International d'Agriculture Tropicale (IITA) pour renforcer davantage le rôle à jouer par la recherche dans le développement de notre pays. J'ai la ferme conviction que les pays Africains comme tous les pays d'autres continents représentés ici partagent avec nous cette vision des choses.

Au regard de cette contribution de la recherche à l'agriculture et, par conséquent à l'économie nationale, la République Démocratique du Congo a eu à lancer l'Initiative Présidentielle sur le Manioc en Juin 2010. A travers cette initiative, notre Gouvernement veut, à un haut niveau, s'impliquer et assurer la promotion de la culture du manioc.

Le chemin à parcourir reste encore long et il faudra viser la diversification des produits à base de ces spéculations, leur utilisation comme matières premières dans l'industrie et le marché national, régional et même international. Aussi, devant les défis de mondialisation et du changement climatique auxquels nous devons faire face, la recherche devra être à l'avant-garde pour ne pas subir, mais elle doit anticiper. Par anticipation, il y a lieu de considérer aussi la conservation des ressources génétiques utiles à la recherche, mais fortement menacées par le changement climatique.

Mesdames et Messieurs,
Distingués Invités,

Dans l'entretemps, la recherche répond déjà, tant soit peu, aux desiratas des consommateurs et utilisateurs congolais, en ce qui concerne le manioc, la culture vivrière la plus importante en termes de superficie cultivée et consommation par habitant. Il a été observé un taux élevé d'adoption des technologies diffusées à partir de 2004 suivie d'une stabilisation de la production du manioc dont la tendance était baissière durant la dernière décennie suite à la recrudescence de la mosaïque africaine. Comme en République Démocratique du Congo, les plantes à racines et tubercules ont largement contribué à l'amélioration de la sécurité alimentaire et nutritionnelle et à la réduction de la pauvreté pour des communautés en Afrique Subsaharienne.

Au delà de la sécurité alimentaire, ces cultures devront contribuer, comme dit ci-haut, à l'économie des nations africaines. A ce point de vue, nous voulons dire que leur production devra viser et exploiter les opportunités qu'offrent divers marchés; c'est-à-dire rendre disponibles des quantités importantes tout en étant compétitif sur les marchés et en assurer une bonne commercialisation. Il y a lieu de dire que c'est toute la filière qui doit être considérée, à savoir, la recherche dans tous ses aspects, la transformation par l'industrialisation et le développement du marché.

C'est ainsi que nous apprécions la participation active du secteur privé notamment les fermiers, les petites et moyennes entreprises, les institutions financières et tant d'autres qui s'attellent au developpement du secteur agricole.

Distingués Scientifiques et Délégués,

Permettez-moi d'anticiper que vos communications et discussions couvriront fondamentalement ces maillons dans les filières de chacune des plantes à racines et tubercules tropicales. Aussi, des résolutions et recommandations pourront apporter des réponses aux défis mentionnés dans le thème de ce symposium de Kinshasa.

Sur ce, je déclare ouvert le 11ème Symposium triennal de la Société Internationale pour les Plantes à Racines et Tubercules Tropicales-Direction Afrique.

Je vous remercie.

IITA Remarks at Opening Ceremony

Dr. Robert Asiedu, Director, Research-for-Development (West Africa)

Mr Chairman;
Your Excellency, the Honorable Minister for Arts and Culture, standing in for the Minister for Scientific Research, DRC;
Director-General of INERA, DRC and Member, IITA's Board of Trustees;
President of ISTRC-AB;
Representatives of USAID, FAO, EU-ACP, and FPI;
Directors and Research-for-Development Colleagues
Ladies and Gentlemen

It is a pleasure and an honor to have this opportunity to say a few words on behalf of the management of the International Institute of Tropical Agriculture (IITA).

I cannot emphasize enough how proud we are of our association with the Africa Branch of the ISTRC. This vibrant branch of the Society has consistently used its triennial symposia for taking stock of progress being made, documenting and sharing relevant information, establishing and strengthening partnerships, planning for the future, and advocating for policies supportive of the root and tuber crop sector.

A lot has happened in science and in our various lines of work since the last symposium in Maputo and most of us can hardly wait for the presentations and discussions to start. From IITA's perspective the spectacular challenges and opportunities in the management of pest and disease dynamics of cassava have been met with constructive partnerships and decisive science-based actions as progress continues towards its expanded use in industry. I am sure equally exciting examples of progress on the other crops will be presented and discussed in this symposium.

Through ISTRC-AB, IITA and other CGIAR centers especially CIAT and CIP, other international research agencies and NGOs, as well as development investors, have an important meeting-point and platform for consultation and joint planning with a broad range of essential partners in the national systems and the private sector, with a focus on root and tuber crops in sub-Saharan Africa .

Colleagues, as most of you may already know, the CGIAR is going through a process of reform that is aimed at increasing efficiency and effectiveness through improvements in partnerships and better integration of programs. A single CGIAR Research Program has been proposed for the continuation of the research on root and tuber crops, banana and plantain that is currently conducted through four CGIAR Centers Bioversity International, the International Center for Tropical Agriculture (CIAT), the International Potato Center (CIP) and IITA. Through the new structure we hope to derive even more benefits or efficiencies from the similarities in this group of important clonally propagated starchy staples.

On behalf of IITA management I wish us all excellent deliberations and conclusions from this symposium in the ultimate interest of the several million beneficiaries from our work for whom root and tuber crops are synonymous with culture, assurance of food, increase in wealth, and good health.

Thank you.

SOCIO ECONOMICS PAPERS

The impact of the emergency response to the outbreak of the cassava mosaic disease in the Democratic Republic of Congo

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Abstract

This paper evaluates the impact of an emergency research for development project implemented in the Democratic Republic of Congo from 2000 to 2009 by a various actors including the International Institute of Tropical Agriculture in response to the outbreak of the Cassava Mosaic Disease that threatened the national food security. It applies methods developed in the econometric and statistical treatment effects literature on evaluation of social programs. The study evaluates impact by analyzing changes over time of outcomes of sample households in the project areas compared to neighboring non-project areas. We find that the project had statistically significant positive effects on technology adoption, area planted cassava, productivity, profitability, household food security and aggregate supply response. The effects are strongest among lower tails of distribution of outcomes mostly made up of female-headed households who grew the crop mainly for food. These findings are useful for informing agricultural and food policy debates in Africa.

Introduction

Cassava is the staple food and wage good in the Democratic Republic of Congo (DRC). It accounts for more than 70 % of annual crop area. It provides around 56 % of the calories in the diet (FAO, 2009).

The leaves are a major vegetable throughout the country. Thus, increasing cassava productivity and production is critically important for achieving household and national food security and for accelerating economic growth in order to reduce poverty. During the 1960s production increased and supply was sufficient to meet demand (Figure 1). But in the early 1970s output growth rate declined. This was largely caused by the spread of Cassava Bacterial Blight (CBB) disease in the southern region and cassava mealy bug in the western region. To combat the spread of these pests and diseases, the government established the Programme National Manioc (PRONAM) in 1974 within the Institut National pour l'Etude et la Recherche Agronomiques (INERA) to carry out cassava improvement research. The government requested the International Institute of Tropical Agriculture (IITA) to provide technical assistance. During the 1980s, cassava production increased to a high of 20 million tons of fresh roots annually as a result of area expansion and yield increases. Area and yield increases were driven by development, multiplication and distribution to farmers of disease-free planting materials of improved varieties, biological control of mealy bug, development and dissemination of improved crop management practices, and capacity building of farmers' associations and non-governmental organizations (NGOs).

During the early to late 1990s annual aggregate production declined by 25 % from 20 to 15 million tons of fresh roots below annual domestic demand averaging 18 million tons of fresh roots. Factors contributing to that decline included lack of disease-free planting materials supply systems, lack of research, multiplication and distribution of clean planting materials of improved varieties, collapse of extension, civil unrest, and high transportation costs because of degradation of roads and infrastructure and transport vehicles. The most important factor however, was the spread of the new deadly Ugandan variant of the East African Cassava Mosaic Virus (EACMV-Ug. The EACMV-Ug was first detected in the country in 1996. In 2000 a team of IITA scientists found that the EACMV-Ug had spread to most cassava production regions. Because all existing varieties were susceptible to this variant, there was a high likelihood that cassava production would collapse, threatening household and national food security.

To reverse the declining trends and get agriculture moving again, the emergency response to the outbreak of the Cassava Mosaic Disease (CMD) project was started in 2001. The project was implemented using what is now known as agricultural research for development approach. This involved working at higher scales and incorporating into the research process work on agricultural input and output markets, farmers' organizations, extension and public-private sector partnerships (Lynam, 2004). Research was embedded within an innovation system consisting of key players along the cassava value chains. The players included INERA, PRONAM, IITA, the South-East Consortium for International Development (SECID), the Food and Agricultural Organization of the United Nations (FAO), community based organizations, farmers' groups and associations.

The project was implemented in two phases. The first phase was from October 2001 to September 2006. The second phase from October 2006 to September 2009. The first phase focused on rehabilitation of cassava production through multiplication and distribution of clean planting materials of existing released cassava varieties, development of new varieties with resistance to the viral disease and acceptable consumption traits, and improved crop management technologies. The first phase was implemented from 2001 to 2006 and was targeted to the western provinces of Bas Congo, Kinshasa, and Bandundu because there was war in the eastern part of the country. The second project focused on improving livelihoods through rehabilitation of cassava production and expansion to the eastern provinces. In addition to variety improvement, emphasis was placed on crop management and post-harvest management.

The problem

Although significant public expenditures have been invested in cassava improvement research for development over the past decade, hard evidence of progress made to guide continued investments and exit strategies is lacking. Project monitoring and evaluation reports indicate that substantial outcomes and impacts have been achieved. These are demonstrated by the reversal of downwards trends in aggregate cassava production which coincides with the timing of investments. However, it is unclear which areas had a supply response, how widely spread was the supply response throughout the country and what is needed to further increase production.

This paper applies methods developed in the literature on econometric and statistical analysis of causal effects in program evaluation to evaluate the impact of the CMD project on beneficiaries and potential beneficiaries. The evaluation focuses on three questions: (a) Does the project have effects on outcomes of interest? (b) Was the project worthwhile? (c) Should the project be extended to other areas?

There is a growing demand by agricultural researchers, representatives of farmers' organization, agribusiness managers, government decision makers, NGOs and donors for impact assessments using rigorous methods to provide more credible impact evaluation. Determining the impact of agricultural research investments is important for accountability to funders and stakeholders, priority setting and learning to improve programs.

This paper contributes to the growing literature on the impact assessment of agricultural research for development approaches in Sub-Saharan Africa using rigorous methods for counterfactual analysis of social programs in order to provide empirical evidence about their effects. Most agricultural research impact studies focus on average impacts in experimental and farmers' plots rather than distributional and on gender. But government decision makers and policy makers differently evaluate programs having the same average effects but different effects for lower and upper tails of the distribution of outcomes. We find that the project caused positive effects on use of improved varieties, increases in area planted cassava, yields and gross margins per hectare, and reduction in household food insecurity. The effects are strongest on lower tail of the distribution of outcomes implying that poor farmers who are mostly female-headed households capture the bulk of the benefits.

Overview of the evolution of cassava improvement research and the Cassava Mosaic Disease project

Formal cassava improvement research in the DRC started by introducing and evaluating varieties in observation plots in the 1920s (Pynaert, 1928). CMD was first reported in the country by Janssens in 1917 (Stoner, 1931). Yield trials carried out at Boma in Bas Congo to test 28 varieties from Brazil, Cuba, Java, Florida, West Indies, Singapore, Sri Lanka and Reunion showed wide variability in yields, ranging from 9 -52 t/ha. Mandioca Creolinha from Java gave the highest yields. Researchers conducted agronomical trials and derived recommendations for dissemination to farmers (Pynaert, 1928). The recommendations included advice on land preparation, soil fertility maintenance, storage of planting materials, preparation of cutting, planting, weeding, intercropping and harvesting.

In 1933, the Belgian Government established the Institut National d'Etude Agronomique du Congo Belge (INEAC) at Yangambi to carry out agricultural research in Central Africa (Nweke et al., 2002). INEAC scientists carried out research on clones selected from introduced and local materials and from crosses between local cultivars and introductions. After independence in 1960, INEAC became INERA. INERA continued to carry out cassava research. However, the organization was poorly structured to work at a large scale until the establishment of the Programme National Manioc (PRONAM) in 1974. Still the research work resulted in the selection of the 02864 variety. This was released and multiplied and distributed to farmers at the beginning of PRONAM. The program was implemented from 1974 to 1990. PRONAM was implemented with IITA's technical assistance through resident scientists, short-term consultant visits and administrative support. Mvuazi station was selected as the main research and training center with other satellite stations throughout the countries in different agro-ecological zones. These included Yangambi, Kiyaka, Ngandajika, Mulungu, and Gimbi.

The Programme National Manioc achieved five key results (Lutaladio, 1986; Ministry of Agriculture, 1988). The first result was the reorganization of the breeding system from on-station, observational and non-replicated trials to fully replicated factorial on-station and on-farm trials for statistical analysis. This resulted in the development and release of five high-yielding varieties with resistance to CBB and acceptable leaf traits. The breeding system used at IITA was introduced and adapted to organize cassava breeding to work at higher scales and reduce the time from variety identification to release, multiplication and distribution of planting materials to farmers. The process from the release of varieties to multiplication and distribution of planting materials to farmers was organized into several stages. In the first stage, a crossing block was used to identify parents with good combining ability and carry out recombination through open pollination and specific crossing for traits of interest. Seedling nurseries were used to screen cassava seedlings for growth habits and resistance to diseases and pests. Best individual seedlings were cloned and moved to clonal evaluation trials in two or three agro-ecological zones. Selections from clonal trials were advanced to preliminary yield trials in different locations. Materials from preliminary yield trials were screened, selected and evaluated in advanced yield trials in different agro-ecological zones. Promising clones in advanced yield trials were further evaluated in uniform yield trials under diversified agro-ecological zones. The outstanding clones in uniform yield trials were evaluated at different agro-ecological sites in multi-locational on-station and on-farm trials. The outstanding clones accepted by farmers were recommended and officially released for multiplication and distribution to farmers. The system reduced measurement errors and allowed experiments to cover a wider range of conditions. This, in turn, permitted faster and more accurate measurements and data analysis and development of robust varieties. Still the time from seedling nursery to release averaged 5 years and an additional two years for multiplication and distribution.

The varieties developed included Kinuani (30085/28), F100 identified in 1976, Tshilobo (30085/28/10) in 1979, Pululu (40230/3) in 1980, Mvuama (83/138) in 1983 and RAV (85/297) in 1985 (Table 1). PRONAM also identified clone 70453 with high resistance to mealy bug but it had no tuberous roots production. It was therefore mainly used as a parent in the breeding program. Two varieties Antiota and Nsumbakani were included in on-farm trials and taken up by farmers although they were not selected by breeders and therefore not officially released. Antiota was introduced from IITA Ibadan in the 1980s for the first time and in 2000 for the second time. Antiota was disseminated and used in Bas-Fleuve (Bas-Congo province) due to its mealy characteristics that were more preferred than those of local varieties. Nsumbakani is now used as a local variety especially around Kisantu and Inkisi in Bas-Congo. Kinuani and F100 were officially released in 1983. Tshilobo was released in 1984 and Pululu in 1987. Although Mvuama was recommended for release in 1987 it was not officially released until 1997. RAV was recommended for release in 1992 but was officially released in 1997. The long time from recommendation to release was due to changes in the official variety release procedures and relationships among different departments in the different ministries. In the 1970s, INERA was within the Ministry of Agriculture. In the 1980s it was transferred to the President's office. In the early 1990s the Ministry of Research and Technology was established and INERA was transferred to this Ministry. Breeders were required to hand over varieties at the end of selection to the Research and Development Program in INERA which then conducted on-farm testing for variety release. PRONAM remained within the Recherche Agricole et Vulgarisation (RAV) project which later evolved to the Service National de Recherche Agronomique et Vulgarisation (SENARAV). This resulted in bureaucratic decision making and delays because the variety release process involved two ministries. The varieties were developed through INERA within the Ministry of Research and Technology and their release was the responsibility of the Ministry of Agriculture.

The second result was identification of factors affecting the spread of mealy bug and green mite, assessment of severity of yield losses caused by these pests and the introduction of natural enemies of the pests with technical and financial support from IITA Africa Wide Biological Control Program. The project had developed integrated pest and disease management methods to control pests and diseases through breeding for resistance to mealy bug, spider mite, CMD and CBB.

The third was the development of rapid multiplication techniques suited to the local conditions and distribution of clean planting materials of improved varieties to farmers which, although susceptible to diseases and pests, were high yielding. Planting materials were made available for planting by farmers while developing resistant varieties. Resistant varieties were bulked up and distributed immediately after release. PRONAM distributed a cumulative total of 3,000,000 one-meter stem cuttings of improved varieties from 1979/1980 to 1987/1988. This was sufficient to plant a lower bound estimate of 1,200 hectares, about 0.06 % of the total national cassava area using FAO data or 0.14 % using Service National de Statistique Agricole (SNSA) data.

The fourth result was post-graduate and group training of scientists and technicians in agronomy, breeding, entomology, pathology, physiology and biochemistry. Because the national extension program was weak PRONAM focused on capacity development of alternative extension suppliers. These included community based organizations, farmers' associations and NGOs.

The final result was the development and dissemination of a basket of crop management practices through on-farm trials and demonstrations to farmers. These included selection and handling of planting materials, planting density, weeding and soil fertility management through organic residues, alley-cropping, in-situ mulch production, crop rotation and intercropping.

In 1990 IITA left DRC. The research program on food crops (SENARAV) was handed over to SECID in 1990 with funding from USAID. SECID had been engaged in agricultural research and development of different crops from 1985 with funding from USAID. SECID began field research activities on cassava in 1991. However, SECID stopped the research and withdrew from the country during the same year because of political problems. Thus, the national program was on its own for a decade. Research investments were very low. Because of economic problems, insecurity, poor funding, dilapidated infrastructure and low staff morale, national scientists resigned. Due to limited funding and staff depletion, researchers focused on maintaining old varieties: F100, Tshilobo, RAV, Mvuama, and Pululu. Despite limited resources and infrastructural and political constraints, researchers developed and released three varieties: Sadisa, Mahungu and Lueki. The varieties were developed before the Ugandan variant of the East African Cassava Mosaic Virus was detected in the country. Consequently, the cultivars were resistant to African Cassava Mosaic Virus (ACMV) but not to EACMV-Ug which was not prevalent at the time of their development. This explains why EACMV-Ug spread in the late 1990s.

Cassava research investments began to intensify in 1996 when PRONAM joined the East Africa Root Crops Research Network (EARRNET) coordinated by IITA. EARRNET provided financial and technical supported the national cassava program. The national cassava breeders observed that there was a cassava mosaic disease problem and requested germplasm: clones from IITA East and Southern Africa Research Centre (ESARC) Uganda and seeds from IITA Ibadan through EARRNET. When evaluating germplasm from IITA, researchers began to place high priority on CMD resistance in their program and selection of clones.

Three key events in 2000 shaped the design of the project. The first was the observation of very severe mosaic disease symptoms similar to those in EACMV-Ug pandemic region of East Africa by a national FAO consultant. FAO then initiated discussions with INERA and PRONAM leading to the introduction of IITA elite clones. In July 2000, 200 in-vitro (tissue culture) elite clones were introduced from IITA Ibadan to INERA through FAO. Consequently the evaluation from the test-tube to the field for hardening and acclimatization of plantlets started in 2000. When project implementation began a year later materials were at clonal evaluation stage. This permitted the researchers to identify promising varieties after only 3 years. The second event was participation of SECID in a forum on public-private partnerships in October 2000 sponsored by USAID. SECID developed relationships with farmer unions and other NGOs. The third was a visit by a team of six IITA scientists consisting of breeders, entomologists and virologists to DRC towards the end of 2000. They made a multidisciplinary team with FAO and INERA/PRONAM experts and carried out a phytosanitary survey and collected samples that confirmed the presence of the EACMV-Ug variant in the western part of DRC. Debriefing meetings to the ministry and USAID officials led USAID to request for a proposal to address the CMD problem.

FAO, IITA and SECID formed a consortium in 2001 to combat the CMD as a multi-donor program funded by USAID and other donors. Project interventions were organized into two components: technology development (IITA and INERA); and technology dissemination (SECID, FAO and other NGOs). The project started in 2001 and IITA was responsible for project management and coordination and research on germplasm development, crop management, crop protection and post-harvest management technologies. IITA and INERA jointly implemented the development of new varieties and crop management technologies, in vitro multiplication of breeder seed in tissue culture laboratory using meristem-tip cultures and multiplication of pre-basic and basic stock of planting materials. SECID, FAO and the Centre d'Appui au Developpement Integral/Mbankana (CADIM) were responsible for multiplying and distributing to farmers disease-free planting materials and promoting technology adoption. In addition, the Bureau Central de Coordination (BECECO), a government clean seeds multiplication and distribution project funded by the World Bank, supported cassava healthy planting material multiplication and distribution and farmer training. PACT-Congo was included during the second phase of the project. A Steering Committee was established with representatives drawn from the implementing organizations and key stakeholders to coordinate activities. The committee organized annual meetings to review and discuss results, learn from previous experiences and develop work plans for the following cropping seasons. Thus, it functioned as an innovation platform in the recent agricultural innovation systems literature.

Turning to cassava germplasm development, varieties were mostly developed at Mvuazi with further testing in other agro-ecological zones of the country. Emphasis was put on resistance to CMD with "zero CMD tolerance" strategy - any seedling or clone showing CMD symptoms was excluded even with very low level of infection. To broaden the source population for better selections, researchers focused on crossing local landraces with introduced improved germplasm from IITA Nigeria, evaluating and selecting varieties that could immediately resolve the CMD problem. INERA researchers visited other scientists in IITA research stations in Ibadan, Cotonou and Uganda for training in cassava breeding, protection, processing and new product development. IITA scientists provided in-country technical backstopping to INERA on breeding, crop protection, and processing. This approach yielded good results. Tissue culture clones introduced in 2000 prior to the commencement of the CMD project were followed with another batch in 2002. These were quickly evaluated. By 2004 the first set of five EACMV-Ug field resistant varieties was officially released for multiplication and distribution to farmers. However, the varieties needed some phytosanitation. The varieties included Butamu (MV 99/395), Disanka (I 95/211), Mvuazi (I 95/528), Nsansi (I 96/160), and Zizila (MV 99/038). Butamu and Zizila were developed from true seeds introduced from IITA-Ibadan via EARRNET and the remaining three varieties imported directly from IITA-Ibadan as vitro plants.

The second set of five EACMV-Ug highly resistant varieties was released in 2008. These were Mbankana (I92/067), TME419, 94/0330, 2001/1661, and 2001/1229. They required less phytosanitation follow-up in multiplication and production fields. Ngandajika (MV 99/150), introduced from Mvuazi station where it was not selected, was preferred in Kasai. It is not officially released yet but is already disseminated around Ngandajika INERA station and other regions in Kasai Oriental. This variety was identified along with Butamu and Zizila in the 1998-1999 seedling nursery. Another set of 5 varieties was officially released in 2008 for the high altitudes in the eastern part of the country. These were Mayombe (MM 96/7762), Liyayi (MM 96/0287), Namale (MM 96/7204), Sawasawa (MM 96/3920), and Sukisa (MM 96/). They were all developed at IITA-ESARC and were introduced through EARRNET for evaluation by INERA in eastern highlands of Kivu provinces. These varieties were largely multiplied and distributed to farmers through the USAID-funded Crops Crisis Control Project (C3P) for Great Lakes managed by Catholic Relief Society (CRS) and IITA. Farmers began to plant all these varieties in 2004. Researchers based in the west could not easily travel to the eastern parts due to the civil unrest in the eastern part of the country. With new emerging threats such as Cassava Brown Streak Disease (CBSD) now prevalent in DRC, researchers are breeding for resistance to CBSD, Cassava Anthracnose Disease (CAD), and high yield in addition to CMD. Cassava research is also focusing on specific needs for end uses, including varieties with high root dry matter and starch contents that are being demanded by processors. Issues of varieties for higher protein content in leaves and high beta-carotene content in yellow-pigmented tuberous roots are also being addressed to improve the nutritional status of the population. Research is focusing on developing varieties that are adapted to different agro-ecological conditions.

Crop management and protection research was implemented through diagnostic surveys, monitoring and forecasting disease and vector spread, development of IPM intervention technologies and on-station and on-farm experiments. Crop management involved borrowing and screening technologies on rapid multiplication techniques, selection and handling of planting materials, planting density, weeding time and method, soil fertility management, intercropping and harvesting to site specific-needs. Farmer Participatory Research (FPR) trials were conducted with farmers to evaluate best-bet soil fertility management options. Farmer Field Schools, demonstrations and field days were organized to disseminate appropriate practices.

Crop protection research used national surveys for pests and diseases to determine the distribution and importance of different pests and diseases of cassava and changes in their pressure in cassava production and in farmers' knowledge and perception of these changes and to ascertain the epidemiology of CMD and CBSD. Surveillance based on farmer monitoring networks was used to monitor new occurrences of severe CMD epidemics and whitefly biotype. Field trials were conducted on the cassava green mite (CGM) and the efficacy of the predacious mite *Typhlodromalus aripo* (*T. aripo*) for its biological control. Trials were carried out on African Root and Tuber Scale (ARTS), a major insect pest in degraded forest zones in DRC, and control practices. Crop trials were planted to determine root yield losses caused by thrips (*Frankliniella* sp), pest insects observed in the last 3-4 years around Mvuazi research center, and develop control methods. Experiments were conducted to study the rate and time of re-infection of planting materials cleaned through phytosanitation by the cassava mosaic virus and time required for the re-utilization of planting materials after roguing. Technologies for biological control of the Cassava Green Mite, and IPM options including tolerant and resistant varieties, cultural practices, soil fertility management were developed and disseminated to farmers. Methodologies for plant quarantine and standards for targeting interventions site were developed to ensure quality control and monitoring of multiplication sites of SECID and FAO and virus detection. Trainers of trainers' courses were organized for NGO technicians, government frontline extension agents and representatives of farmers' association in rapid multiplication techniques, identification of pests and diseases and IPM practices.

Post-harvest management research was implemented through borrowing, screening and adapting to site-specific needs cassava processing machines to improve quality of traditional processing; and developing new products, new markets for products, village processing centers, institutional arrangements to connect farmers to markets, cassava processing enterprises and market information systems. The first set of 20 IITA-designed processing machines consisting of a grater and chipper were introduced from Ibadan in 2004. This was followed by a second set of 30 machines in 2005. When the demand for machines started growing, researchers trained and built the capacity of local fabricators to domestically manufacture and supply processing machines and equipment. Equipment fabricators were sent to Tanzania to learn the technology and bring the machines to Congo. After introducing machines, researchers started promoting diversification of products to high quality flour and use of peels for animal feed. Research focused on improving the quality of fufu by reducing the time of soaking and drying of chips and using peels as feed for pigs and goats. Farmers and micro-enterprises were trained on the production of micro-chips for high quality fermented and unfermented cassava flour and its use for substituting wheat flour in bakery and confectionery products. Bakers were organized into an industry association, the Association of Artisan Bakeries of Congo (ABAC), which promoted the use of unfermented high quality cassava flour in bread making, thereby creating a new market for it. Expansion of production was constrained by a lack of investment by agribusiness firms in the production of high quality flour and supply quantities demanded by bakers because of unavailability of raw materials throughout the year.

Multiplication and distribution of planting materials by IITA/INERA, SECID, FAO, CADIM, BECECO and PACT Congo was implemented using a three tier scheme. The scheme was organized into nucleus and primary, secondary, and tertiary stages. It was based on the approach developed and tested by IITA and national programs in several countries. The scheme was clearly defined and it was similarly implemented by different teams. Breeder and basic planting materials were bulked up by IITA and INERA in nucleus and primary multiplication fields at research stations under the management of breeders and inspectors from SENASEM. To accelerate the production and ensure the quality of disease free pre-basic planting materials, in vitro multiplication in tissue culture laboratories at research stations was used to produce virus-free plantlets grown in nucleus multiplication fields. Materials from nucleus multiplication fields were further bulked in primary multiplication fields. Materials from primary multiplication fields were made available to SECID, FAO, CADIM, PACT

Congo and other organizations for further multiplication in secondary nurseries in areas targeted for intervention under management of field technicians. Materials from secondary multiplication fields were then bulked up in tertiary fields in community fields of participating farmers' associations. Materials from fields of farmer associations were then distributed to participating farmer members and neighboring households for planting.

Different organizations used different strategies to select geographical areas, sites, village communities and households; organization and management of multiplication fields; choice of varieties to multiply and quantities of planting materials to distribute per household; and scale and scope of operations.

SECID started implementing multiplication and distribution of planting materials with funding from USAID during the 2001/2002 and 2002/2003 cropping seasons in Bas Congo and Bandundu. This was because there was war in the eastern part of the country. Bas Congo and Bandundu are major food sheds for the capital Kinshasa city. Bandundu produces about a quarter of all cassava in the country. Planting materials of improved varieties developed by INERA used to jumpstart the project were only available at Mvuazi research station. During the third 2003/2004 cropping season, SECID expanded activities to Equateur targeting Mbandaka and Province Orientale targeting Kisangani. During the second phase of the project SECID stopped dissemination of EACMV-Ug tolerant and focused on multiplication and distribution of EACMV-Ug resistant varieties in the Orientale province.

SECID selected sites and village communities for secondary multiplication based on production potential, accessibility depending on transportation infrastructure; availability of community based organizations linked to higher level organizations for large scale multiplication and distribution of planting materials; organization of the farm communities; and agronomic factors. Within sites, SECID selected community-based organizations to partner with that have experience in agriculture, field technicians to provide advice, physical presence in the targeted sites and a long-term vision to work in agricultural development. Fields for multiplication of planting materials were selected based on interest of farmers' group members to participate, ownership of land by the community and production potential of the field.

Turning to the organization and management of multiplication fields, at the beginning of the project, the source materials were of poor quality because the cuttings were purchased from farmers neighboring Mvuazi research station. SECID began by giving small quantities of planting materials to interested community farmer groups and assisting members to establish community-owned and managed nurseries of about 0.3 hectares. Members produced clean materials using rapid multiplication and phytosanitation. Farmer group members provided land and labor. The materials were harvested after 6 months and further bulked in larger multiplication fields of about 7.5 hectares to produce planting materials for sharing among group members and distribution to other communities. After 2004 when IITA developed new varieties, SECID stopped setting up nurseries and began establishing secondary multiplication fields. To speed up adoption time some varieties went straight to farmers through tertiary multiplication. SECID worked through its partners and field technicians with members of farmer association to produce planting materials in tertiary multiplication fields.

In a similar vein to SECID, FAO began multiplication and distribution of planting materials as part of the multi-agency and multi-investors in development project, with funding from the United Nations Development Program (UNDP), France, Belgium, and USAID/OFDA during the 2000/2001, 2001/2002 and 2002/2003 seasons. Because of the availability of planting materials in Mvuazi and war in the eastern provinces, multiplication and distribution of planting materials were targeted first to Bandundu, Bas Congo and Kinshasa. However, FAO through UN planes air-lifted most of the resistant varieties from the west to Equateur, Kasai Orientale, Kasai Occidental, North and South Kivu, Maniema, Orientale and Katanga. This is because FAO piggy-backed on more than 50 agricultural emergency and humanitarian relief projects that it implemented from 2005 to 2008. The FAO implemented these projects with funding from Belgium, France, USA, Italy, Japan, Norway, Sweden, Switzerland, the Netherlands, European Commission, United Nations Development Programme (UNDP), FAO, The International Fund for Agricultural Development (IFAD), Mission de l'Organisation des Nations Unies en République démocratique du Congo (MONUC) and United Nations Office for the Coordination of Humanitarian Affairs (OCHA).

FAO organized and managed multiplication and distribution of planting materials following the three tier scheme. FAO organized secondary multiplication in the target areas in partnership with NGOs and tertiary multiplication at the village level in partnership with farmers' associations and Farmer Field Schools. Like SECID FAO began by multiplying EACMV-Ug non-resistant varieties because there were no other varieties. When the first set of EACMV-Ug resistant varieties were released and recommended to farmers FAO began to place emphasis on their multiplication. FAO also distributed to participating farmers groups farm implements such as hoes and machetes.

CADIM was organized with funding from the Hanns Seidel Foundation in 1996 following the ending of the Programme for support to farmers in Kinshasa (PIEK). Starting in the 1996/1997 season the NGO conducted preliminary yield, multi-location on-station and on-farm trials with INERA scientists. CADIM supported multiplica-tion and distribution of planting materials, training of technicians and farmers, extension and monitoring disease spread. CADIM targeted its interventions in the Plateau de Bateke, Kinshasa Province. This is because cassava is the most important staple food for most households in the area. The decrease in cassava production especially in 2002 led to food insecurity in most of the households. The global food crisis aggravated the situation as most households could not afford to buy enough food and failed to meet cash expenses such as school fees, and medical bills.

Within the target area, CADIM focused activities in some 30 villages. In each village there was a resident extension agent. For each of these thirty villages, CADIM formulated a development plan which was updated according to emerging needs. Frontline extension agents employed by CADIM collected and provided information within their villages of the total area ploughed and the quantities and the names of farmers in need of planting materials. In case of introduction of a new technology, radio and village to village farmer sensitization approaches were used. Interested farmers then registered at resident extension agent or directly contacted CADIM management office. CADIM had signed an agreement with INERA for CADIM site to be used as an adaptation station. IITA works at CADIM under INERA agreement umbrella. CADIM carried out participatory evaluation of cassava germplasm with farmers through farmer field schools, mainly led by women. Because in Plateau de Bateke if a household cultivates on less than 2 to 4 ha per year it is judged food insecure or poor, CADIM distributed to each farmer enough planting material for a minimum of 2 ha in the second year. CADIM also distributed improved varieties of cowpea seeds (INERA/IITA); beans seeds (Implementation and Coordination of Agricultural Research and Training (ICART) Programme in the SADC Region (ICART)/INERA/The International Center for Tropical Agriculture (CIAT)); maize seeds from improved varieties (ICART/INERA). It also distributed seeds of the New Rice for Africa (NERICA) varieties (ICART/INERA/Africa Rice Center (WARDA)); mucuna or green manure; stylosanthes for green manure; Acacias auriculiformis for farmer agro forestry; and apiculture. The NGO conducted annual surveys to identify basic needs of farmers and determine how much of other inputs to give per household.

The Bureau Central de Coordination (BECECO) implemented the project in Bas Congo, Bandundu, Kinshasa, Kasai Orientale, Kasai Occidental, and Katanga because they were not occupied by rebels. The project components were defined by the World Bank and the Ministry of Agriculture. Each applying institution or NGO had to fulfill specific requirements mainly: to be operational at the area targeted, to be legally registered and to show proof of technical competence. BECECO multiplied and disseminated only planting material from officially released varieties. The breeder seeds came from IITA/INERA primary multiplication fields. Partner NGOs bulked up and distributed cassava planting materials to households. The material given to a household had to cover at least 0.25 ha, therefore each household received a minimum of 600 meters of planting materials. BECECO also promoted high quality seeds of maize, irrigated and lowland rice, and legumes (beans, soy, groundnuts and cowpea). Quantities of inputs distributed per household were decided on basis of land prepared by a household.

PACT is an international NGO based in Washington. PACT implemented the "Market Approach for Livelihood Improvement" (MALI) Project in Kalemie, Katanga Province with funding from USAID from 2003 to 2005. In 2004 the USAID Mission Director visited PACT's project sites. He observed the poor state of cassava in farmers' fields. He requested that IITA to collaborate with PACT-Congo to improve cassava productivity and develop cassava-based micro-enterprises in Katanga. PACT-Congo implemented participatory diagnostic surveys to select the intervention zone for the project. The participatory surveys revealed that the local communities were in need of cassava varieties resistant to CMD and other diseases. PACT selected farmer groups that were participating in the MALI project for planting materials for multiplication and distribution. Varieties were selected to fit in with agro-ecological conditions of Katanga province and particularly those of Kalemie. Five varieties selected at Mulungu research station from germplasm introduced from ESARC -- Mapendo, Ushindi, Liyayi, Sukisa and Sawasawa -- were introduced for multiplication. Ushindi was selected during on farm trials by farmers in North Kivu from where it was taken to Kalemie although it was not formally released. IITA researchers provided 500 kg of quality planting materials of 15 improved cassava varieties (5 of which were recommended for official release), 10,000 botanical seeds from high beta-carotene content families, and one motorized grater/chipper for cassava processing. PACT-Congo officers and IITA researchers supported the establishment of community-based multiplication and demonstration fields, on-farm trials, and training on cassava processing. PACT-Congo multiplied and distributed planting materials with 15 groups drawn from 11 villages. Small farm implements consisting of hoes, machetes, cutlasses and axes were distributed to farmer groups to facilitate multiplication activities. Participating farm households selected varieties to grow based on their own specific criteria (percentage of dried chips and flour, resistance to diseases and pests, cooking and eating factors, market demand and underground tuberous root storability). An agreement in planting material multiplication was signed with farmers. At harvest, planting materials were equally shared between PACT and farmers. The group members shared among themselves their share. However, PACT-Congo only started planting materials for multiplication and distribution in 2007/2008 the last year of the project. This resulted in a shortage of planting materials. Consequently, planting materials were purchased in Goma (North Kivu province) and flown to Kalemie.

To summarize, the CMD project built on cassava improvement research work started in the 1920s. Formal statistically designed on-station and on-farm experiments for deriving robust recommendations only began with IITA in 1974. From 1991 to 2000 the national program was on its own. Research investments were low. This explains why in the late 1990s there inadequate research response to the outbreak of the Ug variant of the CMD disease. From 2001 to 2009 FAO, IITA, SECID and other NGOs implemented the project being evaluated in this study. The partners used an agricultural research for development approach that had multiple interventions. These were applied as a package by different implementing organizations in different locations and at different times. SECID, FAO, CADIM, BECECO and Pact Congo implemented the CMD project at a large scale by piggy-backing on other projects.

Research approach: conceptual approach, hypotheses, methods, and data sources

The conceptual framework that guides this study is drawn from the literature on agricultural impact assessment and econometric and statistical analysis of treatment effects in program evaluation. The conceptual framework is applied to derive hypotheses about causal mechanisms that link project interventions to impact and guide data collection and analysis.

Conceptual framework

Figure 2 summarizes the input-output-outcome-impact pathway that is hypothesized to operate in converting project interventions into outcomes and impacts. The process leading to impact is conceptualized in 4 stages (Walker et al., 2008). The first stage uses inputs through participatory action research to develop public-private research partnerships for working at higher scales of analysis. The partnerships introduce, screen, and adapt technologies. They also develop facilities and procedures for tissue culture and rapid multiplication of disease-free planting materials of improved varieties of cassava and disseminate crop management and post-harvest management practices. The outputs are improved research, extension, NGO and private sector networking and innovation capacity, improved higher-yielding varieties with disease resistance, crop management technologies, post-harvest management technologies, mother-baby trials, Farmer Field Schools, field days, extension publications, and institutional arrangements. The second stage delivers outputs to researchers, extension, NGOs, farmers associations and private sector firms, resulting in changes in their awareness, knowledge and practices. This results in improved delivery to farmers, thereby inducing changes in their awareness, knowledge and adoption among households and village communities in project areas compared to those in non-project areas. The fourth stage is impact on adopting farmers. Adoption of cassava and improved varieties, crop and post-harvest management technologies increases area, yield and land and labor productivity and product quality, which results in increases in profit per hectare and per ton of product, sales to processors and consumers, farm incomes, and food security. The final stage is spontaneous diffusion through farmer to farmer exchange. This leads to scaling up and changes in aggregate area yield and production at the extension planning area, district, and national levels. Adoption of new production technologies enables farmers to lower unit costs and increase volume of throughput, thereby improving the productivity and profitability of processors and off-farm employment. Net food buying households benefit from the access to increased food supplies at lower costs and increased employment and wages. Urban consumers are able to buy cassava at lower prices, thereby reducing risk of food shortages and malnutrition.

The pathway from inputs to impacts results from cumulative cause and effect relationships between many factors and organizations. But there were other factors outside the project control that also change and confound the effects of the project. These confounding factors increased along the impact pathway from intermediate to final goals. It is important to control for these factors. We apply regression adjustment, change-in-changes, instrumental variables, quantile regression and synthetic control methods for comparative case studies to estimate treatment effects controlling for non-random assignment of sites for implementing the project, self-selection of households for participation in the project, heterogeneity, and confounding factors.

Hypotheses

Applying the framework generates three hypotheses about the cause and effect relationships between the project investments and impacts at the household and aggregate district levels tested in this study. The first hypothesis is that the CMD project had an impact on adoption of improved varieties.

The second hypothesis is that the project was a worthwhile investment.

The third hypothesis is that if the project had impacts on aggregate cassava acreage.

Methods

The first hypothesis is tested by estimating the ATE ($\hat{\tau}_{ate,reg}$) and ATT ($\hat{\tau}_{att,reg}$) on farmer adoption of improved varieties. This compares the average outcome of sample households in areas in which the project was implemented to neighboring non-project areas using linear regression, propensity score regression, propensity score and interacted with treatment regression, linear instrumental variables and changes-in-changes methods (Wooldridge, 2002; 2009). Methods based on regression adjustment use selection on observables to control for confounding factors and selection bias in order to identify and estimate treatment effects. The methods are valid under two key assumptions. The first assumption is that treatment is randomly assigned conditional on observable covariates.. The second assumption is that each unit in the population has a chance to be or not to be treated.

The linear IV methods use instrumental variable to control for selection on unobservables and endogeneity of treatment assignment when the effect of the treatment is constant across households. Instrumental variable methods are appropriate when households choose the treatment based on unobservables that affect the response, there exist instrumental variables that predict participation but the instruments do not affect outcomes other than through the treatment variable, and the instruments are valid and relevant. For IV to be valid two key assumptions need to be hold. The first assumption is that the instruments are uncorrelated with the error term. The second assumption ensures that there are enough exogenous variables by ruling out perfect multicollinearity among the exogenous variables and requiring that the excluded instruments are related to the endogenous variables conditional on the included exogenous variables.

We follow the approach in Wooldridge (2002; 2009) and estimate the average treatment effects using linear regression as the coefficient α on W in the kitchen sink regression

$$Y_i \text{ On } 1, W_i, X_i, \quad i = 1,2,...,N$$

We estimate the average treatment effects using regression on the propensity score in regression as the coefficient α on W in the regression

$$Y_i \text{ On } 1, W_i, \hat{p}(X_i), \quad i = 1,2,...,N$$

Where $\hat{p}(X_i)$ is the estimated propensity score. We estimate the average treatment effects using regression on the propensity score and propensity score interacted with treatment in regression as the coefficient α on W in the regression

$$Y_i \text{on} 1, W_i, \hat{p}(X_i), W_i \bullet [\hat{p}_i(X_i) - \hat{\mu}_{\hat{p}}], \quad i = 1,2,...,N$$

Where $\hat{\mu}_{\hat{p}}$ is the sample average of.

$$\hat{p}_i, \quad i = 1,2,...,N$$

We estimate the average treatment effects using linear instrumental variables by first running a probit or logit of W on $1, X$, where X contains the covariates; obtaining the probit fitted values $\hat{\Phi}_i$; and estimating the outcome equation by IV using instruments. $(1, \hat{\Phi}_i, X_i)$

The changes-in-changes approach developed by Athey and Imbens (2006) generalizes the differences-in-differences approach to allow for differences in the distributions of unobservables across treatment and control groups.

The second hypothesis is tested by estimating the yield differential of the vintages of cassava varieties by fitting a fixed effects panel data model on cassava variety experimental yields. It is also tested by estimating the LATE and quantile treatment effects of the project on area, yield, and profitability outcomes of sample households in areas in which the project was implemented compared to neighboring non-project areas using instrumental variable estimation of the local average treatment effects, quantile and logistic regression adjustment.

The third hypothesis is tested at the aggregate provincial level by estimating the effect of the project using the synthetic control methods for comparative case studies and analyzing a placebo treatment effect for each province using the synthetic control as the treated region. Synthetic control methods for comparative case studies are especially appropriate for analyzing interventions that affect aggregate entities such as administrative areas at an aggregate level in situations where traditional regression methods are inappropriate (Abadie, Diamond and Hainmueller, 2007).

Data sources

The data are drawn from four sources. The first source is focus group discussions and interviews with researchers and representatives of implementing organizations. Qualitative surveys were conducted in 2009 to assess the plausibility of the impact pathway and determine whether there is evidence that the project had effects on outcomes of interest.

The second source is repeated cross-sectional survey data on farm households in project and non-project areas. Two surveys were conducted. The first survey was carried out in 2004. The survey used stratified random sampling to select for interviewing 270 households in Bandundu, Bas Congo and Kinshasa. Households were drawn mostly from sectors and villages exposed to the project. The second survey was conducted in 2009. The survey used stratified random sampling to select for interviewing 521 households in Bandundu, Bas Congo, Kasai Orientale, Katanga, Kinshasa, Orientale Province, and South Kivu (Figure 3). The survey collected data on household socio-demographic and farm characteristics; participation in the project; awareness and use of improved varieties and crop management and post-harvest processing practices; plot level, use of planting materials, manure, fertilizer and labor inputs and outputs; and input and output prices. The 2009 survey collected household plot level area and yield using both farmer recall and Global Positioning System (GPS) hand held navigators and crop cuts. Household estimates are likely overstated because farmers harvest cassava over multiple seasons as and when they utilize the crop. Plot cuts estimates likely understate yields because they do not distinguish between mature and immature cassava.

The third source is project documents. These include annual work plans and budgets, technical and financial reports, external monitoring and evaluation reports, and published and unpublished papers.

The fourth source is the Ministry of Agriculture annual district data on agricultural experiment station cassava variety trials from 1976 to 2008; aggregate provincial area, yield and production for cassava, maize and rice; and annual rainfall and population from 1985 to 2008. This includes monthly open market prices of cassava fresh roots, cassava dried roots, cassava flour, chikwangue, maize grain, imported rice, and bread from January 2002 to September 2009. Market price data are available only for Kinshasa city. Experiment station cassava variety yield trial data are missing for the 1989 to 2000. The reliability of the Ministry of Agriculture data has been questioned (FAO, 2006). The Service National de Statistique Agricole (SNSA) and the Provincial Inspectorates for Agriculture collect annual data on area planted, yield and production of crops using multistage stratified random sampling. The sampling levels are the provinces, territory, sectors, villages and households. Data are collected by enumerators based in sample villages. Because of staff shortages, inadequate budgets and lack of transportation, enumerators do not follow rigorous statistically based methods. This results in poor quality data. Demographic data provided by the National Statistics Institute are essentially extrapolations of the census carried out in 1984.

Results

This section discusses characteristics of sample households and researchers and implementing organizations representatives' perceptions of project outputs, outcomes and impacts. The section also discusses impact at the farm and aggregate levels.

Sample characteristics

Table 2 reports descriptive statistics for the household socio-demographic and farm characteristics grouped by farm size. Four farm typologies were constructed based on farm size: sub-family farms ranging from 0.1-1 hectares; small family sizes ranging from 1.1-2 hectares; moderate family farms ranging from 2.01-3 hectares; and large farms exceeding 3 hectares. Sub-family farms are below levels that produce optimal efficiency; small family farms can guarantee subsistence levels; moderate farms can achieve subsistence levels with marketable surpluses; and large farms can generate marketable surpluses. Roughly 29 % of sample households are sub-family farms, 21 % are small family farms, 20% are moderate family farms and 31 % are large farms. Proportionately more sub-family and small farms crop their cultivated area to cassava. However, differences are not statistically significant at the 5 % level. Sub-family and small farms have statistically significant lower proportions of percent cassava harvest sold and self-sufficiency in food production. By contrast, sub-family and small farms have higher proportions of households growing cassava for own-consumption and buying food. Compared to moderate and large farms families, sub-family and small farm have younger and poorly educated household heads, smaller family sizes and family labor, and are less able to hire casual labors and invest in farm equipment and livestock. Proportionately less sub-family and small farms make contact with government and NGO extension agents and are members of farmer organizations. Sub-family and small farms are mostly female headed households and have a lower proportion of households growing more than one cassava variety in the same plot. These results suggest that cassava is more important for poor households who are mostly female headed households.

Compared to farm families in areas not exposed to the project, households in treatment areas have statistically significant higher proportions of families whose major objective in growing cassava is for own-food consumption, are self-sufficient in food, have higher investments in livestock, make contact with government and NGO extension agents and grow more than one cassava variety mixed in the same plot. These findings indicate selection into treatment on observables.

Researchers and implementing organizations' interview results

Interviews with researchers and representatives of implementing organizations revealed that the project delivered five key outputs which, in decreasing order of magnitude, include (a) varieties resistant to EACMV-Ug and pests, tissue culture technology, rapid multiplication methods, intensive nucleus multiplication systems, primary, secondary and tertiary multiplication nurseries and institutional arrangements for distribution of clean planting materials of improved varieties; (b) crop management and crop protection technologies; (c) processing technologies and institutional innovations for organizing markets; (d) partnerships; and (e) capacity building.

Respondents explained that when the project started there were no EACMV-Ug resistant varieties. After 2-3 years there were 5 varieties. Eleven more varieties were released between 2005 and 2008. Tissue culture and institutional arrangements for multiplication and distribution of planting materials enabled implementing organizations to deliver a cumulative total from 2001 to 2008 of 417,354,633 one-meter stem cuttings of disease-free improved varieties to 3,530,666 households (Table 3). However, the total planting materials distributed were sufficient for only planting a lower bound estimate of 166,942 hectares, about 9 % of the total national cassava area cropped in 2007/2008 using FAO data or 10 % using Service National de Statistique Agricole (SNSA) data. Because of the geographical targeting used by the implementing organizations, the bulk of the early distribution was in Bas Congo and Bandundu. By 2008 the new varieties were distributed throughout the 11 provinces (Table 4).

INERA's research competencies were strengthened through mentoring, exchange visits and knowledge exchange with IITA researchers. Crop management and crop protection outputs were delivered in part through breeding for disease and pest resistance and in part through release of pests for green mite and refining extension recommendations. Processing outputs were delivered following the adoption of improved practices and crop management practices and expansion in cassava production in the targeted areas. Small and medium enterprises engaged in cassava processing emerged and drew on the improved processing technologies to expand their operations and marketing of micro-chips and other products such as farinha, gari and starch. Turning to partnerships, collaboration and dynamic learning through interactions was strengthened among IITA and INERA researchers, FAO and NGOs (SECID, CADIM and PACT-Congo), farmers' organizations, agribusiness firms and other key stakeholders. Innovation platforms were put in place. The platforms interfaced with farmers through farmer groups and Farmer Field Schools. Capacity building increased knowledge, skills, and competencies at the individual and organizational levels for researchers, extension agents, farmers, farmers' groups, processors, and equipment manufacturers. Farmer Field Schools helped farmers to gain experience.

Qualitative surveys showed that major outcomes at the institutional level were changes in practice and behavior of INERA researchers, government and NGO extension agents, processors and equipment manufactures. Capacity utilization resulted in the development of supply systems for clean planting materials of improved varieties, crop and post-harvest technology management advice, locally manufactured processing machines and equipment, micro-enterprises engaged in cassava processing, improved quality of cassava flour, output marketing and logistics of distributing cassava-derived products to urban consumers. Respondents explained their belief that the demand for raw cassava roots increased as a result of private sector investments in new processing machines resulting in bottlenecks because of limited capacity to supply fresh roots throughout the year. This explains why cassava processors were expanding investments in their own production of cassava.

Qualitative interviews indicated that outcomes at the level of farmers were changes in their awareness, knowledge and adoption of new varieties and technologies. Respondents explained their belief that farmers now know that mosaic is a disease and to get good yields planting materials need to be sourced from INERA research stations or NGO multiplication plots instead of neighboring farmers. Respondents explained that in the treatment, villages farmers did not initially want to sell to each other cassava cuttings. Farmers were reported to trade in cassava cuttings. Markets for planting materials of cassava are developing as a consequence of the project. Households now know that using clean cuttings of improved varieties pays; growing clean planting materials costs more than producing cassava as a food crop because of additional costs of breeder's seed and weeding and phytosanitation; clean planting materials have value; and the benefits exceed the costs. As a result farmers were expanding use of improved varieties especially RAV because it is more robust across agro-ecological zones.

Researchers and implementers' interviews revealed that the main impacts at the farm level were increases in area planted to cassava, yield, profitability and food security. Respondents explained that there was a reversal in the declining trend in area cropped to cassava and this increased supply of cassava and food security. Processing added value to cassava produced in targeted areas and cassava products were now being distributed and sold in urban markets. Despite increase in production, supply was still insufficient to meet demand. Poor households benefited proportionately more from project interventions because of increased food security.

Impact on farmer use of improved varieties, crop management and post harvest technologies

Qualitative surveys with researchers and representatives of implementing organizations show that the project had effects on technology adoption, productivity, profitability and food security. This section uses econometric modeling to test the hypothesis that the project had an impact on adoption of improved varieties.

Table 5 shows that the simple comparison-of-means estimate on varieties planted in 2004 during the first phase is a reduction of 5% for farmer varieties and 2 % for EACMV-Ug susceptible varieties and an increase of 6 % for EACMV-Ug tolerant varieties and 0.3 % for EACMV-Ug resistant varieties. The estimate in 2009 during the second phase is a reduction of 24% for farmer varieties and 1 % for EACMV-Ug susceptible varieties and an increase of 10 % for EACMV-Ug tolerant varieties and 13 % for EACMV-Ug resistant varieties.

Table 6 presents the treatment effects estimates using the four different regression methods using Stata codes developed by Wooldridge (2009). The outcome variables are the share of varieties planted by the household that are local, EACMV-Ug susceptible, tolerant and resistant. The treatment variable is a dummy variable for residing in a village in which project interventions were implemented, equal to 1 if the village was exposed and 0 if not. The samevariables are used. For the 2004 survey data, the variables include dummy variables for age of household head (equal to 1 if household head is over 40 years, 0 if otherwise), dejure female headed household (equal to 1 if household head is female widowed, divorced, separated or never married, 0 if otherwise), main occupation farming of head of household (equal to 1 if household head is engaged in farming, 0 if otherwise), education level (equal to 1 if household head has never attended formal education, 0 if otherwise), household size (equal to 1 if household has more than 7 members, 0 if otherwise), locations for Bas Congo, Bandundu, and Kinshasa and number of educated household members. Because the 2009 survey had a richer set of covariates, the variables are the total area cropped, years of household head education, number of household members, number of workers, age of household head, gender of household head, value of investments in farm equipment and dummy variables for whether or not household contacted a public extension agent during the cropping season, other sources of information, information from NGOs, participating in farmers' organizations and locations for Bas Congo, Bandundu, and Kinshasa.

The propensity score is estimated by a first-stage probit using a linear probability model where the treatment is the dependent variable and thevariables are the explanatory variables. In the first-stage probit of onfor the 2009 survey data the age of household head and dummy variables for contact with a public extension agent, other sources of information, information from NGOs, participating in a farmers' organization and location for Bas Congo and Bandundu are statistically significant at the 5 % level. Not surprisingly there is a positive correspondence between treatment and contact with a public extension agent, other sources of information, information from NGOs, participating in farmers' organizations and location for Bas Congo. The variables were used in the mechanism for targeting interventions by the implementing organizations. There is a negative correspondence between treatment and age of household head and location for Bandundu. Sub-family and small farm households with younger and less educated household heads were more likely to participate in the project. Project activities were less intensively implemented in Bandundu compared to Kinshasa, the omitted category which is the reference location of dummy variable.

The different methods produce roughly the same estimates. The average treatment effect using the 2004 survey data is estimated to be a reduction of 5-7% for farmer varieties and 0-1 % for EACMV-Ug susceptible varieties and an increase of 5-7 % for EACMV-Ug tolerant varieties and 0-0.3 % for EACMV-Ug resistant varieties susceptible. The average treatment effect using the 2009 survey data is estimated to be a reduction of 11-20 % for farmer varieties and 1-3 % for EACMV-Ug susceptible varieties and an increase of 12-13 % for EACMV-Ug tolerant varieties and 0-0.3 % for EACMV-Ug resistant varieties susceptible. These are similar to the simple comparison-of-means estimate.

The changes-in-changes average treatment effects are estimated without covariates using a Stata code obtained from Imbens (2009). The project is estimated to reduce the reduce probability of using farmer EACMV-Ug susceptible varieties by 5 % and 6 % respectively (Table 7). The project increases probability of using EACMV-Ug tolerant and EACMV-Ug resistant varieties by 10 % and 17 % respectively. The effects are statistically significant at the $p < 0.01$ level.

Impact on farm level yields, profitability and food security

This section tests the hypothesis that the project was a worthwhile investment. This hypothesis is tested by analyzing whether the project confers benefits to households (measured by changes in area, yields, profitability, and food security) that exceed the per-participant costs of providing services to households and whether benefits accrue to poor households.

Table 8 reports the results of fixed effects least squares dummy variable estimation. The outcome variable is the yield of the vintage of the cassava variety at stationin year. The variable is specified in natural logarithms to allow for multiplicative effects. The treatment variables are dummy variables for local, EACMV-Ug susceptible, tolerant and resistant varieties. The varieties are categorized into the following groups: (a) farmer varieties included as local checks; (b) Improved EACMV-Ug susceptible 1977-1996; (c) Improved EACMV-Ug tolerant 1997-2002; (d) Improved EACMV-Ug resistant 2004+; and (e) other improved varieties but not selected by breeders for release to farmers. The dummy variables for station and time are included to control for observable and unobservable differences across research stations and over time in order reduce potential omitted variable bias. The table shows the gains in yield per hectare of different vintages of improved varieties with EACMV-Ug susceptible varieties as the reference category. The results indicate that use of farmer varieties causes a decrease in yields of 9.5 % compared to EACMV-Ug susceptible varieties, calculated as. In a similar vein, use of EACMV-Ug tolerant and resistant varieties causes an increase in yield over the benchmark variety of 36 and 47 % respectively. Productivity is increased using improved varieties that have highest levels of resistance to the EACMV-Ug disease because of reduced disease losses. Surprisingly use of other improved varieties tested but not released to farmers causes an increase in yields relative to the EACMV-Ug susceptible varieties of 19 percent. These findings confirm that improved varieties confer statistically significant potential yield benefits to farmers. But part of the differential appears to be attributable to the characteristics of locations, since there are significant yield gains in sites in the favorable areas (Figure 4).

Farmers are unlikely to achieve these yield gain on-farm because of much slower adoption of complementary crop management practices: seed selection, planting time, spacing, weeding, pest and disease control and harvesting. Figure 5 and 6 show the diffusion of improved varieties and crop management practices over time among the 2009 sample farmers. Diffusion follows the S-shaped curve although for the EACMV-Ug resistant varieties it has still not reached the inflection point. Diffusion of improved crop management practices follows a stepwise pattern: weeding and planting time were simultaneously adopted first, followed by seed selection and spacing. Although the earliest adoption of improved pest and diseases control practices occurred in the 1980s, diffusion was very low until 2001 and diffused more rapidly in the last 8 years as a result of the project.

Table 9 reports the nonparametric estimate of the conditional LATE using Stata codes developed by Frölich (2006). The outcome variables are area planted to improved, local and mixed varieties, cassava plot yields and gross margins per hectare. The outcome variables are also specified in natural logarithms to allow for multiplicative effects. The treatment variable is a dummy variable for residing in a village in which project interventions were implemented, equal to 1 if the village was exposed and 0 if otherwise. The instrument is an indicator of whether the household participates in a farmers' organization. The covariates include total area cropped, formal education of household head, household size, family members who work on household land, age of household head, gender of household head, value of investments in farm equipment and dummy variables for whether or not household contacted a public extension agent during the cropping season, other sources of information, information from NGOs and locations for Bas Congo and Bandundu. The method that estimates and using local linear regression with and is used because it provides consistent results. The estimates of LATE are all positive and economically significant. Thus for the subpopulation of households who are induced to adopt improved cassava varieties and crop management technologies by participation in a farmers' organization exposure to the project caused an increase in both area planted and yields per hectare. The area planted to both improved and local varieties increased by 4 standard deviations and that planted to mixed varieties by 7 standard deviations. This in turn caused an increase in yields using farmer recall by 7 standard deviations for farmer varieties, 3 standard deviations for local varieties and 9 standard deviations for mixed varieties. The project caused an increase in yields using researchers' plot cuts by 0.4 standard deviations. The yield and farm gate price increases caused an increase in gross margins per hectare by 0.5 standard deviations. We conclude that households induced to participate in the project captured substantial incremental benefits averaging US$982 per hectare. The incremental benefits exceed the per-participant costs of US$ 342 per hectare for delivering services to households, including costs of research, primary, secondary and tertiary planting materials multiplication, transportation and FFS training. This implies that the project is a worthwhile investment.

Figure 7 presents the estimates of quantile treatment effects using the quantile regression estimators of Koenker and Bassett (1978). We focus the analysis on household cassava plot gross margins per hectare calculated using researchers' yield estimates. The outcome variables are logged to facilitate interpretation of coefficients. We use the same treatment variable and covariates as in the nonparametric estimation of the conditional LATE model. We estimate the conditional quantiles using the qreg, basqreg and sqreg commands in Stata (Cameron and Tirivedi, 2009). There are 14 bivariate scatter plots consisting of the intercept, the treatment variable and 12 covariates. For each of the 14 coefficients, the quantile regression estimates for ranging from0.05 to 0.95 are plotted as the solid curve. Because the yield is in logs, the coefficients may be interpreted as % change of a one-unit change of the covariate on gross margins per hectare holding other covariates fixed. Thus, each of the plots has a horizontal quantile, or, scale, and the vertical scale in US$ per ha indicating the covariate effect.

The horizontal lines are the OLS point estimate and 90 percent confidence intervals for the least squares estimate. These do not vary with the quantile. The shaded gray area shows a 90 percent pointwise confidence band for the quantile regression estimates.

In the first panel of the figure, the intercept of the model may be interpreted as the estimated conditional quantile function of the gross margin per hectare distribution of a household headed by a male with little contact with government extension agents but high access to other sources of information and NGOs, some participation in farmers' organization, cropped area of 3 hectares, years of formal education of household head of 7 years, size of 7 members, about 3 family members working on household land, 40 years old head of household, and investment in farm equipment of US$135. These are chosen to reflect the means of these variables in the sample. The second panel shows that as expected treated households have higher gross margins than untreated households, by about 0.5 % according to the ordinary least squares estimates of the mean effect. However, the disparity is much smaller in the upper than in the lower tail of the distribution. The quantile of the distribution is at the point of crossover from negative to positive gross margins. At low the quantiles, female-headed household status, government extension contact, participation in farmers group, household head education, household size, household head age and farm equipment investment are associated with modest increases in gross margins. This shows that the benefits accrued mostly to poor households whose major objective in growing cassava is own-food consumption.

Table 10 reports the logit regression adjustment estimates of average treatment effects on food security. The outcome variable is whether or not the household produce sufficient staple foods to meet its requirements for the year. The treatment variable and covariates are the same as those used in the nonparametric estimation of the conditional LATE and quantile functions. The ATE and ATT are estimated to be 0.113 with a bootstrapped standard error of 0.057. The effects are statistically significant at the $p < 0.05$ level. Therefore, participating in the project increases the probability of achieving household self-sufficiency in food by 11.3%.

Impact on aggregate acreage

This section tests the third hypothesis the project had impacts on aggregate cassava acreage. The synthetic control methods are applied to estimate the effect of project in Bas Congo on aggregate area planted to cassava. The project was more intensively implemented in Bas Congo compared to other provinces. The synthetic Bas Congo is constructed as a weighted average of potential control districts. The weights are chosen so that the resulting synthetic best reproduces the values of a set of predictors of area in Bas Congo before implementation of the cassava planting materials multiplication and distribution project from 2001 to 2009. The set of potential controls for Bas Congo is the "donor pool". The remaining 11 provinces are included in the donor pool. The outcome variable is area planted to cassava because changes in production resulted mostly from changes in acreages. The outcome variable is logged so that the coefficients can be interpreted as semi-elasticities. The predictors of cassava area used are the proportion of staple food crop area planted to cassava and quantities of disease free planting materials per capita annually distributed to farmers. The variables are averaged over 1985-2001. We estimate the effect of the project on area planted to cassava as the difference in levels between Bas Congo and its synthetic version during the 2002 and 2008 period.

Figure 8 plots the trends in cassava area in Bas Congo and its synthetic version during the period 1985-2001. The estimate of the effect of the project on cassava area in Bas Congo is the difference between area of the province and the synthetic version during implementation. While synthetic Bas Congo cassava area continued to decline, the real Bas Congo area leveled off and began to trend upwards.

To assess whether the project has a potential positive impact in areas in which it was less intensively implemented and whether it should be expanded, we conduct placebo tests to determine whether the effect estimated by the synthetic control for Bas Congo is large relative to the effect estimated for other provinces that less intensively implemented interventions during the sample period. This estimates the effect of the project as if one of the districts in the donor pool had implemented the interventions as Bas Congo. Figure 9 shows the results for the placebo tests. Not surprisingly, there is much heterogeneity in the distribution of estimated effects for provinces with different intensities of implementation. The locus of cassava area for Bas Congo is the upper boundary? of other provinces that less intensively implemented the approach. This provides evidence of a significantly large effect of the approach in this province compared to other districts in the donor pool. However, the gaps for most provinces are small indicating that there is a significant elasticity of response of area cultivated to cassava and therefore cassava production with respect to multiplication and distribution of disease free planting materials of improved varieties. Consequently the project should be expanded to other provinces.

Conclusion

The emergency response to the outbreak of the cassava mosaic disease project was implemented in the Democratic Republic of Congo from 2001 to 2009 using an agricultural research for development approach. Although process monitoring and evaluation reports indicate that substantial outcomes and impacts have been achieved there is a lack of hard evidence of progress made to guide continued investments and exit strategies. This study applied methods developed in the econometric and statistical treatment effects literature to evaluate the effects of the project on outcomes of interest controlling for endogeneity, non-random selection of project sites, self-selection of households into treatment, and other confounding factors.

Qualitative surveys with researchers and representatives of implementing organizations showed that the project had effects on technology adoption, productivity, profitability and food security. Estimation of the effect of project on adoption using ATE and ATT showed that the project had statistically significant positive effects on use of EACMV-Ug tolerant and resistant varieties. Estimation of impact on food using LATE showed that households induced to participate in the project by the instrument of participation in a framers' organization captured incremental benefits higher than per-participant costs of delivering services. Estimates of quantile treatment effects showed that benefits accrued mostly to poor households whose major objective in growing cassava is own-food consumption. Estimation of effects on aggregate area using synthetic control methods showed that the project caused an increase in cassava area thereby increasing supply response in Bas Congo compared to what would have happened in the absence of the interventions.

The results indicate three main conclusions. The first is that the project caused statistically and economically significant increases in technology adoption, productivity, profitability and food security. The second is that the project is a worthwhile investment. The third is that there is a significant elasticity of response of area planted to cassava and therefore cassava production with respect to multiplication and distribution of disease-free planting materials of improved varieties in most provinces and the project should be expanded to other areas. The estimates have credible causal interpretation. Therefore they are more likely to move prior beliefs of private and public decision makers and policy makers towards bigger effects and shift policy.

The shortcomings of the current study are data problems, assumptions underlying estimation methods, limited duration of the project and geographical specificity. The data sets used in this study suffer from a paucity of good quality crop area, yield, rainfall, population, agricultural input and output price measurements. The administrative project and experiment stations records and farm survey data have clustered sampling and measurement errors. The data sets have missing observations. The farm household survey sample sizes may be too small to reject the null hypothesis of no effect. The assumptions underlying the treatment effects methods used in the study are based on partial equilibrium analysis. The methods assume no interactions among agents being analyzed and rule out externalities, spillovers and general equilibrium effects. Because the project interventions have positive and negative spillovers and general equilibrium outcomes in the long run, the treatment framework needs to be broadened to take into account these effects. Because the duration of the project with target farmers' groups was limited to 2 cropping seasons, the effects estimated in this study may be different than what would be observed if interventions become permanent. The results may not be valid to extrapolate outside the test sites. Future work still to be done includes accounting for clustering of sample observations, measurement error and missing data. Future work needs to use general equilibrium analysis and carry cost benefit analysis using economic surplus methods.

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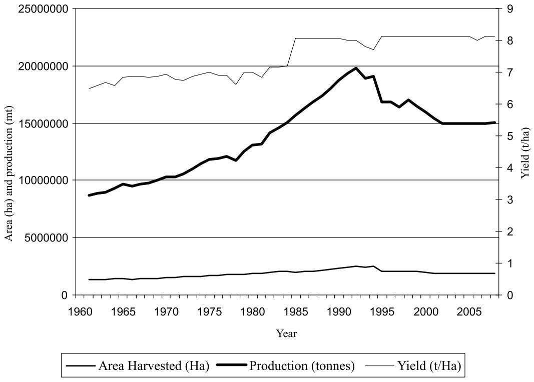

Fig. 1. Annual area planted to cassava, DRC, 1960-2008. Source: FAOSTAT, 2010.

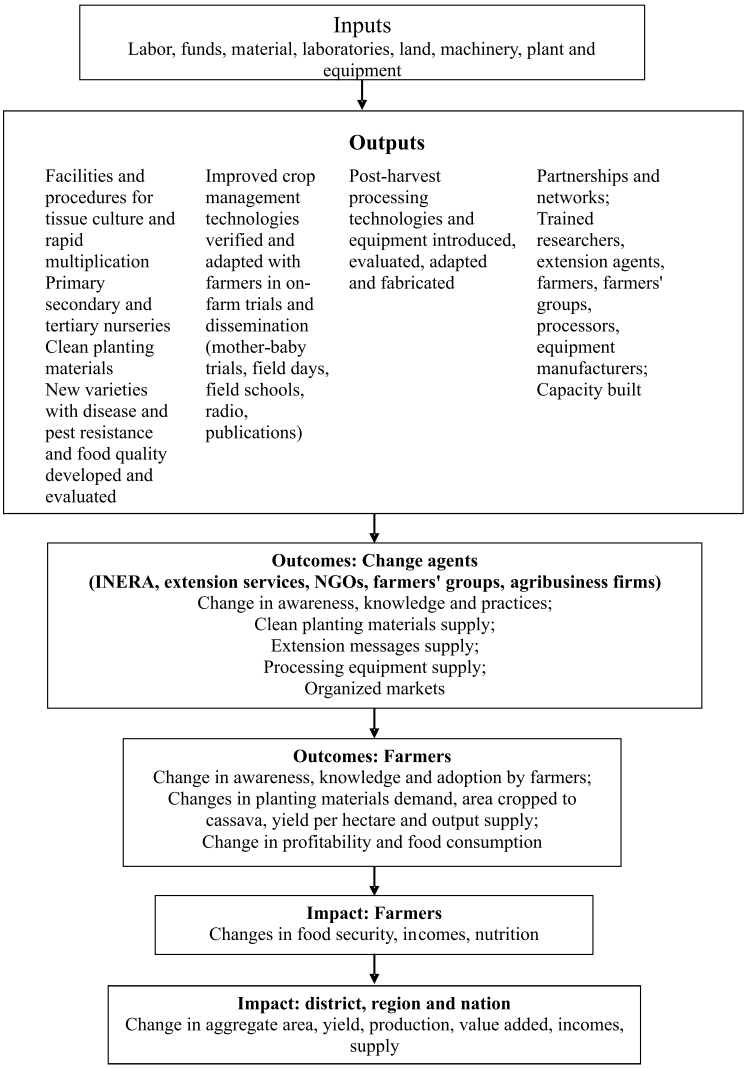

Fig. 2. Cassava research for development inputoutputoutcomeimpact pathway. Source: Authors' representation.

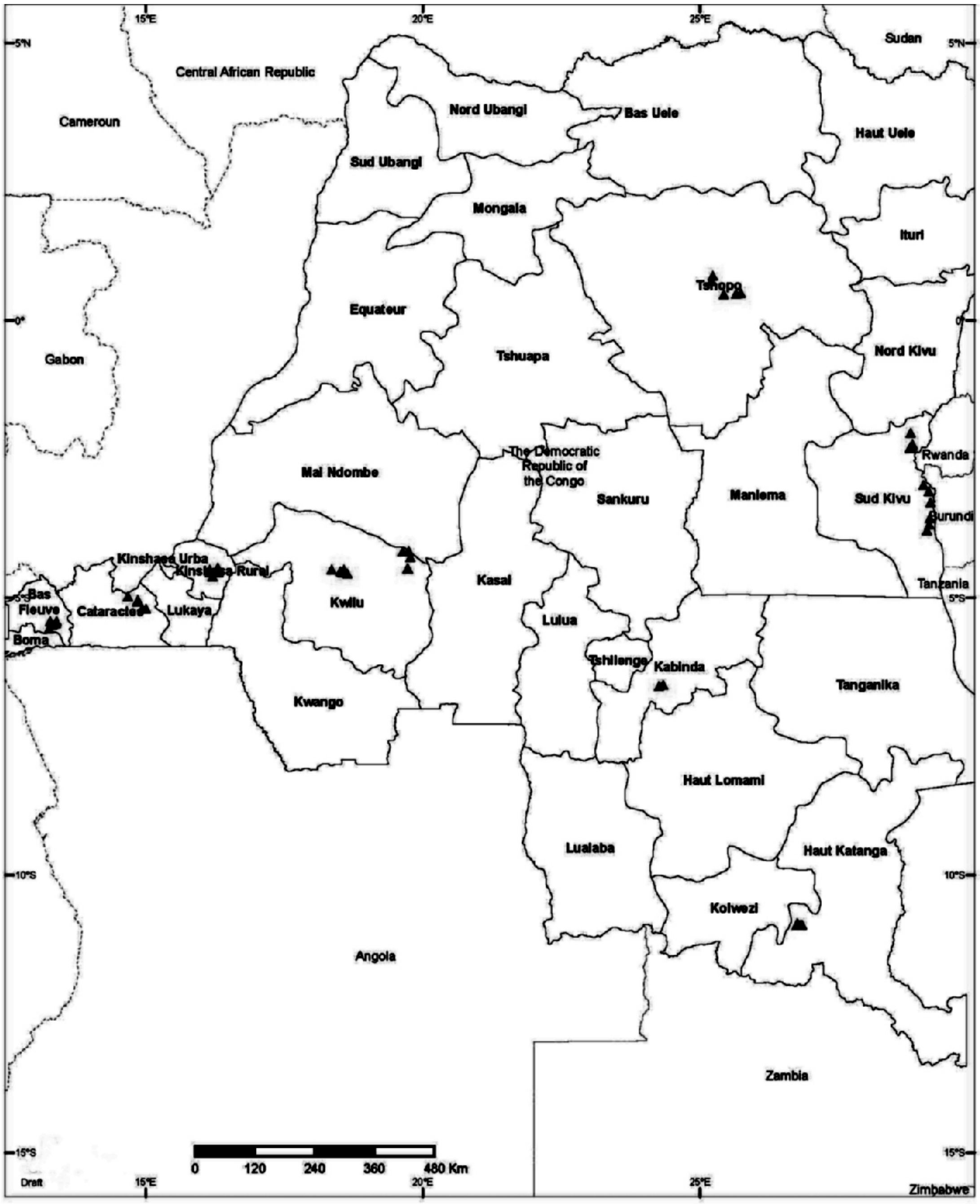

Fig. 3. 2009 survey areas. Source: Geospatial Laboratory, IITA

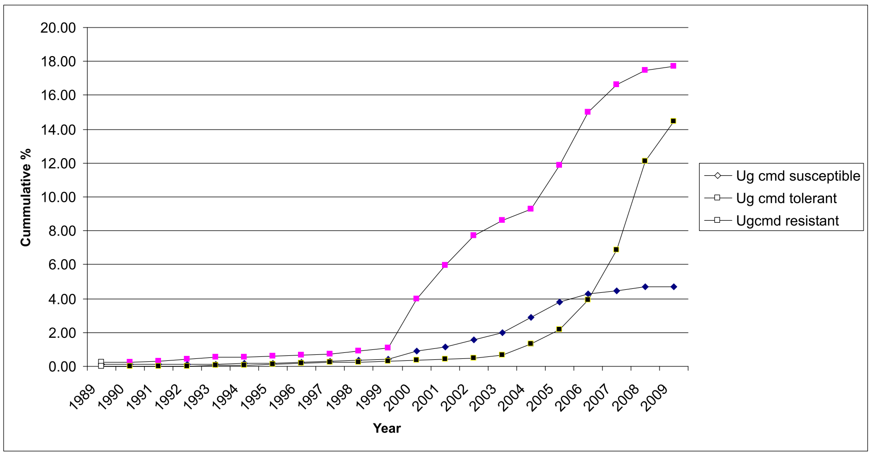

Fig. 4. Diffusion of improved varieties over time among sample farmers, DRC, 2009.
Source: Authors' estimates.

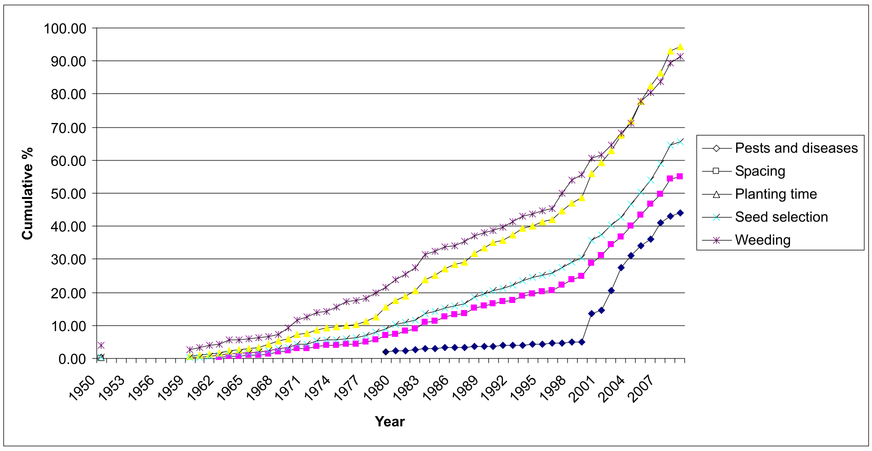

Fig. 5. Diffusion of improved crop management practices over time among sample farmers, DRC, 2009. Source: Authors' estimates.

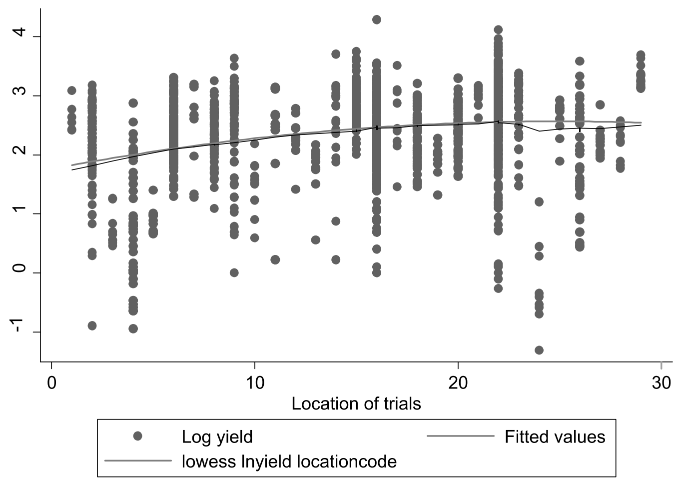

Fig. 6. Within scatterplot of log yield deviations from individual means against location from individual means, DRC, 1976 - 2008. Source: Authors' estimates.

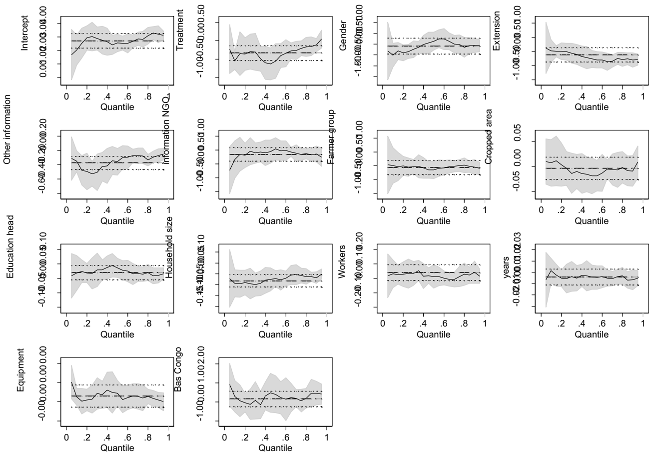

Fig. 7. Quantile regression and Ordinary Least Squares coefficients and confidence interva ls for each regressor as q varies from 0 to 1, DRC, 2009.
Source: Authors' estimates.

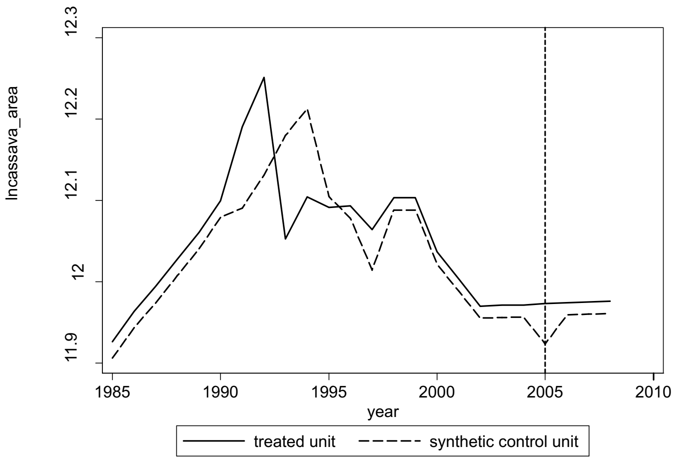

Fig. 8. Trends in cassava area in Bas Congo and its synthetic version, DRC, 1985-2008.
Sources: Authors' estimates

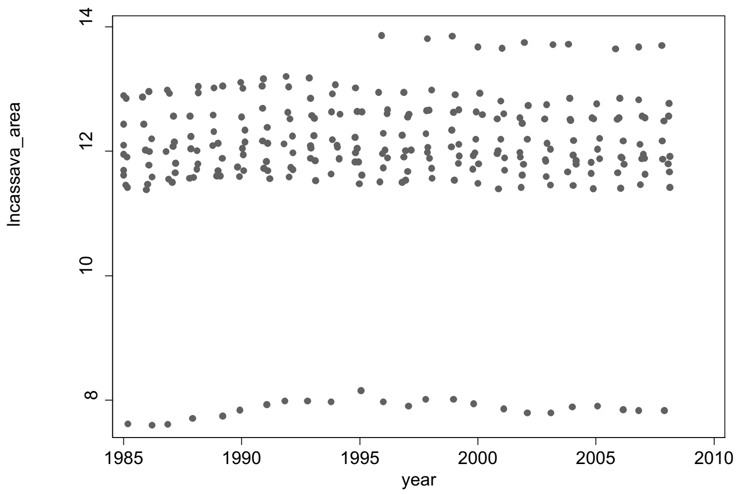

Fig. 9. Trends in cassava area in Bas Congo and placebo trends in 11 control provinces, DRC, 1985-2008
Sources: Authors' estimates

Table 1. Vintage of cassava breeding technology, DRC, 1976-2008.

Vintage of breeding technology	Germplasm source	Year identified	Year released	Traits
Taken up by farmers during on-farm trials but not officially released				
Antiota	Nigerian landrace, not released	1980s	n.a.	High-yielding, EACMV-Ug susceptible but even with CMD can still give a good yield; good for boiling
Nsumbakani	Variety taken up by farmers during on-farm participatory evaluation, not released	1980s	n.a.	High-yielding, EACMV-Ug susceptible but even with CMD can still give a good yield
Improved EACMV-Ug susceptible 1977-1996				
Kinuani ((30085/28)	IITA materials introduced as seeds, local selection	1976	1983	CBB resistant, EACMV-Ug susceptible. Early maturing, bitter, good quality of fufu (white) but low dry matter during fermentation
F100	INERA collection identified by IITA breeder	1976	1983	CBB resistant, EACMV-Ug susceptible. Good stable yields, sweet, good quality product (high dry matter, white flour)
Tshilobo (30085/28/10)	INERA local selection from Kinuani (30085/28) seedling	1979	1984	CBB resistant, EACMV-Ug susceptible. Early maturing, bitter, good quality of fufu (white) but low dry matter during fermentation
Pululu (40230/3)	IITA materials introduced as seeds, local selection	1980	1987	CBB resistant, EACMV-Ug susceptible. Early maturing, high yield, good quality of fufu (white) high dry matter during fermentation.
Improved EACMV-Ug tolerant 1997-2002				
Mvuama (83/138)	Farmer variety seed selected by researchers	1983	1997	CBB resistant, EACMV-Ug tolerant; High yield; Good quality product (fufu is very white)
RAV (85/297)	IITA materials introduced as tissue culture (30555/5) local selection	1985	1997	CBB resistant, EACMV-Ug tolerant; High stable yields; Good quality product (fufu is very white)
Sadisa (91/023)	INERA seeds from locally-bred materials	1991	1999	CBB resistant, EACMV-Ug tolerant, green mite tolerant, High-yielding, high dry matter, high quality flour (cream). Good production of leaves. Leaves good quality for "pundu"
Mahungu (92/278)	INERA seeds from locally-bred materials	1992	2000	CBB resistant, EACMV-Ug tolerant, susceptible to green mite; High-yielding in specific areas; Sweet used in forest areas eaten mostly boiled
Lueki (92/377)	INERA seeds from locally-bred materials	1992	2000	CBB resistant, EACMV-Ug tolerant, susceptible to green mite; High-yielding; Sweet used in forest areas eaten mostly boiled; poundable
Improved EACMV-Ug resistant 2004+				
Butamu (MV99/0395)	IITA materials introduced as seeds local selection	1999	2004	EACMV-Ug resistant, good yield, yellow released for fresh consumption boiled or fried. But also used for fufu and chikwangue
Disanka (95/0211)	IITA materials introduced as vitroplant, local selection	2001	2004	EACMV-Ug resistant, high yielding, fresh consumption, sweet for chikwangue, snow white, high dry matter, wide adaptation
Mvuazi (I95/528)	IITA materials introduced as vitroplant, local selection	2001	2004	EACMV-Ug resistant, high yielding, good for fufu and chikwangue
Nsansi (96/0160)	IITA materials introduced as vitroplant, local selection	2001	2004	EACMV-Ug resistant, high yielding, good for fufu, Chikwangue, bitter
Zizila (MV99/038)	IITA materials introduced as seeds local selection	1999	2004	EACMV-Ug resistant, high yielding, good for fufu, Chikwangue, intercropping because erect
Mbankana (93/067)	IITA materials introduced as vitroplant, local selection	2001	2008	EACMV-Ug resistant, specific to Plateau de Bateke released for mid altitude
Ngandajika (MV99/150)	IITA materials introduced as seeds local selection	1999	not released	EACMV-Ug resistant, selected for mid altitude, not yet officially released but already in dissemination
TME419	IITA materials introduced as vitroplant, local selection also released in Ghana, Ghana	2003	2008	EACMV-Ug resistant, high yield, high dry matter, good for "pondu", sweet and poundable
94/0330	IITA materials introduced as vitroplant, local selection	2002	2008	Sweet, yellow root with high level of beta-carotene
01/1661	IITA materials introduced as vitroplant, local selection	2002	2008	Sweet, yellow root with high level of beta-carotene
01/1229	IITA materials introduced as vitroplant, local selection	2002	2008	Bitter, yellow root with high level of beta-carotene

For Highlands				
Mayombe (MM96/7762)	IITA materials introduced as vitroplant, local selection	1999	2008	EACMV-Ug resistant, Yellow root, high yield with good fufu, well adapted to low and mid alitudes
Liyayi (MM96/0284)	IITA materials introduced as vitroplant, local selection	1999	2008	EACMV-Ug resistant, Yellow and sweet root, fresh consumption, good fufu, adapted to low land
Namale (MM 96/7204)	IITA materials introduced as vitroplant, local selection	1999	2008	High yield, also adapted to low land
Sawasawa (MM 96/3920)	IITA materials introduced as vitroplant, local selection	1999	2008	EACMV-Ug resistant, High yield
Mapendo	IITA materials introduced as vitroplant, local selection	1999	2008	EACMV-Ug resistant, High yield
Sukisa (MM 96/1666)	IITA materials introduced as vitroplant, local selection	1999	2008	EACMV-Ug resistant, High yield

Source: Authors' representation based on researchers and implementing organizations survey.

Table 2. Descriptive statistics for survey farm households, DRC, 2009.

	Farm size (Ha)						Treatment	Non-treatment		
	0.01-1	1.01-2	2.01-3	>3	All	Significance			All	Significance
Households (number)	144	104	99	158	505		275	230	505	
Households (%)	28.5	20.6	19.6	31.3	100.0		54.5	45.5	100	
Proportion cropped to cassava	0.68	0.89	0.43	0.39	0.58	n.s.	0.51	0.68	0.58	n.s.
Percent cassava harvest sold	46.1	49.5	44.7	54.5	49.2	0.003	49.40	48.90	49.20	n.s.
Major objective growing cassava: Household food (%)	60.5	49.5	35.1	29.1	43.1	0.000	52.90	30.50	43.40	0.000
Household produces enough food: Yes (%)	37.5	42.3	43.4	67.7	49.1	0.000	52.20	43.50	48.40	0.029
Household buys food: Yes (%)	63.2	69.2	64.6	51.3	61.0	0.018	62.20	60.00	61.20	n.s.
Household head age (years)	45.7	50.0	46.6	46.3	47.0	0.050	47.60	46.90	47.30	n.s.
Household head formal education (years)	5.5	7.2	8.0	8.4	7.2	0.000	6.98	7.50	7.21	n.s.
Household size (number)	5.8	7.5	7.4	8.5	7.3	0.000	7.26	7.27	7.27	n.s.
Household member work on farm (number)	2.6	3.2	3.3	4.1	3.3	0.000	3.2	3.5	3.3	n.s.
Hire casual workers: Yes(%)	41.0	72.1	57.6	63.9	57.8	0.000	56.4	59.1	57.6	n.s.
Value of farm equipment (US$)	45.0	194.4	65.0	233.1	138.5	0.012	120.63	1467.39	135.01	n.s.
Value of livestock (US$)	69.8	485.5	138.1	463.5	292.0	n.s.	466.25	141.72	284.99	0.042
Visit extension: Yes (%)	20.1	17.9	14.9	47.0	100.0	0.000	64.0	36.0	100	0.014
Extension visit: Yes (%)	20.9	20.0	11.8	47.3	100.0	0.000	67.9	32.1	100	0.001
Other information source:NGO, CBOs: Yes (%)	25.8	18.9	20.0	35.3	100.0	n.s.	60.9	39.1	100	0.044
Farmers' organization	14.4	32.4	33.0	32.7	27.4	0.001	29.0	24.9	27.2	n.s.
Female-headed (%)	70.7	12.2	4.9	12.2	100.0	0.000	51.2	48.8	100	n.s.
Mix varieties (%)	72.9	76.9	91.8	78.5	79.2	0.004	83.5	74.7	79.6	0.009

Source: Authors' estimates.

Table 3. Cassava planting materials distribution and direct household beneficiaries, DRC, 2001-2008.

	SECID		FAO		CADIM		BECECO		PACT		All	
Year	Planting materials	Households	Planting materials	Households	Planting materials	Households	Planting materials	Households	Planting materials	Households	Planting materials	Households
2001	324	1,212	19,124,736									
2002	13726296	10,373	20,462,508									
2003	34828452	48,292	27,907,870		470,200	125	895,000	33,996				
2004	0		8,511,000		55,100	302	4,922,500	396,112				
2005	59315310	91,792	1,651,200		229,500	365	6,535,000	744,040				
2006	81269910	141,490	3,076,800		154,500	51	8,555,000	238,800				
2007	29294190	199,414	27,112,500		1,797	25	4,321,000	400,023				
2008	33678990	265,936	27,393,750		62,200	181	3,736,500	303,580				
Total	252,113,472	758,509	135,240,364	652,316	973,297	1,049	28,965,000	2,116,551	62,500	2,241	417,354,633	3,530,666

Source: Project reports.

Table 4. Cassava planting materials distribution by province, DRC, 2001-2008.

Year	Bas-Congo	Bandundu	Kinshasa	Equateur	Kasai-Occidentale	Kasai-Orientale	Sud-Kivu	Nord-Kivu	Maniema	Orientale	Katanga	Total
2001	2,332,906	2,025,928	1,124,400	2,817,543	637,429	569,163	1,791,067	780,937	61,531	5,881,358	1,102,798	19,125,060
2002	10,233,660	8,595,772	825,773	3,741,445	454,374	372,304	3,385,124	1,189,353	37,101	4,180,964	1,172,934	34,188,804
2003	24,767,802	20,102,375	1,552,741	2,951,015	701,695	752,552	5,198,149	1,663,953	43,894	5,139,578	1,227,768	64,101,522
2004	3,601,500	1,940,000	2,771,600	0	442,500	1,137,000	1,036,000	2,550,000	0	0	10,000	13,488,600
2005	1,327,500	2,597,000	1,557,000	0	1,309,200	15,121,828	520,000	15,124,828	14,828,828	96,000	15,248,828	67,731,010
2006	2,887,500	2,010,000	3,042,000	0	1,148,800	20,921,478	780,000	21,037,478	20,317,478	144,000	20,767,478	93,056,210
2007	2,446,250	950,000	2,973,047	2,775,000	841,250	2,302,500	5,662,500	7,462,500	1,968,750	31,262,940	2,084,750	60,729,487
2008	2,983,750	3,332,750	4,620,950	6,768,750	6,056,250	4,106,250	375,000	431,250	0	34,803,990	1,392,500	64,871,440
Total	50,580,868	41,553,825	18,467,511	19,053,753	11,591,498	45,283,074	18,747,840	50,240,298	37,257,581	81,508,830	43,007,055	417,292,133

Source: Project reports.

Table 5. Comparison-of-means estimate of varieties planted by sample households, DRC, 2004 and 2009.

	Survey year							
	2004				2009			
	Treatment	Non-treatment	All	Significance	Treatment	Non-Treatment	All	Significance
Households (number)	251	18	269		163	231	394	
Varieties planted (%)								
Farmer varieties	0.481	0.527	0.484	n.s.	0.551	0.792	0.651	0.000
Ug susceptible	0.053	0.070	0.055	n.s.	0.060	0.048	0.055	n.s.
Ug tolerant	0.463	0.403	0.459	n.s.	0.215	0.113	0.172	0.000
Ug resistant	0.003	0.000	0.002	n.s.	0.173	0.047	0.121	0.000

Source: Authors' estimates.

Table 6: Estimated average treatment effect on varieties planted by sample households, DRC, 2004 and 2009.

Method		Survey year 2004	2009
Linear regression	Farmer varieties	-0.065	-0.196
	Ug susceptible	0.004	-0.007
	Ug tolerant	0.066	0.073
	Ug resistant	-0.005	0.130
Propensity score in regression	Farmer varieties	-0.053	-0.114
	Ug susceptible	0.007	-0.031
	Ug tolerant	0.046	0.023
	Ug resistant	0.000	0.122
Regression using propensity score interacted with treatment in regression	Farmer varieties	-0.017	-0.124
	Ug susceptible	-0.019	-0.030
	Ug tolerant	0.036	0.033
	Ug resistant	0.000	0.121
IV regression	Farmer varieties	-0.062	-0.196
	Ug susceptible	0.014	-0.007
	Ug tolerant	0.048	0.073
	Ug resistant	0.000	0.130

Source: Authors' estimates.

Table 7: Changes-in-changes average treatment effect on variety adoption, DRC, 2004-2009.

	Coefficient	Standard error	Significance (P>|z|)
Farmer			
Lower bound	-0.151	0.033	0.000
Upper bound	-0.047	0.038	0.208
Ug susceptible			
Lower bound	-0.216	0.015	0.160
Upper bound	0.060	0.010	0.000
Ug tolerant			
Lower bound	-0.177	0.031	0.000
Upper bound	0.098	0.023	0.000
Ug resistant			
Lower bound	-0.827	0.017	0.000
Upper bound	0.173	0.017	0.000

Source: Authors' estimates.

Table 8: Fixed effects least squares dummy variable estimation of yield gains per hectare of different vintages of improved varieties with EACMV-Ug susceptible varieties as the reference category, DRC, 1976-2008.

lnyield	Coef.	Std. Err.	t	P>t
_Ilocation_2 (Gimbi)	-0.194	0.264	-0.740	0.462
_Ilocation_3 (Gungu)	-1.498	0.329	-4.550	0.000
_Ilocation_4 (Katembo)	-1.725	0.267	-6.460	0.000
_Ilocation_5 (Kilunda)	-1.349	0.329	-4.100	0.000
_Ilocation_6 (Kimpese)	0.082	0.265	0.310	0.757
_Ilocation_7 (Kinzau)	-0.164	0.333	-0.490	0.623
_Ilocation_8 (Kisantu)	0.077	0.267	0.290	0.773
_Ilocation_9 (Kiyaka)	-0.034	0.262	-0.130	0.898
_Ilocatio~10 (Kondo)	-0.812	0.323	-2.520	0.012
_Ilocatio~11 (Kunda)	-0.232	0.290	-0.800	0.423
_Ilocatio~12 (Lowa)	-0.007	0.318	-0.020	0.983
_Ilocatio~13 (Lukamba)	-0.513	0.329	-1.560	0.119
_Ilocatio~14 (Mampu)	-0.097	0.285	-0.340	0.735
_Ilocatio~15 (Mankewa)	0.546	0.268	2.040	0.041
_Ilocatio~16 (Mbankana)	-0.306	0.256	-1.200	0.231
_Ilocatio~17 (Mbuela)	-0.025	0.323	-0.080	0.938
_Ilocatio~18 (Menkao)	0.041	0.272	0.150	0.881
_Ilocatio~19 (Mosango)	-0.331	0.329	-1.000	0.315
_Ilocatio~20 (Mpalukidi)	0.180	0.270	0.670	0.504
_Ilocatio~21 (Mulungu)	0.317	0.316	1.000	0.316
_Ilocatio~22 (Mvuazi)	0.204	0.255	0.800	0.423
_Ilocatio~23 (Ngandanjika)	0.175	0.265	0.660	0.511
_Ilocatio~24 (Ngashi)	-2.810	0.323	-8.700	0.000
_Ilocatio~25 (Nkamu)	0.087	0.319	0.270	0.784
_Ilocatio~26 (Nkolo)	-0.485	0.270	-1.790	0.073
_Ilocatio~27 (Ntampa)	-0.048	0.318	-0.150	0.880
_Ilocatio~28 (Ntemo)	-0.107	0.323	-0.330	0.739
_Ilocatio~29 (Savana)	0.975	0.291	3.350	0.001
dummy1996+	0.192	0.057	3.380	0.001
dummy farmer variety	-0.100	0.090	-1.110	0.268
dummy UG tolerant	0.307	0.093	3.290	0.001
dummy Ug resistant	0.389	0.101	3.850	0.000
dummy not selected by researchers	0.176	0.077	2.270	0.024
_cons	2.160	0.268	8.060	0.000
Number of observations	1543			
F(33, 1509)	28.49			
Prob > F	0.0000			

Source: Authors' estimates.

Table 9:Nonparametric estimate of LATE, DRC, 2009.

Outcome variable	LATE	Mean	Standard deviation
Area planted to improved varieties	5.14	1.21	1.26
Area planted to local varieties	13.50	1.24	3.21
Area planted to mixed varieties	27.07	1.53	4.05
Yield improved varieties (farmer estimates)	51.37	9.79	7.15
Yield local varieties (farmer estimates)	17.51	6.86	5.91
Yield improved varieties (farmer estimates)	31.94	6.56	3.37
Yield of cassava plots (researcher estimates)	3.12	14.46	8.85
Gross margin cassava plots	982.22	2,267.74	1,752.00

Source: Authors' estimates.

Table 10:Logit regression adjustment estimates of average treatment effects on food security, DRC, 2009.

Bootstrap results Number of obs = 521

Replications = 400

	Observed Coef.	Bootstrap Std. Err.	z	P>z	Normal-based [95% Conf. Interval]	
ate	0.112615	0.056836	1.98	0.048	.0012187	.2240103
att	0.112615	0.056836	1.98	0.048	.0012187	.2240103

Source: Authors' estimates.

Cassava investment in Africa: taking inventory of initiatives in Africa in view of positioning cassava as a strategic commodity

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Summary

Over the past decades, some extensive research and investments have taken place across Africa by a range of stakeholders to explore and capitalize on the potential of cassava in terms of both a basic food product and a strategic commodity to be processed and refined for trade on the regional, continental and international markets. Such research is multifaceted, and includes, e.g. efforts to improve cassava's resistance to pests and diseases, which have ravaged the crops in most of Africa in the past; increase drought tolerance; increase nutritional value; increase starch levels for industrial uses; bulking of planting material; and building community capacity in terms of planting and maintenance of cassava. Additionally, at a socio-economic level, there are also efforts to address attitudes and stigmas that identify cassava as a “poor man's crop”, etc. The NEPAD Pan African Cassava Initiative (NPACI) through IITA recently commissioned the undertaking of an inventory of key initiatives in Africa in view of positioning cassava as a strategic commodity for investment. The findings of this study are threefold: first, the stakeholders and their interests are identified; second, networks are identified as well; and third, a SWOT analysis identifies the strengths, weaknesses, opportunities and challenges in the cassava sub-sector has been carried out. This paper presents a synthesis of these findings before drawing important conclusions and recommendations. It is quite striking to note the recurrence of themes regarding the strengths and opportunities of cassava in Africa relating to its seemingly unlimited potential, even though its limitations (weaknesses and threats) most often refer to non-realization of this same potential. In fact, the tremendous promise of cassava as a strategic commodity for all of the regions under consideration relies on the coordinated actions and investments of all levels of stakeholders, which is presently a significant stumbling point for the development of cassava value chain in each region. Indications from the surveys conducted in the study insofar as the increasing buy-in from donors, governments, and research institutions concerning cassava's strategic role are very positive. However, this is not yet translating into a tangible reality for producers and marketers of cassava, who remain blocked at the market-entry point in all regions. Despite the high heterogeneity among the regions vis-à-vis the significance and status of cassava as a commodity, the challenges remain remarkably similar: access to funds and credit, access to technology, expertise and improved planting material, market access, processing capacities and coordination of initiatives for maximization of impact, etc. This is indicative of an inherent shortcoming in the approach to developing cassava value chain, as the gap between producers' and donors'/governments' visions for this commodity remains vast.

Keywords: Cassava, value chain, investment, network, stakeholder, inventory

Rationale and Objectives

Given the efforts describe above, NPACI commissioned an investigation into the positioning of cassava as a strategic commodity within the African context. The objectives of the study are to:

- Map the stakeholders in the cassava sector to understand the nature of their relationships and how they are organised
- Identify existing networks in the cassava sector their objectives and membership
- Conduct a SWOT analysis for Africa's cassava sub-sector.

The ultimate goal of these objectives was to produce a report on the status of cassava in Africa and to create a database of the various cassava stakeholders across the continent, which outlines their interests, geographical areas of implementation and their partners in the cassava sub-sector. From this, it was then possible to identify the cassava sub-sector's major networks in each of these regions. The database that also resulted from this effort is in turn, expected to assist in establishing contacts among those within the sector to facilitate information sharing and future collaboration.

Research materials and methodology

The task of identifying initiatives, stakeholders and networks was divided among four Regional Consultants, to examine eastern, southern, and west and central Africa (two consultants were assigned for this region). The methodology for the inventory was two-fold, in that it involved extensive primary and secondary data collection.

For primary data collection, priority countries were identified in each region collaboratively between the Lead Consultant and NPACI. National Survey Assistants (NSAs) were then deployed in these regions with a questionnaire developed by the Regional and Lead Consultants. The priority countries included: Tanzania, Uganda, Kenya, and Madagascar in eastern Africa; Malawi, Mozambique and Angola, in southern Africa; and Nigeria, Ghana, Benin, DRC, Congo and Cameroon in western and central Africa. Because no suitable NSAs could be identified in Angola, this country was eventually omitted from the primary data collection.

Table 1:Repartition of survey team by regions/countries.

Region	Countrysurveyed	National Staff	Regional staff
Central & Western Africa	DR Congo, Nigeria,	18 National consultants	01 Lead consultant
Central & Western Africa	Benin, Cameroon, Congo (Rep.), Ghana	10 National consultants	01 regional consultant
Eastern Africa	Kenya, Madagascar, Uganda, Tanzania	08 National consultants	01 regional consultant
Southern Africa	Malawi, Mozambique	05 National consultants	01 regional consultant
04	**12**	**41**	**04**

The administration of the questionnaires targeted the public, private, donor, research, farmer/CBO and NGO sectors to gather qualitative and quantitative data on the continent's cassava value chain. These questionnaires led to regional reports which were aggregated into one consolidated continental report. The database that has been developed as a result of this investigation is likewise informed by these questionnaires.

Results and discussion

The findings of this study are three fold: first, the stakeholders and their interests within the cassava value chain are identified; second, cassava-related networks are identified; and third, a SWOT analysis. The highlights of these findings are summarized below.

Stakeholders mapping and their interest in the cassava value chain in Africa. The study suggests that on a continental level, USAID, IITA and NPACI appear to be the best established and known players in the development of cassava value chain. In each of the three regions surveyed, major players in the cassava sub-sector were identified. In addition, trends and policies in each region were identified.

In Eastern and Southern Africa, the focus of the cassava value chain tends to be the basic production, multiplication and bulking of clean planting materials among cassava stakeholders. National and international universities and research institutions (ZARI, IIAM, CABI, CGIAR IITA and CIAT, etc) throughout the two regions are active in the efforts to develop and distribute improved varieties to mitigate adverse conditions and improve the quality of crops.

Table 2: Major stakeholders mapping and their interest in Eastern and Southern Africa

Region	Name	Interest
Eastern and Southern	Ministries of Agriculture	Policy guidance, planning and regulation
	Bilateral: USAID, SIDA, NORAD, DFID, JICA, GTZ	Funding
	Multilateral: IFAD	Funding
	IITA	Research, training, technical support and information sharing
	Universities NARS: ZARI, IIAM	Training and research Research coordination
	Farmers organisations	Defense of farmers interests
	Local NGOs, CBOs	Capacity strengthening and funding
	Philanthropy and international NGOs: Rockefeller Foundation, WK Kelloggs Foundation, Gates Foundation, etc.	Funding
	FAO	Funding and technical support

Source: *Study surveys.*

In the donors' community, most notably USAID, SIDA, NORAD, DFID, IDRC, JICA, FAO, GTZ, Rockefeller Foundation, WK Kellogg's Foundation and the Gates Foundation are investing significantly in projects aiming to distribute improved varieties to small scale farmers and to build capacity in basic preservation and production techniques. Some donors, particularly USAID, USDA, Pooled Fund, EED/Bonn, CTB fund cassava-related projects, which are implemented by third parties including

FAO, ACF, IITA, SECID, PIDR, CRS, OXFAM, TEAR FUND. These third parties partner with local service providers (Department of Agriculture, NGOs, CBOs) to implement projects, most often targeting small-scale farmers.

NGOs and CBOs in Eastern and Southern Africa are mainly engaged in implementing government initiatives or donor-funded programs. Because the value chain is underdeveloped in both regions, private sector engagement is slow to react and invest in the cassava value chain. Therefore, there are major opportunities presented by increasing market access and facilitating the development of the value chain in both regions.

Table 3: Major stakeholders mapping and their interest in West and Central Africa

Region	Name	Interest
West and Central	Ministries of Agriculture	Policy guidance, planning and regulation
	Bilateral: USAID, CTB	Funding
	Multilateral: IFAD	Funding
	IITA	Research, training, technical support and information sharing
	Universities and research i nstitutions (NARS) NARS: IRAD, INERA	Training Research coordination
	Farmers organisations:	Defense of farmers interests
	Processors associations	Defense of processors interests
	Local NGOs, CBOs	Capacity strengthening and funding
	Philanthropy and international NGOs: Rockefeller Foundation, Oxfam, CRS	Funding
	FAO	Funding and technical support

Source: *Study surveys.*

The study reveals that despite the high heterogeneity among the regions (even within regions) vis-à-vis the significance and status of cassava as a commodity, the challenges with a few definite outliers for specific regions remain remarkably similar: access to funds and credit, access to technology, expertise and improved planting material, market access, processing capacities and coordination of initiatives for maximization of impact are challenges faced by stakeholders in each region. This is indicative of an inherent shortcoming in the approach to developing cassava's sub-sectors or value chain, as the gap between producers' and donors'/ governments' visions for this commodity remains vast.

The incongruence of the visions of cassava potential is highly related to the core objective of this study: identifying networks that foster information sharing and collaboration among stakeholders at all levels in the development of a bona fide cassava value chain. While strides have certainly been made to collaborate within groups of stakeholders (i.e. researchers developing more resilient crops, or donors providing extensive forum to stimulate innovation) networks that bring all stakeholders to the fore to develop collaborative strategies for this important value chain are not yet realized.

Networking in the cassava value chain in Africa

Eastern and Southern Africa.

Several established networks were identified in East and Southern Africa in the cassava value chain. Because of cross membership of some countries to regional bodies, EARRNET and SARRNET (respectively Eastern Africa Root crops Research Network and Southern Africa Root crops Research Network) emerge as the major cassava-specific networks with a regional spectrum. Apart from EARRNET and SARRNET which prime mandate is research, the networks are reported to focus mainly on promoting production on the one hand while training farmers on processing and commercialization of cassava comes as a secondary objective. ASARECA is one such major research coordinating body in Eastern Africa.

Nationally, there are internal networks working on cassava that are often brought together by government departments. One such example is the network in Malawi that involves the Department of Agriculture and Food Security and the Malawi Entrepreneurial Development Institution both public entities with mandates to complement each other in the development of the cassava value chain.

Though some cassava networks are long-standing (established in the early 1990s), the majority of networks present on the field are quite recent. On average, they are about 5 years old, which may suggest that it is only recently that cassava is becoming important for these regions, apart from Uganda, which has been a lead cassava growing country for some time now. A specific case is the National Network of Cassava Workers (NANEC), which is collaboration between NARO and the Ugandan government through MAAIF (Ministry of Agriculture, Animal industry and Fisheries). Chiefs, opinion leaders and farmers are also included on this team and the network provides a forum for research, planning, in which technical and non-technical (policy) issues related to cassava development are prioritized on the national needs according to the resources available. In Tanzania, cassava networks are still largely informal.

Stakeholders in all sectors often referred to SARRNET and IITA as a primary source of information and capacity in the production of cassava. Technical networks were also identified, such as the Cassava Improvement Network, which comprises stakeholders throughout East and Southern African, as well as the Cassava Biotechnology Network, which targets researchers working on improved and modified varieties of cassava.

Table 4: Networking in the cassava value chain in Eastern and Southern Africa

Region	Name	Prime mandate
	EARNET and SARNET	Information sharing
	IITA	Research and information sharing
	ASARECA	Research coordination
	Cassava Improvement Network	Technical support
	Cassava Biotechnology Network	Targets researchers working on improved and modified varieties of cassava
	Others	Reported to focus mainly on promoting production on the one hand while training farmers on processing and commercialisation of cassava comes as a secondary objective
	National Network of Cassava Workers (NANEC)	Is a collaboration between NARO and the Ugandan government through MAAIF (Ministry of Agriculture, Animal industry and Fisheries)

Source: *Study surveys.*

West and Central Africa: In West and Central Africa, IITA was noted as the most widely known network while it is also seen as a major stakeholder. It was noted by some respondents to the questionnaires that networks in the African cassava value chain currently focus more on the institutions and organizations working in cassava, and that there are few opportunities for producers and processors to interact and exchange information in an organized setting.

As with cassava networks other regions, the majority of networks present on the field in West and Central Africa are relatively recent, having been established for an average of seven years. However, Nigeria emerges as one country where networking in cassava is long-standing. While support in increasing cassava production remains the main objective of most networks, processing comes next. In the specific context of a country like Nigeria, production and processing seem equally to receive the same level of attention with regard to prioritization of segments of the value chain. The networks identified most often have national and community geographical range of coverage, involving production and processing segments.

The public sector in West and Central Africa is making strides in terms of organizing around the issue of agricultural productivity in general. An example of this organization into a network, which has an indirect impact on cassava and its value chain development, is the West Africa Agricultural Productivity Program (WAAPP). It is a sub-regional program shared by all 15 member states of the Economic Community of West African States (ECOWAS), and is being coordinated by the Central African Council for Agricultural Research (WECARD/CORAF) (ECOWAS, 2009). This network brings together various sectors involved in agricultural development. In Ghana, government projects/programs, MOFA and special units like the Ghana Export Promotion Council (GEPC) were identified as role players in the distribution and the circulation of information concerning cassava. Meanwhile, CORAF is a major research coordinating body in West and Central Africa

Table 5: Networking in the cassava value chain in West and Central Africa -

Region	**Name**	**Prime mandate**
West and Central	Central African Council for Agricultural Research (WECARD/CORAF	Research coordination
	IITA	Research and information sharing --- most widely known to the public and also seen as a major stakeholder
	West Africa Agricultural Productivity Programme (WAAPP)	Agricultural productivity Sub-regional programme shared by all ECOWAS States
	Others	While supporting increasing cassava production remains the main objective of most networks, processing comes next
	Nigeria	Production and processing seem equally to receive the same level of attention with regard to prioritization of segments of the value chain

Source: *Study surveys*

A SWOT analysis for Africa's cassava value chain

This is where the discussion seizes the opportunity to analyze the strengths, weaknesses, opportunities and threats within the cassava value chain in Africa. As such, general findings those that apply to the whole continent are presented first, and are then followed by region-specific findings, where necessary.

General Strengths of Cassava in Africa

Key role in Food Security: Cassava's historical role as a food security or emergency crop is found in its ability to withstand stressful environmental conditions, through which other crops do not endure easily, especially with very limited access of the rural population to improved agricultural inputs like fertilizers and this is good for the poorest of the poor in rural areas. This demand, albeit an unfortunate one as a socio-economic indicator, offers a recurring level of demand for the crop. In addition, the crop is growingly becoming a key weapon in fighting food insecurity because of its advantage of performing even under severe climate and soil conditions in marginal lands.. Cassava emerges a food staple that ensures daily diet for the majority of the populations in major growing countries like Nigeria, Benin, Congo and DRC, while the existence of growing domestic demand on the consumption side in all countries is having an important pulling effect on the supply side in the value chain.

High resilience and adaptability: A notably hardy crop, cassava can remain in the ground for up to two years without harvest, making it a reliable choice for a reserve crop (safety net) in times of uncertain precipitation. Because it is not too season-dependent, it can be harvested at any time of the year, as needed. Adaptability of the crop in different agro-ecological zones and drought resistance means that cassava can thrive in harsh environmental and climatic conditions where other crops can barely survive. With the current trends on climate changes, this crop is a good candidate for resilience to climate changes An abundance of research on cassava in recent years has also shown that cassava can potentially be genetically modified to become resilient to arising climatic conditions as well as pests (army worm, green spider mite, etc) and to viruses that can be potentially devastating (mosaic virus, brown streak virus, etc).

A low-input and labor intensive crop: Furthermore, cassava requires few to no inputs and a very small surface area to grow, making it a viable crop in uncertain economic and climatic times. As such, cassava can be grown by small-scale farmers and households' members since they require low capital input and is relatively low labor demanding. Because of these attributes, small-scale farmers with small plots for cultivation and who cannot afford expensive inputs have proven very willing to harvest this crop. This is often referred to as a pro-poor crop has it possesses a huge potential to help fight poverty in rural areas. Further, cassava is, on a commercial farm, a labor intensive crop, therefore it presents employment opportunities in a continent with an abundance of labor and limited employment options.

Increasing investments in the value chain by Stakeholders: The study reveals an upward trend of investment by stakeholders in the cassava value chain. This therefore suggests that in the years to come, these investments could be large enough to transform the crop from subsistence to a cash crop and increase research and development. There has been a lot of research particularly on improved and resistant varieties development. The level of funding provided for these activities is also encouraging even though one would have expected some more efforts. This is seen more in eastern, central and western Africa than in southern Africa.

A crop with a manifold potential uses: In addition, cassava has a plethora of potential uses. In terms of basic foodstuffs, both the leaves and the roots of the cassava plant offer nutritional value, and are the cheapest source of calories in Africa (CGIAR, 2008). The leaves of the cassava are eaten as vegetable in many countries and are high in proteins and vitamins A and B content. Processing of cassava for food requires little mechanization, and can therefore often be done at the village level or at the farm-gate. Processes such as grating, milling, drying are low-cost ways of adding value to a small-scale cassava production. In addition to consumable products, the potential for cassava to be processed into raw industrial products (plywood, starches, adhesives, tissues, etc) is virtually endless.

Though, region-specific strengths do exist: The East African region boasts of several strengths that impact on the general performance of cassava value chain. Some of these strengths include: the presence of active ongoing crop research on cassava thanks to the existence of research bodies and extension services with good reputation. Some of the research organizations include national research institutions such as NARO in Uganda, KARI in Kenya and NRI in Tanzania. Others are ICIPE and IITA. These organizations generally command much respect within the region. Other key strengths include availability of land and the fact that new cassava varieties that have been adopted have a short growing season/ cycles.

In the Southern Africa region, there is scientific innovation taking place. In fact, the region's universities and research institutions are currently the sites of advanced technological research in the field of cassava production and diseases resistance.

In Western and Central Africa, cassava is viewed as a high priority by the majority of region's governments. Among them are DR Congo, Ghana and Nigeria where the legacy of presidential initiatives on cassava is critical precedent in changing the way the commodity is looked at and considered (Agence Congolaise de Presse, 2009). Under the public driven initiatives, strength emanates from the existing government structures (including present Ministries of Agriculture), the ongoing agricultural development programs, the public workforce in terms of competent staff, even at the local government levels. Existing initiatives and skill sets in the region can be built upon. Related to the above, most of the cassava initiatives emanating from, be it, national, state, provincial or local governments build on existing assets, skill sets and resources to promote and implement activities. Some of other strengths are recorded in the area of government patronage (e.g. Presidential Initiatives on Cassava), association and commendation. Active ongoing crop research on cassava thanks to the existence of research bodies (e.g. IITA, NARS, etc.) and support by extension services with good reputation are adding up in making improved varieties and planting materials increasingly available and cheaply accessible to smallholders in some countries.

The cassava value chain has a very long and strong foundation in the socio economic habits of the population in all the four countries surveyed in West and Central Africa. The cultivation and production of cassava roots benefits from a solid experience acquired over years, since its introduction in the equatorial areas. In fact, throughout the years, people have developed and acquired a series of strategies that have helped them to improve their techniques in producing cassava. In many cases, these existing techniques have most of the time been improved to make them more efficient, through various programs in the countries. The production sub sector has been sustained by a huge variety of food habits, from one area to another. This has led to the development of cassava processing activities, with large possibilities and options.

Alongside cassava's mainly natural strengths, there are several important weaknesses that must be fully considered when assessing cassava's sub-sector and its role as a strategic commodity in Africa.

General Weaknesses in Africa's Cassava Value Chain

Poor post-harvest handling: Although cassava is able to remain in the ground for long periods of time, once it is harvested, it has a relatively short shelf life as a fresh product (Aemi, 2005). Therefore, a great deal of the fresh cassava harvested never makes its way to a formal market and it consumed as a subsistence crop. As a highly perishable crop, cassava must be processed within twenty-four hours of harvest. Typically, this means grinding the root into a fine starch or flash-frying meat into cassava chips, processes that must occur in an industrial environment; a luxury that the majority of countries in Africa are not enjoying as yet. Getting cassava to the processing plant is much more difficult than producing it, due to its bulkiness and often dilapidated rural road infrastructure. Preserving cassava for long journeys requires cold chains, modern technologies, and consulting expertise that are largely unaffordable for small-scale farmers.

Limited access to cassava-specific processing technology and inputs: Although non-intensive, the basic processing of cassava, beginning with drying, can be a lengthy process and the quality of the product can be affected if prolonged. Without technology, the dying process can take up to four days, and in this time the root is vulnerable to rotting. While processing technology such as mechanical dryers can limit this risk, the costs associated with operating this machinery can negate the financial benefits for producers and processors. Limited processing opportunities also lead to low market prices (due to lack of value addition), which serves as a deterrent for producers to commit more land and resources to the production of what is perceived as a low value crop.

Limited organization and weak networking among stakeholders: Throughout the schema of cassava stakeholders, networking and organization of the value chain in a way that facilitates sharing of information in a coordinated manner remains limited. Well-structured networks, concerning donors, governments and research institutions continue to struggle to include the others (NGO, CBO, farmers' organizations) in the information exchange. Further down the chain, there is little organization of cassava producers into cooperatives or coordinating bodies. Because of this lack of organization and mobilization, needs for cassava processing, are widely going unmet in vastly disbursed cassava producing rural areas. This limited organization also leads to limited knowledge among producers about the potential of the value chain, thereby creating a cycle of subsistence because of a limited awareness of other opportunities. Despite the existing opportunity given to the various stakeholders to gather into various groupings, the benefits of such structuring (including pricing and bargaining power) are not yet well established. The limitations of effective networking are exacerbated by the limited means of communication and dissemination of information (often limited to site visits and radio) due to high levels of illiteracy in each of the regions.

Limited coordination among stakeholders: Building on the above, the presence of various financial and technical partners in the various countries surveyed should be a great advantage. However, the findings suggest that the coordination and harmonization of these partners on the field is still weak; resulting in overall inefficiency in the development of a cassava value chain. This is exacerbated by the competition noted for scarce funding opportunities and other resources, when collaboration should be a remedy for such issues.

Limited and poor quality market information: Producers in all regions noted that market access and market information was very difficult to come by. While networks like SARRNET were identified in Eastern and Southern Africa as a main source of information on all aspects of cassava, it was noted that these networks cater to more organized or project-based production, which is not the reality for the majority of small-scale cassava producers.

Limited cassava-specific skilled persons: Capacity has been revealed as one of most critical challenges faced in efforts to promote cassava value chain development. In fact, not many specialized cassava technicians with a high level of training and a fair mastery of accessible technologies are available on the market.

Accessibility of improved varieties for farmers: Despite extensive research and donor funding into the amelioration of cassava varieties, the multiplication and distribution of these improved materials has proven logistically difficult due to limited resources to reach the widely disbursed small-scale farmers most in need. The process of cutting stems for propagation is costly and fragile, as the cuts do not store well. This places high onus on those left to distribute the cuttings, often under-trained extension service providers.

Market access limited as a result of poor infrastructure: In many of the countries surveyed (Ghana, Congo, DRC, Benin, Uganda, Kenya and Tanzania) market access is further hindered by poor infrastructure, particularly roads and transport, servicing rural areas. If serious rural and agricultural development is to take place concerning perishable crops and goods, these issues must be addressed.

Policy vacuum and/or inconsistency are an important missing link: Policies impacting cassava are varied throughout the continent; however, very few are production oriented or cassava-specific. On the continental level, NEPAD through its CAADP pillar three is promoting cassava via the NPACI program (NPACI, 2008). Regionally, institutional frameworks like ECOWAS, COMESA and SADC are working on facilitating trade of agricultural commodities in general, therefore including cassava. At national level, whereas in West and Central Africa, particularly Nigeria, there are policies aiming to increase the use of cassava, be it in Benin, Cameroon, Congo (Republic of) or DRC, their respective governments have not yet formalized these efforts through policy. Policies are also starting to result into action in countries like Nigeria, where the government provides import duty exemptions for equipment, machinery and personnel in support of the cassava value chain. Likewise in East Africa, Tanzania's government is highly engaged in cassava, while Kenya and Uganda have not implemented cassava-specific policies though a plan was drafted in Kenya in 2006/07 (KARI, 2009). Mozambique's National Cassava Sub-sector Strategy developed. In the other Southern African countries, government involvement is limited to extension services (for which cassava expertise are sparse) and national agricultural research institutions. However, even in country equipped with cassava-specific public policies like Nigeria, inconsistency in decision made by the government is often blamed for the poor performance of the cassava value chain. One good example to illustrate this is the government's poor handling of the 10% mandatory cassava flour mix in all bakery preparations.

Limited funding support to the value chain: Southern Africa remains the region where cassava is least prioritized by governments, even though many respondents refer to cassava as a priority to high priority crop for governments in southern and eastern Africa. In fact, they note that budget allocations within rural and agricultural development programs are insufficient to sustainably and substantially grow the sector, as opposed to the Maputo Declaration on committing at least 10% of the national budget to agriculture (NEPAD, 2003). As such, funding shortages were noted by all sectors that responded to the questionnaires. This, in large part, is linked to the need identified by several respondents for national and regional cassava-specific policies. In addition, they note that the centralized procurement of materials leads to shortages and unnecessary backlogs. Funding shortages were noted by all sectors that responded to the questionnaires. This, in large part, is linked to the need identified by several respondents for national and regional cassava-specific policies.

Government bureaucracy, unnecessary political patronage and interventions: These are among the weaknesses that bias all transactions and lead to unfair decisions being made concerning cassava. Although the absence of a cassava-specific strategy is lamented for southern Africa, in West and Central Africa the tendency to mainstream initiatives through government channels leads to important inefficiencies. It also gives rooms for over- bearing tendencies by the government officials. Besides, some of the existing government structures are weak, leading to the projects built on them notwithstanding the test of time. On the other hand, the weaknesses of the private driven initiatives are in the area of working independently from other projects. The survey revealed that not enough synergy and collaborations exist between the public and private initiatives.

Struggling social acceptance of cassava: Some Eastern African countries, including Kenya, are quite notorious in the negative perceptions of cassava that are often reported. For cultural reasons, including the labeling of cassava as a "poor man's crop", production of the crop has been adversely affected, as has demand for its products and by-products. Consumers are also discouraged by the bitterness found in some varieties. The largely unrealized potential for cassava in Africa means that there are many opportunities to be capitalized upon in the expansion of the sub-sector.

Comprehensive Africa Agriculture Development Program

General Opportunities in Africa's Cassava Value Chain

Among these opportunities are:

Underexploited value adding / processing potential: Beginning with the multitude of products that cassava (particularly the roots) can be transformed in to, the potential for a diverse expansion of the sub-sector into various markets is enormous. This is an avenue that African stakeholders have not explored so far. Being a rather labor intensive crop when commercially produced, cassava has the potential to generate large-scale employment opportunities both for skilled and unskilled workers, once transformation and processing technologies are accessible to producers on a larger scale. Besides, it has the potential to serve as a multipurpose raw material in industry (biofuels, high quality cassava flour, ethanol, biscuits, etc.). This is backed by research findings from Nigeria that are suggesting over 25 products could be extracted from cassava roots alone (Okechukwu *et al*., 2007). The prospects of diversifying usages of cassava are so significant that it is often referred to as the "miracle crop" (Nweke, 2005).

Stabilization of cassava prices through value addition and market expansion: The development of the value chain through access to processing technologies will assist in stabilizing the market prices of cassava, which are generally considered low and unappealing for small-scale farmers. Because value-adding activities diversify the market for cassava (as the end products cater to different needs), more certainty of prices will be instilled into the market. This provides an opportunity to attract more small-scale farmers to cassava production.

Growing donor and private sector interest: Although funding is thought to be limited by most sectors, it is clear that donors are to cassava's potential to help them meet their various development goals in Africa. As the sub-sector grows, it is possible that more funding for diverse activities will be released to encourage holistic value chain development. Cassava is also emerging as a priority crop for some governments across Africa (IITA, 2006; Mahungu *et al*., 2007, Sanogo and Adetunji, 2008). While this has lead to increased research funding, there is an opportunity to use the momentum from donor and research involvement in effecting policy development to strategically place cassava in local, provincial, national and regional development programs.

Potential for increased trade on continental and international markets: This means different things to different regions. Whereas Western and Central Africa can target the export of processed products to international markets beyond Africa, because of a more highly developed and structured private sector, Southern Africa's medium-term focus will be on trade among African countries though with the exception of South Africa, which imports from other African countries, but exports to wider international markets. Furthermore, the geographical location of Benin and Cameroon creates a serious opportunity to extend their market to the neighboring countries. A study of the market-processed products in Benin (PDRT, 2008) revealed that Niger, Nigeria, Togo and Burkina Faso are important markets for cassava processed products from Benin. On its own, Cameroon is said to be an important platform for cassava distribution and trading in the CEMAC zone (IFAD, 2008). With the increasingly growing population, this market will continue to be important in the coming years. Because Southern Africa is somewhat of an emergent cassava production region, with countries ranging from very high levels of production (Angola, Malawi, Mozambique) to virtually non-existent levels (Botswana, Lesotho), the tendency for initiatives at the research level tend to have a regional focus, covering several countries. This offers a unique opportunity for value chain development within the region, rather than in isolated national markets. As such, it is assumed that SADC will have a major role to play in the elaboration of a regional strategy for cassava as a strategic commodity, which plays on the strengths of each member i.e. production capacity in Angola and Mozambique and processing capacities in South Africa.

Increasing urbanization represents a huge market to tap in: As migration and demographic shifts towards urban centres becomes an increasing reality throughout Africa, a new more sophisticated market for processed cassava food products emerges. This is particularly true in countries with an established cassava culture beyond subsistence demands therefore most predominantly in Western and Central Africa. This market offers a huge and concentrated consumer base and this opportunity has the potential to regularize the demand and prices of cassava. Because cassava is not only a popular staple food in West and Central Africa, but also a product in demand by choice (i.e. in urban areas by the all socio-economic classes) West and Central Africa represents a massive market opportunity for cassava and its processed food by-products. Nigeria and DR Congo alone represent a potential of more than 200 million consumers of cassava products and derivatives for the domestic market (Nweke, 2005).

Emergence of cost effective cassava technology: Very low-cost equipment is now available on the market and could be used both for production and processing on both large- and small-scale levels where farmers could mobilize their local knowledge to add value to cassava products. Improved collaboration and coordination amongst cassava key stakeholders and networks is also possible. For instance, better structuring of cassava value chain could help strengthen farmers' organizations. With the advent of new processing technology packages originating either from Brazil, China or Nigeria, there is the prospect for the development of new products and increased domestic demand.

Increased stakeholders' interest in cassava value chain development: Apart from the national governments, whose interest in this commodity has become fast-growing over the years, other key stakeholders, including donors/development partners, are now paying more attention to cassava. On the one hand, the prospect of scaling-up production of planting material through increased multiplication is real. Land availability increases the prospect of sustained cassava production growing areas, on the other hand. This is associated with the prospect of cassava's ability to cater for food security and to help generate income for the poor that has been demonstrated elsewhere.

General Threats to Africa's Cassava Value chain

Pests and disease outbreaks: The major threats to the cassava value chain, at this point, are natural.

These threats include pests that decimate crops, including the spiraling white fly, green mites and armyworms. But diseases, most notably CBSD and CMV have the potential to debilitate the development of the cassava sub-sector if improved varieties are not continued to be developed, and most importantly made accessible to small-scale producers. The threat of disease becomes even more pressing as trade in the African cassava value chain is facilitated. The potential opening of borders makes it more difficult to isolate outbreaks. Thus the need for resistant and improved varieties and increased biodiversity in cassava is profound.

Funding restrictions and unavailability of credit: Respondents across all regions agreed that availability of funds in quantity and in time allocated for use of funds is a serious constraint, which contributes to failure of projects. There is generally not a clear policy set up by the government, as an incentive, to ensure that individual or group projects in general and in cassava value chain are provided with the required funds to start with their business. In this context, over reliance on donor funds also emanates from the absence of well-structured and accessible credit facilities. The study has revealed that even when credit is available, interest rates imposed could be higher than what interested parties can reasonably afford.

International imports of cassava by-products: The importation of processed cassava products, such as glue, starches etc., from other countries and regions (especially Asia) stifles internal demand and acts as a deterrent to in-country or on-continent processing.

Land tenure insecurity: Additional threats to cassava production that were identified included land tenure security issues and this cuts across regions. Producers are less willing to invest in long-term production if they feel tenure insecure. In fact, it could be assumed that land availability increases the prospect of sustained cassava production growing areas. While it is regularly portrayed as one of the major bottlenecks to agriculture development in general, land is still available in some countries or regions within countries. DR Congo is, for instance, naturally well endowed with land resources, where some 80 million hectares of arable land are available while less than 10% of this potential is reportedly utilised currently (Ministère de l'agriculture, 2008)

Conflict/competition over access to production basins: Building on the above, it's worth mentioning that in countries where farmers and animal breeders share the same basins, particularly Ghana for the West and Central region, conflicts between the two people are very frequent. If this situation is not solved in a sustainable way, it will strongly contribute to reduce the yields, hence affecting the other sub sectors of the value chain.

'Controlled' burning and bush fires: These are common agricultural practice in Cameroon and Ghana. However, in a context of annual cassava cultivation, the burning of farms around cassava fields contributes to damaging and destroying the existing farms of cassava. This results to a serious decrease in yield. In a context where this practice is observed frequently, it will result to serious decline in cassava root production, hence affecting the whole value chain.

Seasonal deficits: In Benin, the seasonal deficits of cassava are a limiting factor to the progress of their processing activities, as both the quantity and quality of cassava are unreliable during these seasons. As such, investors perceive risks in committing to a crop wherein a whole season may be voided.

A Glance at the Cassava Database

Building on the above, the following recommendations are made in light of the need to address this reality, to encourage the collaborative development of an inclusive cassava value chain in Africa.

Key Recommendations

Reinforcement of cassava networks at all levels: Given the strengths and opportunities noted in terms of the increased interest and investment in cassava among donors, research institutions and governments in all of the studied regions, and their respective visions of cassava as an economy-boosting commodity, as well as a source of food security, networks that inform producers and processors of these visions and the strategies to realise them are required. These networks should include stakeholders from all levels of the value chain to ensure realistic goals and to facilitate the effective distribution of first-hand information. While sector-specific networks (e.g. in the research community) are indeed necessary, increased efforts to communicate and disseminate the latest technological and planting material advancements generated within these networks should be encouraged. This could be fostered by increased investment by the private sector into research and development of the cassava value chain; however this requires tangible benefits to entice the private sector into involvement, which is developed in the subsequent recommendation.

Development of stronger cassava (and general agricultural) policies: Because Africa continues to seek many forms of relief from agriculture poverty alleviation, food security, trade, etc. the continent's national governments and regional institutions need to develop policies that commensurate with these expectations. These policies need to provide clear objectives and tangible strategies for a high-potential crop such as cassava to ensure that the required investments are allocated within budgets, that a logical set of tasks are assigned to the implicated departments (e.g. those responsible for agriculture, economic development, infrastructure, service delivery, international trade, etc.) to ensure a synergetic roll out of a comprehensive cassava strategy, or general agricultural strategy of which cassava is a priority crop. It is not until cassava is formally prioritised within a country or region that it will find its way onto the agendas of the necessary stakeholders and warrant genuine investment from other sectors. Governments and regional institutions must set the tone of commitment through feasible strategies and their implementation for other sectors in the region and value chain to follow. While policies to guide the development of a foundation of a cassava value chain should be the domain of national governments, a market-led emergence of the value chain should be encouraged (though it might need encouragement at first, see recommendation below) to ensure that genuine investors in the value chain become involved; this should also assist in ensuring the transparent development of a cassava value chain.

Encouragement of public-private partnerships: In their efforts to mainstream cassava as a strategic commodity, governments cannot feasibly act alone at the national level; the inputs and resources available via the private sector could bolster these efforts and increase efficiency in meeting the objectives of the development a country's or region's cassava value chain. In addition to the potential to be unlocked by the large-scale production of cassava by the private sector, the need for public private partnerships is driven by the need for research and innovation in the other segments of the cassava sub-sector (research, donors through pilot interventions etc.) to maintain relevance in the real market conditions. As such, governments should increase the scope of their cassava strategies to include the private sector in terms of favourable conditions (carefully designed and implemented subsidies, tax breaks etc.) for the mainstreaming of emerging innovations through, for example, the designing and fabrication of cassava specific tools (peelers, dryers, chippers) and inputs (fertilizers, research-developed resilient seeds). While the private sector could be enticed to participate in hopes of gaining early entry into a highly relevant emerging market, the public sector, and its constituents (including other cassava stakeholders), would stand to benefit from the resources and the efficiency of the private sector, thereby limiting some of the bureaucratic blockages noted, for example, in West and Central Africa by the study's survey respondents.

Increasing access to cassava-specific equipment and technology: As part of initiatives implemented by donors, governments and NGOs, access to cassava-specific technology and equipment should be a central consideration. Donors should explore the costs/benefits of investing in technology and equipment provision as a follow-up to inputs provision and other production-oriented initiatives. Governments, in planning their own cassava initiatives and when informing donors of needs in agriculture, should highlight the need for increased access to processing and refining technology. This will decrease the vulnerability of producers and potential investors to natural and market shocks, as the durability of the product will be drastically improved. Further, access to production and processing technology offer better access to markets by offering more diverse products with a longer shelf life, which would address the main challenge indicated by respondents across all regions. Processing facilities should be planned strategically to be central to both production basins and markets (where possible) to minimise transport costs. Until the provision of advanced processing technology is feasible, the interim focus should be on supporting and fostering traditional processing and preservation techniques to increase their reliability and minimise waste of the production.

Building cassava-specific capacities among all

stakeholders: Although a traditional crop in most of the studied regions and countries (Southern Africa less so than the other regions), capacities regarding innovative production, low-input processing, resilience, market access, investment and the potential for cassava as a strategic commodity is needed at local, provincial and departmental levels within countries. While some stakeholders may assume that the vast potential of cassava is widely known, it emerged from the surveys conducted during this study that cassava's main role by far , according to local extensionists, producers and NGOs, remains as a source of unprocessed, un-marketed food security. Thus awareness and skills regarding the other potentials for cassava should be raised and explored through capacity building at the levels of implementation of initiatives concerning cassava.

These recommendations and conclusions have their foundations in the surveys conducted by the NSAs in each country, which were aggregated to regional levels. The predominance of these issues in each of the regions, despite their heterogeneity insofar as the status and significance of cassava among the regions, is indicative of the needs experienced in Africa in relation to positioning cassava as a strategic commodity and facilitating the realisation of he potential it represents for stakeholders across all sectors of the yet-to-be-fully-developed African cassava value chain.

Through the SWOT analysis provided above, in accompaniment with the trends, policy frameworks, stakeholders and networks identified throughout the report, important conclusions and recommendations can be drawn from the present enquiry into cassava as a strategic commodity in Africa.

Concluding Remarks

It is striking that the recurring themes regarding the strengths and opportunities of cassava in Africa relate to its seemingly unlimited potential some respondents even refer to it as a ”miracle crop” yet its limitations (weaknesses and threats) most often refer to the fact that this same potential is not being realized. The tremendous promise of cassava as a strategic commodity for all of the regions studied relies on the coordinated actions and investments of all levels of stakeholders, and this is presently a significant stumbling point for the development of the subsector and value chain in each region. Indications from the surveys conducted in the study insofar as the increasing interest among donors, Governments, and research institutions concerning cassava's strategic role as a commodity that can generate income by activities far beyond those generated by production and primary processing (marketing of inputs, technology development, bio-fuels etc. are very positive. However, this is not yet being translated into a tangible reality for the producers and marketers who remain blocked at the market-entry point in all regions.

Despite the high heterogeneity among the regions (even *within* regions) vis-à-vis the significance and status of cassava as a commodity, the challenges with a few definite outliers for specific regions (see Section 6) remain remarkably similar. Access to funds and credit, access to technology, expertise and improved planting material, market access, processing capacities and the coordination of initiatives for the maximization of impact are challenges faced by stakeholders in each region. This is indicative of an inherent shortcoming in the approach to developing cassava's subsectors or value chains, as the gap remains vast between the visions of producers and donors/Governments for this commodity.

The incongruence of the visions of cassava's potential is highly related to the core objective of this study: identifying networks that foster information sharing and collaboration among stakeholders at all levels in the development of a *bona fide* cassava value chain. While strides have certainly been made to collaborate within groups of stakeholders (i.e., researchers developing more resilient crops, or donors providing extensive fora to stimulate innovation) networks that bring *all* stakeholders to the fore to develop collaborative strategies for this important value chain are not yet in place.

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Adopted villages and outreach schools as vehicles for increased adoption of technologies, youth employment and rural empowerment in Nigeria

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Abstract

The recent challenges to the Agricultural Research Council of Nigeria to show in practical terms the direct benefits of the research findings and trainings to farmers in Nigeria gave rise to the concept of Adopted Villages and Outreach Schools. The objectives of this project is to create ways for the Research Institutes to impact positively on the lives of the members of the communities surrounding the Institutes by encouraging large scale adoption of improved technologies, economic empowerment of resource-poor farmers, creating job opportunities for youths and ensuring food security. The approach entailed selecting two villages and two schools within 20 kilometers where the institute demonstrated to the villagers and school children current recommended packages on her technologies. These demonstration farms also served as a training ground for the villages and schools.

Community analysis on the socio-economic status of the communities was carried out. Two villages and two secondary schools were selected in Abia State of Nigeria where NRCRI is situated. The Institute adopted the team approach as the operational model for the implementation of the project. Discussions were held with the community members for participation. Farmers groups were formed and Agricultural Schools Outreach Centers (ASOCs) were established in the communities and schools where available technologies were displayed and served as training and meeting venues as well as demonstration centers.

Preliminary results proved successful in dissemination of root & tuber crops technologies. The Adopted Villages and ASOCs provided an effective linkage between research and farmers. The Adopted Villages provided increased adoption and production of institute's mandate commodities, emergence of units of profitable farming enterprises, employment for the youths, improved the economic status of the farmers for better standard of living. Implementation of ASOCs in secondary schools increased interest among the secondary school students in agriculture and home economics. This is expected to increase the percentage of students offering agriculture in tertiary institutions and hence school graduates who go into agriculture as a business.

Keywords: Improved roots & tubers technologies, Adopted villages, Schools Outreaches, Positive impact.

Introduction

Overcoming poverty in the Nigeria is one of the fundamental challenges confronting the Nigerian government. The existence of wide-spread poverty in the country despite the high food production potentials is inconsistent with the principle of sustainable development. In the past, Nigeria was largely self-sufficient in food production. However, the situation has since changed and the food security situation is likely to deteriorate if urgent steps are not taken to put the country on the path of sustained agricultural growth. A major challenge in achieving this is the partial accessibility of the small-holder farmers to improved technologies emanating from the National Agricultural Research Institutes (NARIs). In addition, there is lack of effective linkage between extension, research and farmers. In the past, it was thought that the only way in which the scientists could be aware of the social and economic environments of the farmers was to work closely with extension agents who would communicate the farmers problems to them. In recent times, however, it has become obvious that due to poor funding by State Governments, the extension agents of the Agricultural Development Projects (ADPs) have not been as close to the farmers as expected.

To address these challenges and facilitate the dissemination of improved agricultural technologies, in 1996 under the World Bank assisted programme the National Agricultural Research Project (NARP), the Adopted Village Concept was introduced to the National Agricultural Research Institutes (NARP/NRCRI 1998). The concept was introduced for developing and evaluating technologies emanating from the NARIs. The villages were to help in the early evaluation and dissemination of the technologies. The Institutes were to conduct their On Farm Adaptive Research (OFAR) in the identified adopted villages. Each institute was to identify two communities in their mandate areas and select farmers who were willing to put these technologies on their fields. The villagers were to serve as showrooms for convincing intending farmers and end users on the viability of the technologies being promoted. Most research institutes identified the villages during the NARP era but subsequently after NARP when the funds dwindled they were unable to carry out activities in these villages. Due to funding problems, however, the adopted village concept was not implemented.

Renewed Vigor in the Implementation of the Adopted Village Concept

The Agricultural Research Council of Nigeria (ARCN) recently became interested that these adopted villages be revived (ARCN, 2009). ARCN will like the NARIs to view the villages not merely as field laboratories but also as impact villages. The Council is aware that the gains from research are not immediately-self evident. ARCN is also aware that without clear and persuasive demonstration of research benefits, the NARIs are unlikely to attract sustained funding they require to be successful. The Council therefore expects that even if the impact of research is not felt elsewhere in easily quantifiable terms, it must be felt in quantifiable terms in these communities. Because the gains from research are not self-evident, research will not receive appropriate levels of support or guidance unless they are discovered and disseminated. The Council expects the villages to be showrooms for convincing government and donors that investment in research and extension is worthwhile.

Guideline for Reviving the Adopted Village Concept

- NARI to select two nearby communities in which agricultural activities of its research mandate predominate.
- The extension staff in the institute and the scientists would be expected to hold discussion with the community members and their representatives with the purpose of sensitizing them and ensuring their participation in Adopted Village Concept.
- The Research Institute would carry out a

baseline survey on the socio-economic status of the community, which would serve as a yard stick for future impact assessment.

- A rapid appraisal of the community problems would be undertaken.
- As a result of this appraisal, a village committee would be established comprising a cross section of the community where the analysis of the appraisal of the problems would be discussed thoroughly. The intention was to get the full participation of villagers in identifying their problems and proffering solutions to them.
- Using participatory approaches, the researchers and the extension team would then design appropriate procedures for the transfer of the technology and its evaluation.
- Procedure for conducting various activities in the villages should be discussed with the village committee, goals and objectives set and decision made on the means for achieving the objectives and goals set.
- Within the framework of the decided goals, a more specific programme of action would then be planned. Decisions on organizational structure, designation of responsibilities, training, timing and planning of specific activities would be undertaken at this stage; still with the active involvement of the villagers.
- At the end of the year, the results achieved would then be discussed with the village committee.
- The results obtained should be evaluated and recommendations which can be demonstrated in the village developed.
- Finally, the impact of the new technology on the productivity and income of the farming community in the village would then be demonstrated.
- The NARI is also expected to establish outreach centres.

Objectives of Adopted Villages

- To encourage large scale adoption of improved technologies
- For economic empowerment of resource poor farmers
- To create job opportunities for youths
- To enhance and ensure food security

Methodology

Criteria for selecting Adopted Villages

- The village should not be further than 20km from the Institute (NRCRI) or its Out Stations.
- The community members are into production of the mandate commodities of NRCRI.\
- Community members are willing to work with the Institute.
- Community members are willing to work in groups
- Community members are to provide facility (Space or Building) to be used as outreach centres.

The Main Features of the Adopted Villages

The essential features expected in an adopted village are:

- Participatory technology generation and dissemination;
- Empowerment of the communities through initial provision of some facilities;
- Capacity building of the communities through training.
- Empowerment of farmers to identify their problem and search for solutions;
- Facilitation of community activities
- Grass-root extension in the communities to be carried out by the NARI.
- Institutional linkages and partnership;
- Operation of an agricultural research outreach centre;
- Promotion of the farmers to farmer information exchange;
- Participatory monitoring and evaluation
- Promotion of value addition in the communities;
- Cost-sharing between the communities and the institute;
- Keeping up-to-date records of all activities by both groups and institutes;
- Economic impact.

The establishment and operation of an agricultural research outreach centre should be a feature of each adopted village.

Activities

Farmers Groups Formation and Empowerment

NRCRI operated in the adopted villages with four farmers groups according to commodities (technologies) of choice. The groups were helped by the institute to nurture their associations to maturity following established principles. These people ensured that all facilities provided in the centers are preserved.

The groups were guided by the cooperative

principles, namely:
- Voluntary membership
- Distribution of surplus according to patronage.
- Religious and political neutrality.
- Sound business practices.
- At least minimal level of education.

Establishment of Agricultural Research Outreach Centers (AROCs)

In addition to the Villages/Communities, NRCRI established an AROC in each of the identified adopted villages around the Institute The centers were sited within the community in accessible location to the farmers.
- An AROC serves as a resource centre where all available relevant information on agriculture and other aspects of community livelihood are displayed.
- An AROC serves the purpose of farm service centre where NRCRI displays available technologies and renders services to the communities.
- An outreach centre also serves as a training venue where NRCRI conducts training for the farmers.
- It serves as a meeting venue for the farmers groups.
- It serves as a demonstration centre as well.
- It also serves as a centre where NRCRI receives feedback on technologies being promoted.
- These communities are Amawom Oboro in Ikwuano LGA and Ubahu Oriendu in Umuahia North LGA of Abia State, Nigeria.

Community Analyses were carried out (Tarawali et al. 2007a, 2007b)
- To obtain a baseline data on the two communities selected for the adopted village project
- To identify prominent farm constraints requiring institute's intervention
- To identify existing local resources, indigenous knowledge etc that will complement institute's efforts in enhancing the livelihoods of the community members

With the baseline information on the two communities in place, the Institute was better equipped with informed knowledge to bring to the communities necessary interventions that will satisfy their felt needs and enhance their livelihoods as well.

Before this, visits to Royal Fathers, sites selection, land preparation were done between 25th March-29th April, 2009. One hectare of farm land was acquired at each location. All the activities where participatory in approach

Four crop-based technologies were demonstrated as follows:
- Cassava / Maize / Melon inter crop.
- Yam minisett /Maize inter crop.
- Improved sweet potato varieties.
- Improved Cocoyam technologies.

For the Schools Outreaches, the following secondary schools were choosen:
- Ibeku High School, Umuahia, Abia State.
- Santa Cruz Sec. Schl. Olokoro, Abia State.

The main aim was to:
- Arouse the interest of young people in agriculture and home economics.
- Increase the number of students registering agric science and home economics at West African Examination Council.
- Increase adoption of improved technologies in the students' farms & households.
- Increase the percentage of school graduates who go into agriculture as business.

The farm size provided by each of the schools was 0.5 ha. Land preparation operations were carried out. Improved production of cassava/ maize/melon, yam minisett/maize, cocoyam and improved sweet potato varieties were participatorily carried out with students including NPK 15:15:15 fertilizer application.

Establishment of Agricultural Research Outreach Centres (AROCs) in the Secondary Schools

Apart from establishing adopted villages in which there were agricultural research outreach centers, NRCRI also identified two secondary schools around it for the purpose of establishing AROCs. The main purpose of this is to ensure that impact of agricultural research and training is felt in these schools.

NRCRI ensures the followings in each of these schools:
- A resource centre with up-to-date information on various aspects of agriculture;
- Provision of agricultural bulletins, guides, text books and other information materials at the AROCs.
- Empower the schools with relevant technologies and facilities;\
- Promote modern agricultural technologies in the schools' farms;

- Promote value addition in the school agriculture;
- Training and retraining of Agricultural Science/Home Economics teachers;
- Attachment programme for agricultural science teachers;
- Practice training and demonstration for the students;
- Formation of the students into Young Farmers Clubs;
- Organize excursion for the students.

The schools are not more than 20km drive from the Institute. Agricultural Science is taught in these schools.

In 2010, The Raw Materials Research & Development Council of Nigeria (RMRDC), Abuja came in the area of Capacity Building on Adoption of Improved Processing Equipment/ Cassava Cluster development in NRCRI Adopted Villages and Outreach Schools. The farmers, processors and participating Students were exposed to different cassava processing equipment in Ubaha oriendu Adopted Village.

Conclusion and recommendation

The technologies were successfully promoted and disseminated using schools outreach programme (SOP) which were participatory in nature (NRCRI, 2009). The students and teachers gave maximum co-operation.

NRCRI is going to work closely with major stakeholders in the locality to further consolidate the gains of this project. These stakeholders include but not exclusively State Ministry of Agriculture; State Agricultural Development Project, Local Government Council; Traditional rulers; Credit institutions; Input dealers; NGOs and CBOs and Major industries.

This school outreach projects should be extended to other States of Nigeria in view of the interest shown.

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Livelihood enhancement from cassava enterprise: building experience from Benin Republic

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Background

The impact of cassava value chain development has not just been to expand utilization of the crop but also to improve livelihood of the key players especially in the rural sector.

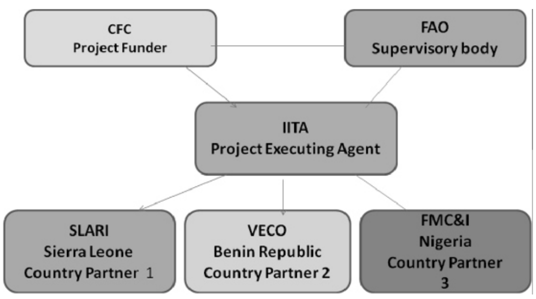
This duo benefit is usually achieved through enhanced productivity and capacities of the key players involved. The Common Fund for Commodities (CFC) project focused on this people-oriented approach to improve livelihoods of rural farmers and processors in three selected countries in the West Africa. This is by agreeing to fund the three year intervention project, **Cassava Value Chain Development in West Africa** with the aim of creating enabling environment for key players in the rural sectors, thus increasing their productivity and enhancing their livelihoods

Objective

The overall objective of t he project on Common Fund for Commodities is the development of new market opportunities and supply lines for cassava farmers and small and medium scale processors in West Africa.

This paper therefore focuses on the experience from Benin Republic.

Project Organogram



Strategies to achieve the objectives

The set objectives were to be e achieved by Supporting Processing and Value Addition by Small and Medium Enterprises through

(1) Development of Supply lines for High Quality Cassava Flour (HQCF) for Bakery and Confectionery Markets

(2) Upgrading Traditional Processing Practices to Make Products for defined markets

(3) Project co-ordination, monitoring and evaluation, exchange and dissemination of results

Expected Results

It is expected that at the end of the project,

- Increased productivity of farmers and Processors
- Available processing facilities
- Traditional processed foods improved and promoted
- Value addition to cassava
- Higher revenues for Processors and Farmers
- Better working conditions for the labour force
- involved, especially women
- Enhanced Farmers' access to the new high yielding
- IITA varieties.
- End users' access to affordable good quality products.
- Results and experiences exchanged and shared

Selected locations within the country

IITA developed selection criteria, in line with CFC requirement from beneficiaries. These include citing project locations with most efficient drying technology, consistent raw material supply and supply chain. The country coordinator was asked to go round the selected region within the country and identify potential beneficiaries. The IITA team then followed up with visits to screen and validate the locations and the beneficiaries, and assess processing activities and identify areas of intervention. The final recommendations were based on willingness to partner with the project, to use processing center for enterprise development and as a pilot plant. The identification and selection process was conducted in collaboration with the Country Coordinators and their partners and where necessary, scoring and SWOT analyses were used to finally select the beneficiaries. After the selection of the beneficiaries, agreement was signed between the community and VECO who is the project partner for the country. A copy of the agreement was sent to IITA, the project executing agent

Initially two locations for micro processing centers were selected but following the monitoring visit of FAO, additional two were requested to be added so altogether, the project has four micro processing centers in the country.

The selected locations

1. Houmvi in Dija local government area
2. Amakpa in Djija Local Government
3. Adjahomme in Kpodiro
4. Lanta in Kpodiro Local Government Area

All of the selected beneficiaries are in groups and into micro processing of gari and Lafou, cassava flour, tapioca and Kimpouka. The source their raw material from either own farm, purchase from neighboring farms or both.

Needs assessment and areas of intervention at project sites

At the processing centre of each selected beneficiaries, IITA project team with the country coordinator thoroughly evaluated the centres to identify processors' needs with respect to processing centres and their lay-out, equipment and processing facilities, processing activities, hygiene practices, product quality control and standards, product marketing. From this assessment, a good well laid out processing center was found lacking in all the locations. appropriate equipment was also found missing in the locations followed by the need for training of the processors on hygienic processing, waste management and energy conservation. This obviously had implication on civil works. Also, the issue of product quality control and standard was general to all the locations. Equipment and processing facility problem was found to be more pronounced in all the locations coupled with storage facilities for finished products.

The Project Intervention

The project provided integrated intervention, covering the entire value chain; production, processing, marketing and capacity development and involved experts in these fields, the detail of intervention is highlighted below;

Production

Establishment of demonstration plots: Agricultural technologies targeted at rural farmers must be properly packaged to ensure adoption. Demonstration plots of new technologies and practices in cassava production were established in two of the communities (Hounvi N07^{0}19.07'; E0010.56.88' and Amakpa N07^{0}28.12'; E001^0.47.923') to help farmers compare new and old practices in terms of yield and cost per unit area. IITA deployed and planted, in the two demonstration plots 17 improved high yielding cassava varieties previously reported to be adapted to the savanna belt in Benin. Thirteen of these were introduced from Nigeria; three were obtained from our national partner, l'Institut National de Recherche Agronomique du Benin (INRAB) and one was provided by farmers as their improved check. The varieties introduced from Nigeria included TMS 95/0211, TMS 95/0289, TMS 98/0505, TMS 96/1632, TMS 92/0057, TMS 91/02324, TMS 92B/00061, TMS 98/0581, TMS 92B/00068, TMS 4(2) 1425, TMS 98/0510, TMS 92/0326, and TME 419. The three varieties from INRAB were 91/02327, 92/0057 and 92B/00068 while the farmers' check was RB89/0509, an improved variety widely popularized in Benin. The use of pre-emergence and post emergence herbicides, smooth stake cut, density (12500/hectare), stake length (20 - 25 cm), stake orientation (inclined) and others were demonstrated with active farmers' participation.

In establishing these demonstration plots farmers and beneficiaries were allowed to play dominant and ownership roles. They took responsibility for land clearing, tillage, ridging and planting while the project simply provided technical support and quality planting materials.

Cassava varietal selection: Following the introduction of 17 improved cassava varieties from IITA to Hounvi and Amakpa in 2008 and the selection of 12 of these varieties by farmers during the first evaluation in 2009, further evaluation in collaboration with farmers was done in 2010 to select and recommend varieties to farmers in these target sites. Selection emphasized major commercial traits like yield and quality without compromising environmental and safety traits like multiple pest resistance and cyanogenic potential. All the improved varieties produced significantly higher yields than the local check and farmers did not reach a consensus on which varieties should be dropped. They were however able to rank the varieties relative to each other, thus providing a rank sum estimate that was used to select the farmers' best. The following six varieties (TMS 98/0505, 92/0057, 96/1632, 92B/00068, 98/0581 and TME419) were the most preferred by farmers in the two communities.

Distribution and multiplication of improved planting materials: Farmers at Hounvi and Amakpa who participated actively during the establishment of demonstration plots were encouraged and technically supported to plant their own farms following the same practices under demonstration. VECO sourced 60,000 stems of RB89/0509 locally and distributed to 61 farmers, 30% of which were women, in the two communities. As at the end of July 2008 15 ha of new cassava field at Hounvi and 14.4 ha in Amakpa had been planted by farmers. Fresh roots harvested from these fields will contribute towards ensuring regular supply of raw materials to the processing centres in all the communities while stems from the fields will be distributed to more farmers in the next cropping season. This is a sustainable action put in place for the project so that after the project ends, access to raw material for uninterrupted processing can continue.

Since after this activity, the processors affirmatively said cassava root is no longer a problem since CFC had given them IITA improved varieties to plant; they even have enough now to sell fresh to other processors in the neighborhoods

Processing

Construction of processing centres: Good processing centers were built in each of the locations to enable processors maximize production of cassava products; Gari, starch, lafun and other traditional cassava products. The civil work was supervised by the IITA expert while local hands were used in the construction. The group beneficiaries, as counter part contribution, provided water, labor and food for the laborers during the construction

A new processing center

An old processing centre

Equipment fabrication and Installation: Another major intervention in the project was the fabrication of equipment. Prior to this project, processing methods and approaches were rudiment with high drudgery, which limits productivity. The women had no access to grater; a commercial mobile grater was being used for serve all the processors. This slowed down processing according to the processors. In intervention, two stainless steel gari roasters, a starch settling tank, a grating machine and press were fabricated and installed in each site, using a locally identified, trained fabricator and supervised by IITA Engineer. The floors of the processing centers were also upgraded by laying tiles and further improving the water drainage system.

Of particular interest was the improved gari roaster with in-built chimney, which takes care of the processors' exposure to fire and flame with health hazards.

Old gari roasting method

Grater use

Frying Gari on the stainless steel top

Storage facility: One major expressed need of the processors was storage facility of their finished products. The project provided a store with wooden pallets to stack their finished products prior marketing and distribution. From one of the monitoring visits to one of the sites in Houmvi, the store was found being used as a depot for all other villages around it,

A processor from another village delivering Lafou

Measuring Lafou

Product diversification: Two of the centres; Houmvi and Amaakpa are not just producing gari but other traditional products like lafou, starch, Tapioca, etc. the other two were encouraged to do this as well. In one of the processing centers, Houmvi, a new Congolese cassava-based product called Kimpouka was introduced to the processors through the country coordinator who met a Congolese in Cotonou. The Congolese was linked with the processors and trained them on the processing of Kimpouka for supply to the Congolese community in Benin. The women processors were not just making money from the supply, they also introduced it to their households and consumption of kimpouka became an issue in the community and its neighbors while they also engaged processors from other communities to join in meeting the Congolese demand of the product, which was about 250kg weekly. Kimpouka is a fermented cassava cake, which is made into dough at home and consumed with choice soup.

Construction of a pilot hybrid solar house: Appropriate drying technology was one of the major challenges of the micro processors across the country. The CFC project also attempted intervention in this area. The project designed a pilot hybrid solar house which uses sun to hygienically dry products in the day and finish up drying if need be at night with firewood. The design consisted of a drying building roofed with white plastics while the inside consists of raised platforms. The heating chamber was made of hollow drum inserted from outside of the building. Local mason and fabricators in Bohicon were hired for the fabrication and were supervised by the PEA. The processors now have the opportunity of using direct solar energy to dry cassava products during the day. The dryer would be replicated in other sites after ensuring its functionality, suitability and acceptability by the processors. The test running of the dryer is ongoing.

Drying house with plastic roof and heating source

Drying house with plastic roof and heating source

Drying testing by women

Capacity development: Series of training were conducted for the farmers and processors beneficiaries of the project

Farmers' training of trainers : Two extension agents and over twenty-five farmers from Hounvi, Amakpa and six neighboring communities were trained on best practices for increasing cassava root yields competitively. They are expected to train other farmers for a wider impact. The training focused on stem handling, density management in sole and intercropping systems, varietal characterization and identification, sustainable land use practices and business opportunities in agriculture.

Another training was organized following distribution of stems to farmers. Here, the (CEIRAD and CIRAPIP) NGOs, partners of VECO took part in this training. The training emphasised on preparation of plots, pre-germination of cuttings, the size of cuttings, planting techniques, suitable period for planting with respect to gauges, plots maintenance etc.

It is planned that this training be replicated to other recipients of the project by farmers already trained with the assistance of NGOs staff.

Operators training: At the processing centers, operators of the equipment were specially trained on equipment handling, safety and maintenance by the CFC project engineer at IITA. The trainer developed a training manual for this purpose and key steps in equipment maintenance were pasted on the factory walls for their regular use.

Processors' Training: Training of trainers approach was also explored here; processors in Houmvi were trained and they are being used to train processors in the other project locations and also other locations on good processing practices.

The project intend to also further up training on product quality control/assurance coupled with development and maintenance of product standard

Business plan development training: In preparation for the drafting of a business planning for the two units, a training was organised to familiarise the beneficiaries, coordinators and NGO partners (CEIRAD and CIRAPIP) with business plan, development of business plan, advantages and disadvantages of business plan. The training was conducted by an IITA Agro-specialist. It was an occasion for some hands-on activities oriented towards cassava by-products such as "lafu, gari and bread flour". On the last day of the training, there was a validation of the costs inherent to the different processing operations by the representatives of the producers of Hounvi and Amakpa. A tutorial compiled by the trainer was translated into French and given out to the trainees.

Other areas of intervention

Marketing: The country coordinator was given the mandate to identify market outlets for the processors and link up appropriately. They were to assist in mopping up products and avoid product glut as much as possible. One of the major output of this was the introduction to kimpouka, which had been earlier mentioned.

Business plan development: Development and implementation of business plan was found necessary for all the CFC sites in this project. The plan provides an opportunity to determine the viability of these centers and provide sustainability plan afterward. It projects future opportunities for the centers, identifies markets and potential customers and maps out the marketing, operational and organization and management strategies. At the end, the expenditure and finances required for each centers were projected in a cash flow analysis, which gave room for the projected revenue and cost over one year period to be synthesized.

So far, business plans for Houmvi and

Amakpa had been completed, translated into local language and ready for use while the other two additional locations are yet to be developed.

The findings and implications are to be communicated to the beneficiaries followed by enterprise management training so that the processors can continue with or without the project in future.

Monitoring

One of the major components of the CFC project is monitoring of the sites and the beneficiaries to ensure continuous use of the facilities and improvement on their livelihood. To ensure this, there is quarterly monitoring visit to all the sites to check their activities, processing and sales records, facility use, etc. The visit is coupled with regular on-line and telecommunication to promptly attend to issues as they arise.

On the other hands, the project has Food and Agriculture Organization (FAO) as the official supervisory body of the project. So far, FAO representatives had visited the project sites twice, made recommendation, which most of them had been implemented in the project. Also, the coordinator of the CFC-East and Central Africa had visited the sites as well and made his inputs.

Also, the project progress report is regularly sent to CFC to monitor the project activities.

Project sustainability approach so far

- Stem distribution to ensure continuous access to raw material.
- Business plan on ground to continually guard beneficiaries in their business
- Site commissioning for awareness and future policy support
- Collaboration with other local NGOs
- Involvement of local fabricators for future use and maintenance of equipment

Impacts of the Project on the MPCs so far

The CFC project in Benin especially Houmvi had obviously attracted attention in term of aids/supports to the community.

Beneficiaries' extended income source

The group built a piggery house from proceed of their cassava business. The beneficiaries said it was their counterpart contribution towards a development project on piggery brought to them by an organization, Eleveurs Sans Frontière. who gave them some pigs to rear. According to them, they used dried cassava peel as feed for the pigs, which they intend to be selling later to earn more money and improve their livelihoods.

Enough roots to process and sell

The processors affirmatively said cassava root is no longer a problem since CFC had given them IITA improved varieties to plant.

Impacts of the Project on the beneficiaries' livelihood in Houmvi and Amakpa so far

When the beneficiaries were asked of what the project has done for them so far, they affirmatively said the profit from their cassava processing had been able to improve them economically; they claimed to eat well now, take care of their health needs, clothing and also able to pay their children's school fees within the one year of setting up the centre.

The following responses were specifically mentioned;

- Assets acquisition
  - Mobile phones
  - Motor cycle
- Improvement in meeting household needs
- Improved household food security
- Improved health status
- Ability to pay children's school fees.
  Other needs like clothing are also being met

Key Achievements

- Appropriate pilot hybrid solar dryer fabricated in Benin republic for Beneficiaries' use
- Successful harvesting of year 2 cassava multiplication and selection of six best suitable varieties by farmers in Benin
- Business plans developed for all the existing sites in all the countries
- Beneficiaries in one of the sites in Benin use proceeds from processing center to advance livelihoods
- CFC processing centers now attract developmental aids.
- Capacities of CFC project beneficiaries enhanced through trainings at all levels

Constraints/challenges so far

- Hounvi farmers' diversion of cassava roots to processors outside the communities for higher profit.
- IITA having to spend more time to supervise the Country Coordinators and project beneficiaries to ensure effective utilization of allocated resources and final project

deliveries.

- Slow working pace of country coordinators in implementing the project. The PEA had difficulties with the countries' timely delivery of expected outputs. This is probably due to other competing assignments from their superiors.

Conclusion

The development of commodity value chain in Africa especially the developing world could be a sustainable approach to poverty alleviation so let's adopt it.

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- VECO-CFC team for project implementation
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Policy options for Promoting Off-Farm Market Participation Mitigated by Transaction Costs among Smallholder Cassava Producers in South Eastern, Nigeria

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Abstract

The study employed the heckit (Heckman selectivity) models to estimate the level of off-farm market (selling in the market) participation for cassava producers in South-Eastern Nigeria. A multi-stage randomized sampling procedure was used to collect cross sectional data to identify factors of level of sales among 360 cassava producing households. To reflect the existence of proportional transaction costs (PTCs), these constructs were included in the model for level of participation, thereby testing the hypothesis of influence of PTCs. The coefficients for personal means of transport, marketing experience and road conditions to the nearest town were positive and significantly related to level of off-farm sales at 10%, 5% and 1% level of probability respectively. The coefficients for distance from the farm to the market, distance from the house to the farm and crop transportation costs were negative and significantly related to the level of off-farm sales at 5% level of probability. The coefficient for distance to the nearest town was negative at 10% level of probability. The study raises issues which, when attended to, might reduce these proportional transaction costs, particularly by providing market outlets and bulking centers for farming households. Institutional policies aimed at better feeder road networks to mitigate transaction costs thereby increasing volume of sales.

Keywords: Market participation, Transaction costs and Cassava Producers

Introduction

Cassava is a staple food crop in South-Eastern Nigeria and it contributes about 15% of the daily dietary energy intake of most Nigerians and supplies about 70% of the total calories intake of about 60 million people in Nigeria (Ezulike *et al*., 2006). Nigeria is the world's largest producer of cassava, with about 47,274,320mt and yield of 13.027tonne/ha. The South-East zone is leading in cassava production accounting for over 37% of the National production (NAERLS and NFRA, 2009). The fact that fresh cassava is both perishable as well as very voluminous determines the behaviour of each of the groups/participants in the cassava market. Local processing and transport are key services that need to be performed efficiently. These are the key issues in the whole cassava value chain process from the production of fresh roots until the use of a cassava ingredient by the final consumer (Knipsheer *et al*., 2007).

Promoting market-orientation among agricultural producers, more so the smallholder farmers, in developing countries is pivotal for development of effective agribusiness value chains that could supply adequate food. This will involve improving the production and marketing processes as well as capacity for income generation among resource-poor farmers (Otieno *et al.,* 2009). One variable that can be used to access the trend in Cassava commercialization at the rural farm level is the proportion of cassava output that farmers sell after harvest from their fields. Cassava roots can either be sold (in roots or processed form) or consumed at home in the South-South and South-Eastern Nigeria (Ezedinmma *et al*., 2007). The proportion sold suggests a higher degree of commercialization of the commodity.

In developing countries, smallholder farmers find it difficult to participate in markets because of a range of constraints and barriers reducing the incentives for participation, which may be reflected in hidden costs that make access to markets and productive assets difficult (Makhura *et al*., 2001). Transaction costs, that is, observable and non-observable costs associated with exchange, are the embodiment of access barriers to market participation by resource poor smallholders (Coase, 1960; Delgado *et al*., 1999; Holloway *et al*, 2000 and Makhura, *et al*., 2001). Households commonly incur fixed costs in making the decision to trade in a market. Such costs are known to exist irrespective of transactions volume and surely affect the decision about how much quantity to supply to the market noted by (Cogan, 1981) in a neo-classical model of labour supply. Yet the standard estimation of market supply equations fails to account for these fixed costs (Holloway *et al*., 2005).

There are quite a few papers that touch on market participation issues with respect to higher value cash crops, livestock or animal products, such as fruits and vegetables in Kenya (Dolan and Humphrey 2000; Kherrelah 2000; Humphrey *et al*. 2004 and Minot and Ngigi 2004), coffee in Uganda (Fafchamps and Hill 2005), livestock in Ethiopia and Kenya (McPeak 2004, Barrett *et al*. 2006, Bellemare and Barrett 2006), milk in Ethiopia (Holloway *et al*., 2000, 2005), cotton in Mozambique, Tanzania, Uganda, Zambia and Zimbabwe (Poulton *et al*., 2004), and cotton and tobacco in Mozambique (Boughton *et al*., 2006). Market participation for cassava in Benin (Takeshima, 2009)

The literature on market participation has been thin, especially in developing country settings where significant frictions make this question most salient (Bellemare and Barrett, 2006). Improving our understanding of the many complexities impeding the transition from subsistence to market oriented production is important to understanding the path of agricultural development and economic growth. The objective of the paper is to identify policy options for promoting market participation among smallholder cassava producers in south-eastern, Nigeria.

Methodology

(a) The theoretical model: The study employs selectivity models to identify factors of market participation. It was conjectured that the variable transaction costs factors will influence the level of participation. These models were estimated using the second stage of selectivity (Heckman) model and involves inclusion of a variable to absorb selectivity bias (Makhura *et al*., 2001). The aim of the study was to look at factors that increase the level of participation in the market. Ideally, the OLS model is applicable when all households participate in the market. In reality not all households participate. Some households may not prefer to participate in a particular market in favour of another, while others may be excluded by market conditions. If the OLS regression is estimated excluding the non-participants from the analysis, a sample selectivity bias is introduced into a model. Such a problem is overcome by following a two-stage procedure as suggested by Heckman (1979) or Tobit procedures.

$$\text{Prob}\,(D = 1|Z) = \phi\,(Z\,\gamma) \qquad (1)$$

Where *D* indicates market participation (*D* = 1 if the respondent participates and *D* = 0 otherwise), *Z* is a vector of explanatory variables, γ is a vector of unknown parameters, and ϕ is the cumulative distribution function of the standard normal distribution. Estimation of the model yields results that can be used to predict this probability for each individual. In the second stage, the researcher corrects for self-selection by incorporating a transformation of these predicted individual probabilities as an additional explanatory variable. The level of market participation equation may be specified,

$$w^* = X\beta + u \qquad (2)$$

Where w* denotes an underlying level of participation (Cassava sales in naira), which is not observed if the respondent does not participate. The conditional expectation of level of participation given the person participates is then

$$E[w|X, D = 1] = X\beta + E[u|X, D = 1] \qquad (3)$$

Under the assumption that the error terms are jointly normal, we have

$$E[w|X, D = 1] = X\beta + \rho\sigma_u\lambda(Z\gamma) \qquad (4)$$

where ρ (rho) is the correlation between unobserved determinants of propensity to participate E and unobserved determinants of level of participation u, σ_u is the standard deviation of u, and λ is the inverse Mills ratio evaluated at $Z\gamma$. The level of participation equation can be estimated by replacing γ with Probit estimates from the first stage, constructing the ë term, and including it as an additional explanatory variable in linear regression estimation of the level of participation equation. Since $\sigma_u > 0$, the coefficient on λ can only be zero if $\rho = 0$, so testing the null that the coefficient on λ is zero is equivalent to testing for sample selectivity. Some people who use sample selection models do not even mention rho, others try to interpret it.

The components of equations (1) and (4) consist of two terms making total effects of the whole sample. The first component is the direct effect of the explanatory variables of those households participating in the market. The second component is the effect of the inverse mills ratio based on all the observation. Basically, they are the difference between direct and total effects. The total effects are technically equivalent to the tobit procedure with iterations constrained to one. The two-stage selectivity procedure tends to provide more relevant information for this study. In the light of the theoretical framework used in this study (to elicit the fixed and variable transaction costs) the tobit procedure seems to conceal some information. In fact, the procedure tends to combine the effects of both fixed and variable transaction costs, which is not the intent of this study.

(b) The empirical model: The level of participation equation for cassava sellers is specified thus;

$$Y_i = b_0 + b_1X_1 + b_2X_2 + b_3X_3 + b_4X_4 + b_5X_5 + b_6X_6 + b_7X_7 + b_8X_8 + b_9X_9 + b_{10}X_{10} + b_{11}X_{11} + b_{12}X_{12} + b_{13}X_{13} + b_{14}X_{14} + u \qquad (5)$$

Where;

Y= Value of cassava sold in naira, X_1 is personal means of transportation (dummy variable; 1=yes, 0=no), X_2 is distance to nearest town (km), X_3 is distance from the farm to the market (km), X_4 is distance from the house to the market (km), X_5 is distance from the house to the farm (km), X_6 is amount of credit borrowed in Naira, X_7 is crop transportation costs (Naira/tonne), X_8 is household size, X_9 is dependency ratio (the number of dependents below 18 and above 60 per household of working age), X_{10} is road conditions to nearest town (dummy variable; 1=good, 0=bad), X_{11} is marketing experience (in years), X_{12} is farm income in naira, X_{13} is non farm income in Naira, X_{14} is Cassava yield (kg/ha), b_1 b_{14} are coefficients to be estimated and u_i is error term. Table 1 shows the hypothesized relationship between the explanatory variables and market participation.

Table 1. Some Variables included in estimation and expected signs

Proportional Transactions Cost Related	Level of Sales
% that have personal means of transport	+
Distance from the farm to market	-
Distance to the nearest town (km)	-
Distance from the house to the market	-
Distance from the house to the farm	-
Volume of Credit (N)	+
Crop transportation costs (kg)	-
Household Size	-
Dependency ratio	-
Cassava Marketing experience in Years	+
Farm income (N)	±
% of Road conditions to the nearest town good	+
Yield (kg/ha)	+
Non-farm Income (N)	±

(c) The data: The South East Agro Ecological Zone of Nigeria was our main focus. The Zone lies between latitude 6° and 9°E and 4° and 7°N longitude, has a total land mass of 10,952,400ha. The zone is made up of five states viz: Abia, Anambra, Ebonyi, Enugu and Imo States. About 60-70% of the inhabitants engaged in agriculture, mainly crop farming and animal rearing. Three out of the 5 states in the South-East agricultural zone were randomly selected for the study. They were Anambra, Abia and Enugu States. A multi-stage randomised sampling procedure was used to collect cross sectional data to identify factors of market participation among cassava producing households. At the second stage two agricultural zones per state were randomly selected given a total of six agricultural zones. In the third stage, two LGAs were randomly selected from each zone given a sample of 12 LGAs. In the fourth stage, three communities were selected randomly from each Local Government Area given a sample of 36 communities. In the last stage 10 household producers were randomly selected, given a total of 360. Data were collected by means of structured questionnaire to collect a range of information, which entailed information about households regarding transport equipment, proximity to the nearest town where the markets are and the conditions of the roads to the markets etc.

Results and Discussion

Level of cassava sales

The second stage of the selectivity model (heckit or OLS accounting for bias) was estimated to determine factors influencing the level of cassava sales. Table 2 presents the results of the determinants regarding the level of cassava sales. The ÷2 was highly significant at 1.0% level of probability. The inverse mills ratio (lambda) for the level of cassava sales was significant, implying that a sample selection bias would have resulted if the level of sales in cassava had been estimated without taking into account the decision to participate in the cassava market. Heckman selection model allows us to use information from non-market participants to improve the estimates of the parameters in the regression model. The Heckman selection model provides consistent, asymptotically efficient estimates for all parameters in the model.

Table 2: Factors Influencing the Level of Cassava Sales (Off-farm): Heckit Results

Variable	Direct	Indirect	Total
Personal means of transport	1.2025	1.9741	3.1766
	(1.7142*)	(2.3211**)	(4.0353***)
Distance to the nearest town (km)	-0.1444	-0.3252	0.4696
	(-1.9159*)	(-3.5973***)	(5.5122***)
Distance from the farm to the market (km)	-0.0723	0.0264	-0.0459
	(-2.5905**)	(1.1255)	(-1.4650)
Distance from the house to the market (km)	-0.0029	-0.3051	-0.3081
	(-0.0369)	(-0.3702)	(-0.4071)
Distance from the house to the farm (km)	-0.0766	-0.1593	-0.2359
	(-2.5876**)	(-2.2108**)	(-4.7984***)
Volume of Credit (N)	0.00049	-3.82e-06	0.0005
	(0.5911)	(-0.3978)	(0.1933)
Cost of transportation (N/kg)	-0.0004	-0.0006	-0.0010
	(-2.5858**)	(-2.7104**)	(-5.2962***)
Household Size	-0.0161	-0.2610	-0.2771
	(-0.1962)	(-1.4487)	(-1.6449)
Dependency ratio	-0.1549	-0.0718	-0.2262
	(-0.8508)	(-0.2662)	(-1.1170)
Road conditions to the nearest town	0.5374	0.6409	1.1783
	(2.8579***)	(3.6638***)	(6.5217***)
Marketing experience	0.2637	0.0357	0.2994
	(2.6311**)	(2.7795**)	(5.4106***)
Farm income (N)	0.0002	4.29e-06	0.0002
	(0.0202)	(1.6250)	(1.6452)
Non farm Income (N)	-0.0004	-6.54e-06	0.0004
	(-0.0203)	(-1.7301*)	(1.7504*)
Yield (kg/ha)	0.0020	0.0005	0.0025
	(0.7857)	(-0.7143)	(-1.5000)
Constant	4.0445	1.1590	5.2035
	(9.5728***)	(1.3397)	(10.9125***)
ρ	0.9172		
λ (Mills's ratio)	5.7400 (3.1037***)		
χ^2	0.00001		
σ	6.2582		
Number of Observations	166	261	

*, ** and *** = Significant at 10%, 5% and 1% respectively. Figures in parenthesis are t-values

Heckman estimated ñ (rho) as 0.92, the correlation of the residuals in the two equations and sigma (ó = 6.25), the standard error of the residuals of the on-farm equation. In this case we can reject the null that rho = 0, so indeed we should be using a sample selection model on this data. Six of the thirteen variables had coefficients significantly different from zero in the direct effects, implying that the factors were important in the level of cassava sales. The direct and indirect effects are the outcome and selection equations respectively.

The coefficients for personal means of transportation and road to the nearest town were significant variables positively associated with the level of cassava sales at 10.0% and 1.0% respectively. The results suggest that an increase in personal means of transport by 1.0% will lead to an increase of about 1.20%, 1.97% and 3.17% in cassava sales for those who are already selling, participating as off-farm sellers and for all farmers respectively. A 1.0% increase in road conditions to the nearest town will increase sales by 0.53%, 0.64% for off-farm participation and 1.17% for all households respectively. These results might provide a motivation to increase sales as a result of reduction in variable transaction costs.

The coefficient for the distance to the nearest town was negative and significantly related to level of sales at 10.0% level of probability. The coefficients for distance from the farm to the market, distance from the house to the farm and crop transportation costs were also negative but significant at 5.0%. Further, the decrease of distance from the household to the nearest town by a kilometer causes the value of cassava sold to increase by 0.14%, 0.32% for off-farm participation and 0.46% for all households. As such, the location of farmers in respect of potential markets is an important factor in encouraging farmers to increase their sales (Makhura, 2001). For example, farmers close to urban towns were able to market much of their cassava since they were relatively close to where a range of marketing facilities were available and accessible.

A 1.0% decrease in the distance from the house to the farm will increase off-farm sales by 0.07%, 0.15% for participation and 0.23% for all households. Farmers who travel long distances to their farms may prefer to increase their off-farm sales before going back home to decrease the transaction costs associated with traveling. A 1.0% decrease in crop transportation costs will increase sales by 0.0004%, 0.0006% for participation and 0.01% for all households. Increase in variable transaction costs associated with poor infrastructure (mostly road and information) will lead to increase in crop transportation costs per kilometer.

The coefficient for marketing experience was significant at 5.0% level of probability. This implies that a 1.0% increase in marketing experience for off-farm cassava sellers will lead to a 0.26%, 0.35% and 0.29% increase in level of sales, participation and among all the households. This is expected probably because farmers may bargain for better prices in the market than at the farm gate.

The coefficients for distance from the house to the market, household size, dependency ratio and non-farm income were negative but not significant. The coefficients for volume of credit, farm income and yield were negative but not significantly related to level of cassava sales.

Conclusion

Smallholder cassava is characterized by low levels of market participation. The results support previous studies that existence of transaction costs constrains households from selling. Policies that reduce transaction costs through improved transportation would increase output by both increasing market participation and increasing production for market participants. In addition, improving rural infrastructure (e.g., access roads) would facilitate faster delivery of farm produce (especially perishable commodities such as cassava) to urban consumers.

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Economic damages of cassava brown streak disease in sub-Saharan Africa: a framework

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Abstract
Cassava brown streak disease (CBSD) remains a major threat to the livelihoods of millions of smallholders in sub-Saharan Africa. This viral disease was initially confined to the coastal lowland areas of eastern and southern Africa. More recently there has been a major new outbreak in the Great Lakes region of eastern and central Africa, and two virus species have been shown to cause the disease.

This paper describes a framework that could be used to make a meaningful assessment of economic damages of CBSD. The model is then applied to the current situation of sub-Saharan Africa (SSA) using secondary data collected from various studies on cassava-growing areas of SSA. The virus causing CBSD generates two broad categories of damages: quantitative and qualitative. The variables associated with the quantitative damage include: total abandonment of roots with a severity score of 3 and above, reduction in yield due to disturbances in the physiology of the plant and through early harvesting to escape total crop failure, and by additional labor required to process damaged fresh roots. On the qualitative side, roots affected by the virus experience changes in their chemical content (e.g. lower starch content or provitamin A), which result in lower nutritional or industrial quality of the produce. Such products attract lower prices in the markets compared to healthy products, or are rejected altogether. Farmers can use thrown-away roots as livestock feed or to process into other products such as local alcohol. Such residual gains (if any) must be discounted when assessing the economic damages of CBSD. The main challenge in estimating the economic damage at a continental level remains the lack of data or insufficient data beyond those few from the experimental plots. Another bottleneck from research is to generate adequate information on the relationship between CBSD incidence and production loss. This relationship is all the more complex since CBSD has multiple symptom types, some or all of which may be present.

The application of the above framework resulted in the identification of 6 countries where CBSD is confirmed and 2 countries where the disease is suspected out of the 39 countries that produce cassava in SSA. In the eight countries, about 1.6 million tons of fresh roots are lost annually due to CBSD, amounting to about US$75 million. The true economic losses are certainly much higher, since several of the types of losses highlighted in the framework have not been factored in due to lack of data and knowledge. In addition, recent survey data from the affected countries suggest that incidence of CBSD continues to increase. Accurate estimates of loss are vital in this dynamic situation. The challenge to both research and development institutions, therefore, is to assemble authoritative data on ALL the key components of CBSD damage in order to capture fully the economic consequences of this deadly disease in the continent.

Keywords: CBSD, economic losses, framework, sub-Saharan Africa

Introduction

Cassava brown streak disease (CBSD) is considered a major threat to the livelihoods of millions of smallholders in sub-Saharan Africa. CBSD produces foliar necrosis that affects photosynthesis in leaves and may result in reduced growth of the plant. On the stems, the plant shows brownish necrotic blotches, which led to its name of brown streak disease. On the roots, one can observe necrosis of whitish color at the beginning that later turns into a dry brown necrotic rot in the storage tissues of cassava tuberous roots. The more serious form can lead to either a complete spoilage or significant reductions in quality (Hillocks, 1997). Secondary losses occur as a consequence of early harvesting, which farmers use as a strategy to avoid root necrosis and complete crop failure (Hillocks et al., 2001). Inexperienced farmers identify damages only after harvesting and peeling the roots. In the case of seriously damaged roots, labor invested is lost. Even in the case of light damage, the harvester spends additional time to scraping away the damaged parts of roots in order to recover the good parts. Damaged roots undergo changes in their chemical composition that can result reductions in the nutritional or industrial quality of the harvest.

CBSD had previously been confined to coastal regions of eastern and southern Africa, where it caused moderate yield losses. Recently it has become far more devastating, causing near total yield loss in some areas (Muhana and Mtunda, 2002; Mtunda et al., 2002, Legg and Hillocks, 2002). CBSD was found also along the shores of Lake Malawi at low altitudes between 400-1000masl. Over 40% of the crops were infested with mean loss in production estimated at 20-25%. In Mozambique, the incidence of CBSD is mainly in the northern provinces of Nampula and Zambezia provinces with a mean incidence of 30% and 40% respectively (Thresh, 2001).

CBSD was first reported from coastal Tanzania in the 1930s and was thought to be restricted by altitude (Nichols, 1950) to coastal regions of East Africa and the shores of Lake Malawi. More recently there appears to have been a surge in the occurrence and distribution of the disease. It is now causing significant crop losses in the zone around Lake Victoria (Tanzania, Kenya, Uganda), has been reported in Burundi, and is suspected to occur in Rwanda and the Democratic Republic of Congo. Speculations exist that this viral disease is also spreading to the entire central African region in the Republic of Congo, Gabon, etc. A recent survey based entirely on questioning farmers (KIMETRICA, 2009) reported more than 50% disease incidence in coastal Tanzania, from 30-50% incidence in parts of Uganda and parts of the Lake Zone in Tanzania, up to 10-30% in the Democratic Republic of Congo and from 0 -10% in Rwanda and Burundi. CBSD can be considered now as the greatest threat to food security in the Great Lakes region of Africa where cassava is the major food security crop. New reports of high CBSD incidences in areas surrounding Lake Victoria that are at altitudes greater than 1000 m.a.s.l. have confounded the earlier view that CBSD cannot spread at these altitudes.

Cassava brown streak viruses (CBSVs) are monopartite positive sense single-stranded RNA viruses that have a flexuous rod shape. CBSVs are in the genus *Ipomovirus* and family *Potyviridae*) (Mbazibwa et al., 2009). Sap transmission (mechanical transmission) and transmission to herbaceous hosts has been demonstrated in graft transmission (Thresh, 2003). More recently, the insect vector has been shown to be *Bemisia tabaci* (Maruthi et al., 2005), the insect that is also responsible for transmitting the viruses that cause cassava mosaic disease (CMD). However, like other viral diseases affecting vegetatively propagated crops, its major means of dissemination is through the use of infected planting materials (Kanju et al. 2007). Recently it has been accepted that the disease is caused by two distinct species of viruses, *Cassava brown streak virus* (CBSV) and *Cassava brown streak Uganda virus* (CBSUV) (Winter, 2010; Fauquet, 2010). This makes it complex the control strategies that might be required to contain the viruses. CBSD and other biological threats are the main causes of low cassava yields in Africa (Fig 1).

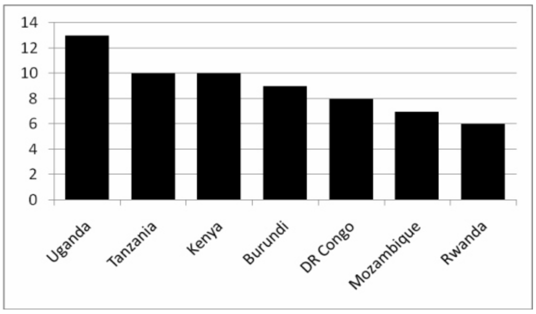

Fig.1. Yields of cassava in selected countries of eastern and southern Africa.

Cassava (*Manihot esculenta* Crantz) provides the cheapest source of food calories to more than 200 million in Africa who derive over 50% of their carbohydrate intake from cassava (Manyong et al. 2000). Nweke et al. (2001) described cassava as a powerful poverty fighter with the potential to help alleviate poverty both through food security and commercialization for millions of small-scale farmers.

Although the current and potential threats of CBSD to food security and poverty alleviation are well recognized in Africa, there have been only scanty and limited anecdotal stories about its economic importance.

This paper describes a framework that could serve as a guide for a meaningful and comprehensive assessment of the economic damage due to CBSD. Using the current up-to-date knowledge on CBSD, this section of the paper applies the framework to cassava producing countries of sub-Saharan Africa in order to make the estimates of economic damage for the continent. The third and final part of the paper identifies gaps in knowledge and data required to make a comprehensive assessment of the economic damage caused by CBSD. The identified gaps should form the basis for new research to be conducted so that more accurate assessments of the impact of CBSD in the continent can be carried out.

Basis for the economic evaluation of damage of CBSD

Root Symptom Severity Classification of CBSD damage: The cassava researchers apply two systems to assess the reaction of cultivars to CBSD. The first system is the plant disease incidence, usually expressed in percentage as the number of plants showing CBSD symptoms on the foliar parts (leaves and stems) or on roots over the total number of plants. The second system uses a subjective scale of 1 - 5 to assess the symptom severity of CBSV on cassava roots (Fig. 2). Level 1 or score 1 applies to roots with no visible discoloration regardless of the CBSD incidence on the foliar parts. Level 2 or score 2 is for roots with small streaks of white, yellow or brownish discoloration. Level 3 or score 3 includes roots with 2-10% of the cross-sectional area with brown/black discoloration and necrosis. Level 4 or score 4 is for roots found with 10-30% of the cross-sectional area with brown/black discoloration and necrosis. And Level 5 or score 5 is for roots with more than 30% of the cross-sectional area with brown/black discoloration and necrosis. Roots with scores 3 to 5 correspond to severe root incidence. Clones with severe root incidence are classified as susceptible and are therefore discarded from the breeding process. Economically, roots that score 3 to 5 are considered unmarketable and are not sold in the market. Roots with score 2 are sold after getting rid of the necrotic spots. To reduce the labor input, farmers can process such roots without any paring away of the damaged parts. In this case it can be expected that the quality of such products will be inferior to that produced with symptom-free roots. Score 1 root are fully marketable. Culinary and organoleptic tests made with consumers on products from cassava roots on Score 1 did not show any significant difference for consumers between score 1 from CBSD-infected and score 1 from CBSD-free (Mkamilo, personal communication). However, such score 1 would affect the grading of the products for industrial uses. Results from tests are missing in order to ascertain that the industrial quality of roots does not suffer any significant deterioration (e.g. starch content) in roots at score 1 from CBSD-infected plants compared to those from CBSD-free plants.

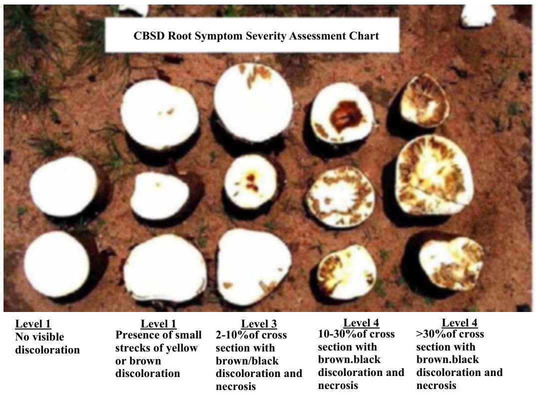

Fig. 2. IITA's Root Symptom Severity Classification of CBSD damage

Possible effects of CBSV on Cassava: The second element of the framework relates to the possible effects of CBSD on the economic parts of the plant. A plant affected by CBSD has impaired growth. This may result from a reduction in photosynthesis due to chlorotic leaf symptoms or, in the most severely affected plants, from the die-back of one or more stems. Both of these effects will result in reduced root number, reduced root weight or both. In CBSD-infested areas, farmers have developed coping strategies that consist of early harvesting of immature roots before they express symptoms of CBSD. This is done, since CBSD symptoms become increasingly severe as tuberous roots increase in maturity. Such a coping strategy is not ideal, since it results in reduced yields as well as an asynchrony between harvesting and planting operations. The fourth negative possible effect of CBSD is on the cost of labor of harvesting and processing CBSD damaged roots. Farmers invest labor to plant cassava, only to realize later on that no produce can be collected because of CBSD. Even before rejection of the damaged roots, farmers may invest labor to peel and cut roots before noticing that the roots are of no value. At score 2, farmers may spend additional time paring away the bad portions of the flesh in order to make use of those portions that show no streaks or discoloration. At a more aggregated level beyond each individual household, the cost to maintain plant health (research, extension, quarantine, etc.) in order to contain the viral infection is another consequence of CBSV. Finally, reduction in the quantity and quality of cassava roots could affect international trade. Where cassava roots are to be used for industrial applications such as starch or biofuel, substitutes might be needed, which would have a negative effect both on the quantity and reputation of industries of cassava-producing countries. Roots discarded for human uses (either direct or indirect) might however be utilized for other purposes, such as for animal feeds or the production of local products such as alcohol. Such a gain should also be considered alongside losses.

Framework for economic evaluation

The total economic losses due to CBSD come from the quantitative losses through the rejection of a proportion of harvest for roots of severe CBSD infestation with score 3 and above and the reduction in crop productivity of infested plants. The second broad category of losses is from the qualitative losses due to the reduction in quality of processed cassava products. The total losses can be modeled as follows:

$$EL_t = f(EL_q + EL_l) \quad (0)$$

Where
EL_t = total economic losses due to CBSD
EL_q = economic losses due to quantitative damages
EL_l = economic losses due to qualitative damages
$EL_q = Q_q * P_m$
Q_l = quantity lost due to CBSD
P_m = international market price

The economic losses due to quantitative damages are a function of three elements, as follows:

$$EL_q = f(Q_{score3+} + Q_{score2} + Q_{growth}) * P_m \quad (1)$$

Where

$Q_{sccore3+}$ = quantity (weight) of roots harvested on score 3 and above and rejected
Q_{score2} = reduction in production due to early harvesting to escape total failure due to CBSD incidence on score3+
Q_{growth} = reduction in productivity of cassava due to physiological disturbances in the plant growth on scores 1/2

Each of the three parameters in Eq (1) can be modeled as follows in the next sub equations;

$$Q_{score3+} = f(Area * Y * R) \quad (1.1)$$

Where
Area = total area grown to cassava in the study area (e.g. country)
Y = Average cassava yield (fresh weight)
R = Average CBSD severe root incidence on score3+ for the study area (e.g. Country)

And

$$Q_{score2} = f(((Area * xY) * (I- ((I_{score1} + I_{score3+}))) \quad (1.2)$$

Where

Area and Y = as above in Eq (1.1)
x = percentage reduction in Y due to CBSD incidence on score2
I = CBSD plant incidence
I_{score1} = CBSD incidence on score1
$I_{score3+}$ = CBSD incidence on score3+

And

$$Q_{growth} = f(Area * yY * (I_{score1} + I_{score2}) \quad (1.3)$$

Where

Area and Y = as above in Eq (1.1)
y = percentage reduction in Y due to physiological disturbances in plants with CBSD incidence on scale 1/2

Re-writing Eq (1) by integrating together its sub-equations leads to the generalized equation for the quantitative damages in Eq. (1+) as follows:

$$EL_q = f(((Area * Y * R) + ((Area * xY * (I- (I_{score1} + I_{score3+})) + ((Area * yY) * (I_{score1} + I_{score2}))) * P_m \quad (1+)$$

Using the same reasoning, one can come up with the following second equation for the qualitative damages caused by CBSD as follows:

$$EL_l = f((LP + CL + CN) \ RG)) \quad (2)$$

Where
LP=economic losses due to lower price in scale 2; CL=cost of additional labor; CN=economic loss due to reduction in nutritional and industrial quality; and RG=income from residual gains

$$LP = f(Q_{score2} * pP_m) \quad (2.1)$$

Where
$Q_{score2\ and}\ P_m$ as in previous equations
P = reduction the unit international market price of

the product due to a lower quality of roots.

$$CL = f((Q_{score3+} * lLabor * P_l) + (Q_{score2} * nLabor * P_l)) \quad (2.2)$$

Where

$Q_{score3+}$ and Q_{score2} as in previous equations

Labor = mandays required to process one unit (e.g. MT) of fresh roots

l = proportion of increased labor required to process one unit (e.g. MT) of fresh roots severely damaged by CBSV at Level 3 and above

P_l = unit cost of labor for processing cassava roots

n = proportion of increased labor required to process one unit (e.g. MT) of fresh roots with CBSD at Level 2

$$CN= f(Q_{score2} * zP_m) \quad (2.3)$$

Where

Q_{score2} and P_m as in previous equations

z = proportion of loss in international market price due to deterioration in the nutritional quality of damaged roots at Level 2.

$$RG = f(Q_{score3+} * P_f) \quad (2.4)$$

Where

$Q_{score3+}$ as in previous questions

P_f = unit price for feed or any raw materials from using roots at Level 3 and above

Re-writing Eq (2) by conbining together its sub-equations leads to the generalized equation for the qualitative damages in Eq. (2+) as follows:

Or

$$EL_l = f(((Q_{score2} * pP_m) + (Q_{score3+} * lLabor * P_l) + (Q_{score2} * nLabor * P_l) + (Q_{score2} * zP_m)) \ (Q_{score3+} * P_f))) \quad (2+)$$

Pooling together the detailed equations from quantitative (Eq. 1+) and qualitative (Eq.2+) damages, the comprehensive assessment of the economic damages as shown in Eq. (0) is modeled in Eq. (0+) as follows:

$$EL_t = f[(((Area * Y * R) + ((Area * xY) * (I-(I_{score1} + I_{score3+})) + (Area * yY) * (I_{score1} + I_{score2}))) * P_m + (Q_{score2} * pP_m) + (Q_{score3+} * lLabor * P_l) + (Q_{score2} * nLabor * P_l)) + (Q_{score2} * zP_m)] \ (Q_{score3+} * P_f) \quad (0+)$$

The parameters indicated in Eq. (0+) should guide data collection in order to make a comprehensive assessment of economic damages due to CBSD.

Application of the framework to Sub-Saharan Africa

Data sources for the application of the Framework

The application of the full framework was constrained by lack of data and by insufficient knowledge on the relationship/association between CBSV and various types of losses depicted in the framework. Data currently available were extracted from the FAOSTAT database (FAO, 2009) for areas grown to cassava, production and yield. Recent findings on CBSD plant incidence and CBSD severe root incidence are from the GLCI project in four of its target countries, namely: Tanzania, Uganda, Kenya, and Burundi. For this paper, we applied data for Burundi to two other GLCI countries namely Rwanda, and Congo DR where data are missing because CBSD is suspected to start occurring in these countries as it is the case for Burundi. Data on CBSD from non GLCI countries (Malawi and Mozambique are from literature (e.g. Vercauteren, 2005 or Cuambe et al. 2010). The international market prices for fresh roots are from the FAO Food Outlook for December 2009. The interaction with cassava breeders, virologists, economists was also important to provide additional knowledge required in assessing the economic damage caused by CBSD.

Results from the application of the Framework

There are 39 countries in SSA that produced cassava. According to FAO (2009), the total production reached 116.5 m metric tons of fresh root from an area estimated at 4.5m ha, resulting in an average yield of 10 tons per ha of fresh roots. Results from a recent survey conducted by the GLCI project in six countries and previous knowledge of infestation in the coastal regions of Africa, CBSD is confirmed present in six countries and suspected in two countries. The confirmed countries are Burundi, Kenya, Malawi, Mozambique, Tanzania, and Uganda. The two suspected countries are Congo DR and Rwanda. Altogether, the eight countries represent 31.7% for production and 35.1% for area grown to cassava in Africa. The CBSD plant incidence varies from a low 1% in Burundi to a percent as high as 40% in Malawi and Tanzania. The CBSD severe root incidence ranges from 0.12% in Burundi to 14% in

Mozambique. Those figures are relatively low compared to figures generally reported in literature (e.g. Mtunda et al Tanzania, Cuambe et al. 2010 for Mozambique). However the GLCI assessment was the most detailed and extensive done to date. In the absence of a generalized evaluation of CBSD in each country (beyond geographically limited experiments), we retain our figures with the understanding that estimates made in this paper are conservative.

The total annual production lost to CBSD is estimated at 1.6 m metric tons. Using the international market price of US$45/metric ton of fresh roots (FAO Food Outlook for December 2009), the corresponding economic loss is as huge as US$75 m annually. Four countries (Malawi, Mozambique, Uganda, and Tanzania) represent 97% of the above economic loss. The real economic loss is certainly bigger that the amount reported here because data are available on parts of quantitative damages due score3 damages. The current lack of knowledge and data is responsible for not conducting a comprehensive assessment of the damages caused by CBSD as it is demonstrated in the following section.

Gaps in data and knowledge for the application of the framework

Going back to Eq (0+), we can indicate those parameters for which there is lack of knowledge or data in order to make the comprehensive assessment of the economic damages. These missing parameters are shown in bold in the general equation (0+) to which we have added the aggregate costs beyond the farming level in E3. (3), as shown below.

$$EL_t = f[(((Area * Y * R) + ((Area * xY) * (I-(I_{score1} + I_{score3+})) + ((Area * yY) * (I_{score1} + I_{score2}))) * P_m + (Q_{score2} * pP_m) + (Q_{scale\ 3+} * lLabor * P_l) + (Q_{score2} * nLabor * P_l) + (Q_{score2} * zP_m)]\ (Q_{score3+} * P_f) + \text{[Costs for control programs and those from effects on the international trade]} \qquad (3)$$

As one can see in the above Eq (3) compared to Eq (0+), only damages caused by CBSD severe root incidence were counted in the result of US$75 m. The missing parameters are reduction in quantity due to slow growth rate, reduction in quantity harvested due to early harvesting and low vigor of the plant, cost of labor lost due to the rejection of roots on Level 3 and above, additional labor required to prune out the damaged parts of the roots on Level 2, reduction in nutritional or industrial quality of roots from plants with incidence on Levels 1 and 2; any income gain from the utilization of roots discarded for direct human consumption, costs for CBSD control programs and those indirect costs on the international trade. Another element to take into consideration is that quantity lost due to CBSD severe incidence is higher than that used in the model because the production itself is already affected by the viral infection. This deviation can be easily corrected if knowledge is gained on the incidence of the disease on growth and vigor of the cassava plant. Finally the market price of the produce is also an important parameter in the economic evaluation. In this paper, we did consider the price of fresh roots in the international market. In Africa, the price of fresh roots is about half of that in the international markets. In that case, the economic loss will be about 50% only of the current estimates.

Future Research Directions for a Comprehensive Assessment of Economic Damages of CBSD in SSA

The missing parameters would be the basis of suggested themes as future research directions for a comprehensive assessment of economic damages of CBSD in SSA. Looking at the above Eq (3), research themes to fill the gaps are as follows for three types of expertise:

Technical scientists (breeders, IPM, animal scientists, etc.):

- Relationship between CBSD incidence on Scale 2 and reduction in crop productivity
- Reduction in crop productivity due to physiological disturbances caused by CBSD incidence on Scale 1.
- Residual utilization of cassava roots discarded for human consumption

Crop utilization specialists:

- Relationship between CBSD root severity scores of 1 or 2 and reduction in nutritional and industrial quality of cassava products
- Labor required to process cassava roots from plants with various levels of CBSD severity

Economists:

- Market prices of cassava products from roots with various levels of CBSD incidences
- Costs of programs to control CBSD
- Effects of CBSD on international trade (direct and indirect effects)
- Database on cassava, including detailed

statistics on CBSD affected areas.

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Economic impacts of cassava improvement in Malawi and Zambia

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Abstract

This paper measures the economic impacts of IITA/SARRNET led cassava improvement research in Malawi and Zambia over the period 1990-2008. The data come from sample household surveys, expert opinion surveys, and a series of cassava improvement experiments conducted in the two countries. Past investments in cassava improvement have led to the development and release of a good number of high-yielding cassava varieties. The results show relatively higher adoption rates for the CMD-free local varieties compared to CMD-resistant modern varieties that have been released in the two countries. The adoption of new varieties has been low and slow largely due to the fact that most of these varieties lacked the consumption attributes highly valued by farmers. The multiplication and distribution of CMD-free planting materials of the recommended local varieties led to greater adoption, but infection with CMD three to four years after adoption meant that the yield gains and economic benefits could not be sustained. Nevertheless, the multiplication and distribution of clean cassava planting materials generated a modest rate of return of 18%, which is actually consistent with an earlier rate of return estimate of 9 to 22% for cassava improvement in developing countries. Analysis of the ex ante impacts of current and future investments in cassava improvement from 2009 to 2050 shows that cassava improvement research that focuses on the development and dissemination of varieties with highly preferred consumption and industrial attributes would yield a greater rate of return of 40%.

Keywords: Impact assessment, economic surplus, cassava improvement research, Malawi, Zambia

Introduction

The Cassava Economy in Malawi and Zambia

The importance of cassava as food security and cash crop in the two countries is now well recognized. Cassava is a staple food for more than 30% of the Malawian population, occupies 60% of roots and tubers cultivated area and contributes nearly 50% of their total production. Cassava in Zambia accounts for roughly 15% of national calorie consumption (Dorosh et al. 2007). The crop was ordinarily grown and regarded as a staple in the five provinces of Luapula, Northern, North-Western, Copperbelt and Western provinces (Soenarjo 1992) but in recently its cultivation and use is making significant spreads towards the Southern and Eastern parts of the country (Chitundu 1999). Besides the already existing markets for sweet cassava in the cities and towns, there is great potential for industrial use (eg cassava flour and starch in the confectionary and starch-manufacturing factories).

Motivation for the cassava improvement research in Malawi and Zambia: Despite all the known advantages cassava has over other crops, the potential of the crop has also not been fully exploited due to continued use of traditional varieties, disease pressure and unfavorable policy environment (Haggblade and Zulu 2003). In an attempt to enhance the performance of cassava varieties and acceptance of its products, IITA/SARRNET in partnership with the Root and Tuber Improvement Programs (RTIP) continues to spearhead various cassava improvement initiatives in the network member countries. Since early 1990s there has been massive selection of cassava varieties for drought mitigation as well as disease tolerance. Following the 1992 accelerated cassava multiplication and distribution program as well as the subsequent breeding programs, numerous cassava cultivars have been screened and improved[2] varieties developed for formal release in the two countries. Through the USAID/OFDA-funded cassava multiplication/ distribution program(s) and other initiatives like PAM in Zambia, clean stems of local best cassava clones particularly *Manyokola* and *Bangweulu* were distributed to Malawian and Zambian farmers. The hybridization trials by the Root and Tuber Improvement Programs (RTIP) have successfully developed and released a total of nine new varieties between 1999 and 2009 in Malawi and seven varieties between 1993 and 2000 in Zambia. This paper evaluates the ex-post impacts of cassava multiplication and distribution program and secondly assesses ex-ante the potential benefits of cassava improvement research in the two countries.

Data and Methods

The paper uses 2007 survey data conducted in six major cassava growing districts in Malawi and the 2009 expert survey carried out in the two countries. Supplementary data on aggregate annual cassava area, production and prices was sourced from FAOSTAT online publication whereas the research costs and experimental yield results were extracted from SARRNET annual reports and project documents. Use of simple statistics was employed to estimate adoption proxied by the proportion of farmers growing cassava varieties and area of land allocated to the improved varieties. Economic surplus approach is used to estimate the economic impacts.

Results and Discussion

Socioeconomic characteristics of the sampled households: The socioeconomic characteristics of the households are presented in Table 1. On average, a household had five members and owned 1.9 hectares of crop land. Land pressure was not intense since only 21% of the households owned less than a hectare of total cultivable land. Household size is an important element in the adoption of crop technologies because of its influence on farm labour availability on the supply side and food consumption on the demand side. In the sample 47% of the households had larger than average family size estimated at six members and only 15% of the households were female headed. The youthful age bracket coupled with fairly large family sizes suggest that labour wouldn't be a major constraint to crop production or modern variety adoption in these areas.

Table 1: Socioeconomic characteristics of the sample households

Variable	Mzimba	Nkhatabay	Nkhotakota	Lilongwe	Zomba	Mulanje	All
Age of the household head	46	47	43	39	46	45	44
Gender of household head	20	28	8	7	15	17	16
Household size	6	7	6	5	5	5	6
Total cultivable land *(ha)*	2.3	2.3	2.4	2.0	1.3	1.3	1.9
Asset value (000 Mk)	60	131	69	29	40	55	64
Distance to output market *(hrs)*	1.5	0.9	1.9	1.1	1.1	1.5	1.3
Farm club membership (%)	43	40	50	48	34	35	42

[2] *Improved cassava varieties refer to clean best local varieties like Manyokola or Bangweulu and any of the new RTIP-bred varieties combined*

Adoption of modern cassava varieties

The source of cassava cuttings was used as a proxy for whether farmers cultivated CMD clean materials or not. Planting materials sourced from research institute, government extension agents, NGOs, or church organizations were regarded as clean because these institutions were part of the major distribution outlets for the accelerated multiplication and distribution program and some have continued with the distributions. Cassava is found to be cultivated by over 80% of the households in Malawi. However the adoption of improved cassava varieties is generally low estimated at 18% of the cassava growers. When adoption is analyzed in terms of area allocation, we find that 20% of the total available land (0.4 hectares) was allocated to cassava production and 14% was under the cultivation of improved cassava varieties. The adoption of new varieties released before 2007 is estimated at 7% of cassava area (Figure1). This low uptake could among other factors be attributed to scarcity of clean planting materials, negative farmer perception towards variety attributes, or somehow due to morphological identification problem where farmers fail to recognize a variety or a variety is identified by a new name that completely disguises its original name.

Table 2: Land allocation to cassava and share of cassava area in Malawi

	Land allocation *(ha)*					Land allocation (%)				
Region	Local	Clean local	New	Improved	Cassava	Local	Clean local	New	Improved	Cassava
North	0.29	0.37	0.02	0.05	0.48	44	8	5	13	21
Centre	0.41	0.02	0.04	0.05	0.56	55	10	12	19	27
South	0.13	0.01	0.00	0.01	0.17	61	9	1	10	13
All	0.27	0.02	0.02	0.04	0.40	54	9	6	14	20

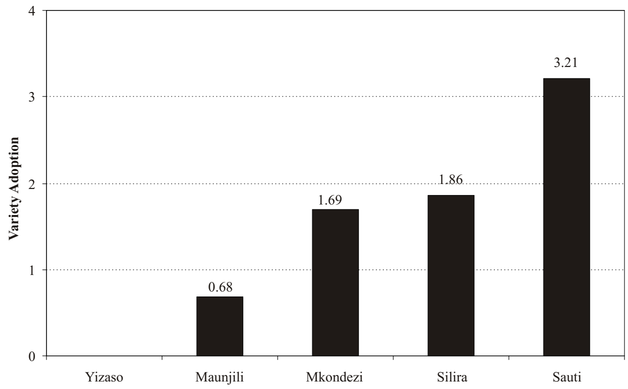

Figure 1: Adoption of improved cassava varieties in Malawi (% area)

Similarly, in Zambia local varieties are still popular among cassava growers (Table 3). The biggest share of land allocated to cassava is still used to grow local cassava varieties estimated at over 70%. Eight years after their release, the new RTIP-bred cassava varieties (Chila, Mweru, Tanganyika and Kampolombo) occupy slightly above 1% cassava area as of the total 2008 cassava area.

Table 3: Adoption of cassava varieties in Zambia, 2006-2008 crop season

Variety	Area planted (1000 ha)		Adoption (%)	
	2006-2007	2007-2008	2006-2007	2007-2008
Bangweulu	27	47	3.2	4.2
Nalumino	79	109	9.4	9.8
Kapumba	8	11	1.0	1.0
Chila	4	7	0.4	0.6
Mweru	7	7	0.8	0.6
Tanganyika	1	1	0.1	0.1
Other improved	47	58	5.6	5.2
Local variety	669	873	79.5	78.4
Total	841	1112	100	100.0

Source: CSO 2006/07; 2007/08 crop forecast

Relative yield gains for improved Cassava varieties

The effects of cassava improvement through cleaning or breeding were dominant in all ecological zones as evidenced by significant yield gains for improved cassava varieties over local checks. Using propensity score matching methods (PSM) the estimated yield for CMD-clean and newly released varieties were 12 t/ha and 14 t/ha respectively compared to 9t/ha for uncleaned local varieties. This translates to 33% and 56% yield increase for CMD-free local varieties and newly bred varieties respectively, over the generic local cultivars. For purposes of comparison, we aggregated experimental yields recorded at five research stations in Malawi from 1990 to 1997. The yield gain of new varieties over local varieties ranges from 30-58% depending on the region but the national average was 42%. In Zambia varietal trials were conducted at Mansa research stations and in the Lusaka province from 2002 to 2004 (Barratt *et al.* 2006). From these experiments Bangweulu (clean local) yielded 4 tons higher than the 21t/ha for Muganga (non clean local) while Mweru, one of the new RTIP-bred varieties produced 29t/ha. Despite data limitations, this still demonstrates substantial yield gains of 21% and 41% over Muganga as a local check representing other generic local varieties.

Economic Impacts of cassava improvement programme

Ex-post impact assessment of cassava improvement program

The Economic surplus Approach

Economic surplus analysis is the widely used procedure for economic evaluation of technological change (Alston 1991). In an ex-post closed economy analysis, total benefit is given by $\Delta TS_t = K_t P_t Q_t (1 - 0.5 Z \eta)$.The key parameter Kt, denotes the supply shift resulting from unit cost reductions and has been simplified as

$$K_t = (\frac{\Delta Y / Y}{\varepsilon}) A_t$$

Because cassava production is not capital intensive. The proportionate decrease in price associated with the new technology is defined by $Z = K\varepsilon / (\varepsilon + \eta)$. Pt and Qt respectively represent the prevailing output price and quantity produced; η and ε denote the absolute value of price elasticity of demand and supply. The stream of benefits and costs is aggregated over the project horizon and discounted to their present values using the net present value (NPV) formula.

Estimates of price elasticity and cassava producer prices

In the absence of exact measures for price elasticity of supply, Alston et al. (1995) proposed use of unitary supply elasticity. This analysis therefore adopted unitary supply elasticity and demand elasticity of 0.2 because cassava is only traded locally. For the same reason, the benefits are calculated based on average domestic market prices prevailing in the two countries. In Zambia the real average cassava price was estimated at US$110/t dry weight. This is derived from Otterdijk (1999), Haggblade and Zulu (2003) and Haggblade and Nyembe (2008). For Malawi cassava prices for the 1990-2006 period were readily available on the FAOSTAT online publication. We applied this series of prices in the expost analysis and a four-year average real price of US$138/t dry weight (2003-2006) in the ex-ante analysis.

Estimating relative yield loss (gain), K-parameter

CMD yield loss has two components that correspond to production gap attributed to attack with and without any interventions. We use experimental data to estimate relative yield loss (gain) and extrapolate total benefits associated with the use of CMD-free planting materials. The results presented in *Table 4* show yield loss of 10-50% depending on the level of severity of CMD symptoms present in the cassava plant. Yield under CMD attack without any interventions corresponds to 50% loss under disease severity scale five but the damage can take any value between 10-48% with some form of interventions. If the cleaning program reduces the CMD severity from class five with 50% loss to mild infestation class two with 10% loss, then there is a relative yield gain (avoided loss) of 40%.

Table 4: Effect of CMD severity on cassava yield (t/ha) at Mkondezi research station 1991/92 and 1995 cropping season

Severity	1991/92		1995		Mean	△Y/Y (%)
	Mbundumali	Gomani	Mbundumali	Gomani		
1	9.24	11.17	8.8	13	10.55	-
2	8.87	7.14	6.8	15	9.45	10
3	7.72	8.93	5.1	2.8	6.14	42
4	6.98	7.21	3.5	4.2	5.47	48
5	3.36	3.78	4.8	9.1	5.26	50

Source: Adapted from Mahungu and Shrestha (1993); Muimba-Kankolongo et al. (1999)

We construct the counterfactual and adjust the supply shift parameter to account for the fact that the observed annual production figures also embed production gains attributable to the phyto-sanitation program. Let Y_0, be national cassava production without CMD infestation, Y_1 represent production with CMD infestation but without any intervention and Y_2 production under CMD influence in the presence of an improvement program responding to CMD attack. The production level Y_1 is the maximum that the crop can achieve under disease stress. If CMD was left unchecked production level Y_1 would have prevailed with loss factor α which depends on severity and incidence of the disease. However we observe production level Y_2 with a new loss factor α which embeds the effects of cleaning. It follows that $\beta < \alpha$ and $Y_0 > Y_2 > Y_1$ because cleaning efforts cannot recover the full potential of the crop under CMD attack but can contribute to some increased production (avoided yield loss). Without baseline information Y_0 is not available but Y_2 is observable in the annual national agricultural statistics. Using experimental data Y_0, and Y_1 can be constructed based on the following relationship:

$$\frac{Y_0 - Y_1}{Y_0} = \alpha \text{ (Relative loss without any intervention)} \Rightarrow Y_0 = \frac{Y_1}{1-\alpha} \quad (1)$$

$$\frac{Y_0 - Y_2}{Y_0} = \beta \text{ (Relative loss with intervention)} \Rightarrow Y_0 = \frac{Y_2}{1-\beta} \quad (2)$$

$$\frac{Y_2 - Y_1}{Y_0} = \alpha - \beta \text{ (Avoided loss)} \quad (3)$$

Equation (3) is expressed as the difference between equations (1) and (2) and represents the avoided yield loss attributed to the adoption of pathogen free planting materials distributed countrywide. By substitution the value of supply shift *(K)* is given as:

$$K = \frac{Y_2 - Y_1}{Y_2} = \frac{\alpha - \beta}{1 - \beta}$$

With technology adoption rate *A*, the actual production that would have been lost due to CMD attack (production saved) is the difference between production with intervention (Y_2) and that without intervention (Y_1) or $(\alpha - \beta) Y_0 A_t$.

From Table 4 above a comparison of yield with and without intervention gives three estimates of supply shift (K) corresponding to three-year period lag, K_t, K_{t-1}, K_{t-2}. The first parameter K_t= 0.44 corresponds to maximum cleaning gains achieved by reducing CMD severity from class five (with 50% loss without any intervention) to class two (10% loss with intervention). We assume this is only achievable in the first year of distribution but the performance deteriorates in the subsequent years if the same planting materials are repeatedly used without further re-selection and cleaning. The second parameter K_{t-1}= 0.14 is equivalent to reducing CMD from class five to class three (42% loss with some intervention). This is achieved with the cleaned planting materials recycled for one season. In the same manner, if the same planting materials are used for a consecutive third season (recycled for 2 seasons), the parameter K drops to K_{t-2} = 0.04 corresponding to severity reduction from class five to class four (48% loss). In any year *t*, the overall supply shift (K^T) is given by the sum of K_t, K_{t-1}, and K_{t-2}. For Zambia we adopt 21% yield advantage based on experimental results as explained in previous sections.

Adoption of CMD clean cassava materials

In order for the new varieties to have an impact on production and human welfare, they must be adopted by the farmers and show superiority over the local varieties (Johnson et al. 2003). The logistic curve (Figure 2) was used to map out the adoption pattern of the clean cassava materials from 1993 to 2008. The principal rates of adoption shown in Tables 5a and 5b are derived from multiplication and distribution nursery area or stem cuttings and other studies. In the 1992/93 cropping season 46 hectares of cassava nursery was established in the three regions of Malawi in order to provide disease free planting materials to the farmers. From the cassava multiplication ratio of 1:20, it is estimated that the nursery material can produce cassava cuttings equivalent to plant 920 hectares of farming households. Records show that in the 1993/94 cropping season, a total of 92 hectares were established which would generate enough planting materials to service 1840 hectares of farmer area. The second phase of the program implemented between 1998 and 2001 managed to set 300 hectares of cassava nursery which is enough to cover 6000 hectares of farm land at 10000 cuttings per hectare. There is a multiplier effect generated through farmer-to-farmer distribution of planting materials. These primary beneficiaries acted as secondary distributors of the program thereby extending the benefits to other families that the program would not have reached or recorded.

Table 5a: Cassava multiplication in Malawi

Year	Cassava area (ha)	Multiplication area (ha)	Planted area (ha)	Cumulative area (ha)	Adoption (%)
1993	75,050	46	920	920	1.23
1994	72,149	92	1840	2760	3.83
2003	110,196	300	6000	13060	11.85

Source: Adapted from SARRNET reports

Using the above adoption and the 1998 adoption estimate of 10% (Manyong *et al.* 2000), we project a diffusion path for improved cassava varieties in Malawi. For Zambia, we use the 1999 and 2000 from SARRNET survey and the 2007 results based on data from Zambian Central Statistical Office. The appropriate adoption ceiling was estimated at 17% based on the survey findings.

Table 5b: Adoption (%) of CMD clean cassava varieties in Malawi and Zambia

Year	Adoption (%)		Adjusted	
	Malawi	Zambia	Malawi	Zambia
1998	10		7	6
1999	22	7	8	7
2000	21	14	10	9
2001	23	15	11	10
2002	24	19	12	12
2003			13	13

Source: Manyong et al. (2000); SARRNET (2004); Authors computation

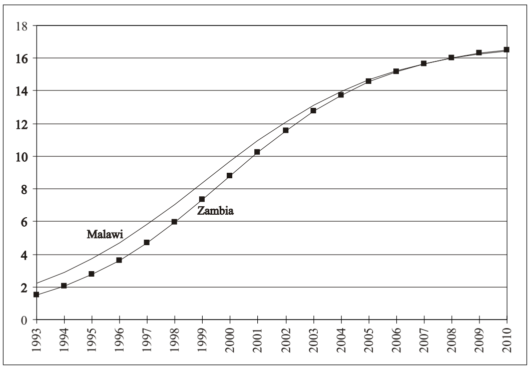

Figure 2: Adoption of improved cassava varieties in Malawi and Zambia

Cassava multiplication and distribution costs

The accelerated multiplication and distribution projects were running concurrently with other institution-led cassava improvement activities like breeding which also had components of seed multiplication and distribution. The entire period from 1990 to 2008, IITA/SARRNET project budgets and workplans show that a total of $12 million had been used for purposes of root and tuber crops research, multiplication and distribution of disease free planting materials in the SARRNET member countries. These expenses were equally distributed between cassava and sweet potato such that 50% of the total costs accrued to cassava multiplication and distribution. This gives an average undiscounted expenditure of $0.32 million every year and a total of $6 million as the operating cost for cassava research, multiplication and distribution program within the analysis period.

Economic benefits of the multiplication and distribution program

The benefits of the cassava multiplication and distribution program are presented in Table 6. The stream of benefits accruing from the cassava multiplication and distribution program is positive and higher relative the project costs incurred. In the base model, the stream of benefits and costs were compounded at a 5% rate to their respective 2008 values. Loss avoided ranged from 600-1500 tons annually and by 2008 a total of 29000 tons in dry weight are estimated to have been saved from the influence of CMD in Malawi. This production gain translates to US$6 million. In Zambia, the program on average generated US$0.5 million annually and a total of US$9 million was realized by 2008. The cassava multiplication and distribution program was quite successful and worthwhile when evaluated on the basis of benefit-cost ratio (BCR) and rate of return (IRR). Using a discount rate of 5%, the benefit-cost ratio (BCR) was estimated at 3:1 and the rate of return for the program was found to be 18%. Given that the benefit-cost ratio for the multiplication and distribution program equals 3:1 it means that returns are three times higher than the research investment costs incurred.

Table 6: Benefit and Costs ($) of Cassava multiplication and distribution program

	Annual Benefits ($)	Annual Costs ($)	NPV ($)	-Cost ratioB	IRR (%)
Malawi (A)	248,668	99,184	2,840,200	2.5	7
Zambia (B)	381,824	99,184	7,162,153	3.8	21
Total (A + B)	630,492	198,368	8,210,356	3.2	18

In order to test the base model assumptions, a sensitivity analysis was run with 3% discount rate and open economy assumption imposed. There was little variation between the base model and the two alternative scenarios. In the alternative scenario NPV ranged from $7-$8 million and the rate of return was between 16% and 17% representing a relative gain or loss of 1-9% on the base model. The NPV, rate of return and BCR values were slightly lower in the open economy case compared to the closed economy.

Ex-ante economic impacts of cassava breeding (2009-2050)

The effect of CMD was quite devastating hence the first generation of cassava breeding research placed much emphasis on breeding for disease tolerance. So far, almost all of the newly released varieties in Malawi are bitter to taste and are only suitable for traditionally cassava consuming districts. The major thrust in the second generation cassava breeding program would therefore be to develop new varieties which build on the desirable consumption traits of local materials e.g. sweet taste, nutritive value, industrial application and cooking ability while maintaining the known enviable record on yield potential and disease tolerance. This is the scenario that is projected in the sections that follow and whose potential benefits are being modeled.

Estimation of potential adoption: Due to a proper blend of consumption traits, yield ability and disease tolerance, the adoption of the new research technology is expected to be faster and somewhat more widespread throughout the two countries. It is expected that the adoption ceiling will be higher than what was initially the case. We use the recently available active but minimum nursery area of 300 hectares (SARRNET 2004) which would produce 6.6 million stems at the rate of 22000 plants per hectare. A one-metre long cassava stem can give 4-5 cuttings of 20-25 cm each. With this multiplication ratio, a 300 hectare nursery area generates planting materials enough to plant 2640-3300 hectares at a plant population of 10,000 plants per hectare in the farmers' field. We use the recommended plant population for sole stand of 10000 plants per hectare but the area under new cassava varieties would be much larger if we adopted 3000 plants per hectare, the plant population for intercropped cassava as reported by McSween et al. (2006). Assuming each farmer allocates an average of 0.2 hectares of land to the new cassava varieties, a total of 13200 farmers would benefit from the first batch of cassava materials produced in the first year of seed distributions. There is evidence of strong farmer to farmer dissemination of planting materials given for free or at times sold at some modest fee. In order to account for farmer to farmer diffusion of cassava planting materials we assume each farmer distributes at least one bundle (150 stem each 1m in length) to three more farmers. This gives 7.9 million cuttings, enough for 792 hectares of land at 10000 plants per hectare. Using the same procedure, the number of farmers grows to 17,160 with a total of 3432 hectares of land in the second cropping season. By the year 2012 (the third cropping season) 10.3 million cuttings would have reached farmer fields covering at least 3670 hectares. The total cassava area estimated at 161318 hectares is based on the 5 year average (2004-2008) from the Ministry of agriculture crop statistics.

Table 7: Potential adoption of new cassava varieties in Malawi

Year	Cassava area (ha)	Multiplication area (ha)	Equivalent Planted area (ha)	Farmer-to-farmer area (ha)	Total planted area (ha)	Adoption (%)
2015	161,318	300	2640	-	2640	1.64
2016	161,318	300	2640	792	3432	2.13
2017	161,318	300	2640	1030	3670	2.27

The above adoption information was used to estimate the logistic curve to forecast the potential adoption of the new varieties as shown in the Figure 3 below. We assume the initial stages of adoption for the new varieties mimic the currently released varieties but the difference between the adoption patterns for the two is the ceiling set at 30% for the former and 17% for the later.

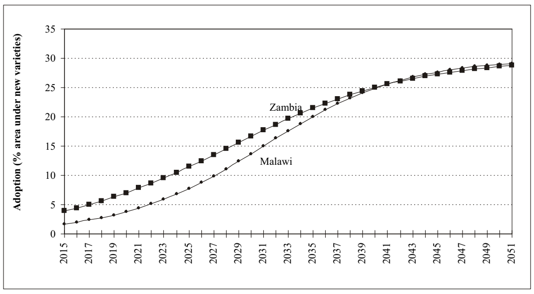

Figure 3: Potential adoption for new varieties in Malawi and Zambia

Research and extension costs: In order to compute net returns on cassava improvement research, we need to compare the stream of benefits with investment costs made in the process of breeding and disseminating modern cassava varieties. The research costs used in this analysis were adapted from existing SARRNET cassava improvement activity budgets but were adjusted to cater for additional extension costs necessary to push for the adoption of the new varieties upon release. Based on previous budgets, 70% of the costs were distributed to breeding and 30% went to extension activities. The average annual expenditure for cassava research and extension in the SARRNET member countries is estimated at $390 thousand for twenty-three years starting from 2009 to 2050 when the maximum adoption is attained. A total of US$8 million is estimated to be devoted to the development of the new varieties and dissemination of information on the new varieties.

Ex-ante economic benefits of new cassava varieties: Table 8 presents the potential economic benefits that will be generated due to yield increases of the new varieties upon adoption in Malawi and Zambia. The economic benefits of new cassava varieties presented here only represent the value of increased root yield and none of the other cassava products that could be utilized by the industries eg starch was considered. We assume benefits accrue from the period of initial investment up to 2050. The results show that the cassava research investments in the two countries are quite remunerative and worthwhile. The first few years have negative stream of benefits because while the research costs are incurred within this period no technology has been released yet. The research lag before formal release is six years and the other year is reserved for start-up seed multiplication and distribution. The adoption of the prospective new varieties would generate an annual average of US$6 million in Malawi and US$3 million in Zambia. Within the analysis period, a total of US$97 million would be realized from the use of the new cassava varieties in the two countries. The cassava improvement research program under analysis is economically efficient in the sense that production benefits outweigh the investment costs. The efficiency indicators are positive and reasonably high. The internal rate of return for cassava improvement in the two countries is estimated at 40%. This is almost twice higher than the findings by Johnson et al. (2003) who estimated the rate of return for CIAT cassava improvement program to be between 9 and 22%.

Table 8: Potential benefits of cassava improvement research program in Malawi and Zambia

	Annual Benefits (000 $)	Annual Costs (000 $)	NPV (000 $)	B-Cost ratio	IRR (%)
Malawi (A)	1,640	58.9	66,386	28	47
Zambia (B)	792	58.9	30,784	13	32
Total (A + B)	2,431	117.8	97,170	21	40

Conculution

There has been significant progress in the improvement of root and tuber crops particularly cassava and sweetpotato in the two countries. Following such crop improvement efforts cassava yield and production has significantly picked up from the early 1990s when IITA/SARRNET and national programs launched the accelerated multiplication and distribution program. The use of these varieties and other new cassava varieties increased yield by 40% when compared to conventional local varieties. Although adoption of improved cassava varieties has been relatively low, there has been notable impact in terms of economic benefits associated with these varieties. The value of increased root yield for the CMD free varieties was worth $8 million with a rate of return of 18%. With the new varieties poised to embrace major desirable attributes, the speed and intensity of adoption of the prospective varieties is expected to be far better and hence generate high economic impacts. The new varieties are poised to generate $97 million worth of benefits with a rate of return as high as 40%. A comparison of rates of return showed that the returns for the potential breeding program (ex-ante assessment) are twice higher than the cassava multiplication and distribution program (ex-post assessment). This is because the prospective varieties are expected to be widely accepted because of their attractive attributes.

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Appendix 1: List of cassava varieties released in Malawi and Zambia, 1980-2009

Malawi			Zambia		
Variety	Year	Category	Variety	Year	Category
Gomani	1980s	Local	Bangweulu, LUC55	1993	Local
Manyokola	1980s	Local	Kapumba, LUC327	1993	Local
Mkondezi, MK91/478	1999	RTIP-bred	Nalumino, LUC304	1993	Local
Silira, TMS 60142A	1999	RTIP-bred	Mweru,	2000	RTIP-bred
Maunjili, TMS 91934	1999	RTIP-bred	Chila,	2000	RTIP-bred
Sauti, CH92/077	2002	RTIP-bred	Tanganyika	2000	RTIP-bred
Yizaso, CH92/112	2002	RTIP-bred	Kampolombo	2000	RTIP-bred
Mulera, TMS 83350	2008	RTIP-bred			
Phoso, LCN8010	2008	RTIP-bred			
Sagonja, CH92/82	2009	RTIP-bred			
Chiombola, TME 6	2009	RTIP-bred			

Increasing cassava productivity in Nigeria: The commodity value chain development approach

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Abstract
The cassava value chain development approach was put into use in the last one year to transform the cassava productivity in some selected states of Nigeria by creating linkages between sustainable supply of raw materials and the large scale cassava processors. In this market-led model, farmers are empowered to use best agronomic practices and disease resistant cassava varieties to increase their yields, while readiness of major input dealers to provide agro-chemicals to the farmers at affordable prices, and loans from the financial institution is facilitated. The project is also highly responsive to emerging opportunities that enable the value chain to be efficient, for example establishment of demonstration plots for farmers' training and commercial weed control business groups who can assist farmers with cost effective weed control practices are brought into the arrangement.

Three major cassava processing companies which are providing a sustainable market outlet for the farm produce for a minimum of 1000 farmers were involved in the model. A total of 112 sustainable farmers groups were created in the 2009 planting season. This led to the establishment of 1304ha under improved technologies or management practice. Six (6) technologies or management practices were made available for transfer to farmers and investigations indicate that about 85% of farmers are adopting all the improved technologies made available for transfer to farmers except the use of fertilizers. Over 200 farmers were gainfully employed as agrochemical sprayers and sellers, while over USD100,000 was realized as income generated from stem sales in the project states. Full business operation has resumed again in these cassava processing companies. This paper therefore shows that market-led as demand driven cassava development approach can lead to efficiency in the crop, generates employment for youth and should be promoted.

Introduction
In designing an effective and sustainable approach that will promote competitive cassava sub-sector in an evolving consumer-preference system in Nigeria, it was important to establish: the reliability and efficiency of the input system, the effect of adoption of improved production technologies by farmers, the contribution of the value-addition through best processing practices and the contribution of effective linkages between major actors in the cassava value chain. It was against this background that the Maximizing Agriculture and Key Enterprises in Targeted Site (MARKETS) and IITA initiated a holistic commodity development chain approach in 2009 in conjunction with selected agro-processors (EKHA Agro, MATNA Foods and NSM) the south-west and south-east of Nigeria. The objective were to support large-scale cassava agro-processors, expand economic opportunities in the cassava industry by increasing productivity, enhancing value-added processing, and increasing commercialization through private-sector led and market-driven growth and development.

The Genesis
Cassava is one of the most important crops for Nigerian agriculture. It is widely cultivated and provides food and income for nearly 30 million farmers (Ezedinma, 2006). However, the crop is threatened by Cassava Mosaic Virus Disease (CMD) which devastated crops in Uganda in the late 1980s (Ogbe, 2001). By 1999, CMD had become a pandemic in East and Central Africa where it caused up to 100 percent loss of the crop. In 2001, a diagnostic survey of CMD by IITA in farmers' fields of 17 States found that mixed infections of the viruses are now widespread in southern Nigeria (Figure 1). This situation posed a threat to the entire cassava industry in Nigeria.

The fast-track participatory selection approach
To mitigate this possible setback, the strategy adopted was to assemble a large pool of human resources from NARS, the universities, industry, government, farmers, and processors to engage in breeding/evaluation activities. The objective was to facilitate cultivar-substitution by replacing the susceptible varieties on farmers' fields with superior genotypes that were not only CMD resistant/tolerant but also high yielding (Figure 2). From this exercise, 12 new varieties (TMS 98/0510, TMS 98/0581, TMS 98/0505, TMS 97/2205, TME 419, TMS 92/0326, TMS 96/1632, TMS 98/0002, TMS 92/0057, NR87184, THS 96/1089, and NR 930199) were officially released by the Nigerian National Variety Release Committee in only 4 years (2005-2008). These

varieties are resistant/tolerant to CMD, and other major pests and diseases of cassava, such as bacterial blight, anthracnose, cassava green mite, and cassava mealy bug. They are also high yielding (25-40 tons/ha compared to the national average yield of 10-12 tons/ha; Figure 3), early maturing (about 10-12 months compared to 18-24 months for the old varieties) and suitable for food, industry, and livestock feed.

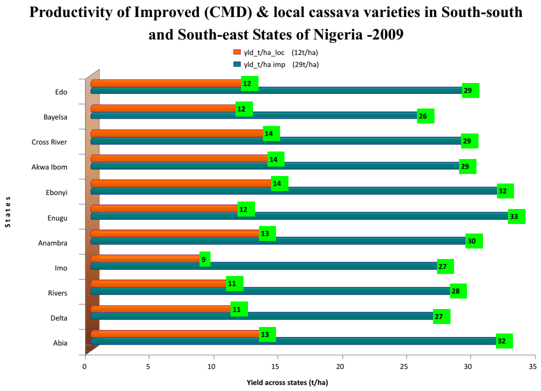

Figure 1: Histogram showing yield in various States

Improving on-farm productivity for large-scale processors

Recently, this large pool of improved cassava germplasm was used to increase the on-farm productivity of farmers supplying tubers to large-scale processing industries. These agro-processors are: EKHA Agro (specializes in glucose syrup), MATNA (Starch production) both in the south-west of Nigeria, and NSM (industrial starch), south-east, and NOVUM (cassava flour) in the middle belt of Nigeria. From the preliminary discussions with the large scale agro-processors, it was clear that the major constraint faced is lack of sufficient fresh cassava roots to feed the factory. These agro-processors are currently operating below 30% of their installed capacity. They find it difficult to source for enough cassava to feed their factories; this is partly due to high demand for traditional food items and partly due to subsistence nature of farming with inherent low productivity. Therefore, the supply was made to be more cost-efficient by increasing cassava productivity, using clustering arrangement and linking farmers to service providers. This has produced good results in several cassava projects of the institute resulting in not lest that 150% increase in productivity and commercial farming orientation The role of IITA in the USAID-MARKETS Cassava Value Chain Project is to ensure that the farmers grow and manage these high yielding varieties very well to supply the much needed raw materials to the industries. To achieve this objective requires a series of activities:

Mobilization and clustering

This task commenced by selecting/identifying the large-scale industries (through visits and discussions) which will provide a market for cassava raw materials produced by small-scale farmers. EKHA, MATNA, and Nigerian Starch Mills (NSM) were recommended for participation in the USAID-MARKETS Cassava Value Chain Project. Several joint stakeholders' meetings were held by IITA and USAID-MARKETS with the agro-processors to discuss business plans and ascertain the suitability of the processing facilities. Following these were several formal and informal meetings between IITA and the large-scale agro-processors to further develop strategies for improving the supply of raw cassava materials to optimize the performance of their centers. Series of these workshops were held with farmers in project different locations of the agro-processors, with resource persons coming from USAID-MARKETS, IITA, Nigerian Agricultural Co-operative and Rural Development Bank (NACRDB), and First Bank. At the end of these workshops, farmers were clustered around each of the agro-processors. IITA currently adopts three farmers' clustering approaches: clustering farmers within their traditional settings with non-contiguous farms, clustering farmers on large expanses of communal or State-owned land outside traditional settings, and clustering of farmers on a large expanse of land owned and managed by farmers.

Training programmes

The majority of farmers producing cassava depend on inherited knowledge mostly from parents or neighbours. Extension agents do not also update knowledge frequently and their efficiency is constrained by a farmer-extension agent ratio estimated at over 2000:1 in Nigeria. Therefore, improved practices for enhancing yield, though have been developed, remain on the shelf partly due to inefficient extension systems and less hunger for information by farmers. As a result, strategies for enhancing yields among small holder cassava farmers should address capacity building and training of farmers on competitive cassava production. It is against this background that IITA exposed more than 4000 farmers to various trainings ranging from pre-planting and pre-harvest agronomic practices, cost-efficient use of herbicides, land clearing and soil fertility management and enterprise development. These trainings were also supported with series of demonstration event such as the use of mechanical, planter, brush cutter, stem handling techniques, and mechanical harvester.

Demonstration trials/events

For competitive and commercial cassava production, introduction and demonstration of the use of cost effective and time saving machineries for farming operations is important. This will not only replace or complement human labour with machines but it also ensures that farmers perform their farm operations within a short period of time. Most farmers do not have access to these machine, thus the project demonstrates it use and ensures linkages with such service providers.

The project is also highly responsive to emerging opportunities that enable the value chain to be efficient, for example establishment of demonstration plots for farmers' training. IITA established a total of 40 on-farms Demo Trials managed by selected farmers and closely supervised by IITA technicians to ensure that the recommended practices are followed. These practices included optimal plant spacing, cost-effective weed control practices, soil fertility management, mechanical harvesting and post harvest handling. The sizes of the demonstrations were between 0.5 and 1.0 ha, depending on the land available to the farmer. The trial was demonstrated such that half of the plot received farmers' practices while the other half demonstrated improved technologies. Data generated from demonstrations was used to validate existing crop budgets for cultivation under various technologies, e.g., with and without fertilizer application; herbicide application, selection verse non-selection of stems, etc. These On-farm demonstrations were used during field days and other training events to illustrate and discuss improved practices in an interactive way with farmers. IITA provided inputs, including cassava stems, fertilizers, CPPs, tractor and harvester needed for the demonstrations while partnering agro-processors/farmers provided tractors for land preparation.

Development and distribution of extension guides

To complement capacity building activities and demonstration events, IITA developed and distributed comprehensive extension materials targeted at improving knowledge and transferring technologies to farmers. One advantage of the extension materials is that farmers could refer to them at anytime. 6 different technologies were transferred to farmers through extension publications on soil fertility management, stem handling techniques, weed management, harvesting and post-harvest handling, zero input technologies and cost-efficient mechanization practices.

Linkages to service providers

IITA facilitates linkages between the service providers such agro-dealers and mechanization providers especially the ones close to farmers and the farmers to ensure easy access to their services by the farmers. In the same vein, formation and training of commercial weed control business groups who can assist farmers with cost effective weed control practices are brought into the arrangement. Major input dealers provide agro-chemicals to the farmers at affordable prices, and loans from the financial institution are facilitated. These linkages led to the creation of new jobs to about 219 farmers. The incentive stimulated farmers to patronize the input dealers and this has led to the opening of village shops in the participating communities, thus making the inputs to be readily available and accessible to farmers. Various chemical companies have established close contact with farmers, willing to deliver their inputs to farmers on time. The price has also become competitive and farmers now have choice to make.

Distribution of germplasm

Yield gaps in cassava production can be bridged using high yielding and multiple pest resistant varieties developed by IITA in addition to improved agronomic practices that combine cost-efficiency and environmental friendliness (Nweke, 2002). However, access to these planting materials by farmers has been constrained over the years by low multiplication ratio and weak extension systems (Tarawali et al, 2008). IITA empowered farmers in this program through the multiplication and dissemination of improved high yielding varieties to farmers in the project locations. Each farmer mobilized and clustered around the large scale agro-processors received 60 bundles of improved planting material, which was adequate enough to plant 1ha.

Monitoring and evaluation

The institute has in place a monitoring and evaluation system that follows up the project activities to ensure that all the stakeholders particularly the farmers are properly carried along and facilitate proper linkages and extension services. The system also guarantees timely collections, management, and reporting of valid and reliable data that meet donor reporting requirements

Achievements

This scheme which started in April 2009 has so far distributed cassava stems sufficient to plant more than 1000 ha to more than 1000 farmers, established 40 DEMOs in strategic locations, trained over 4000 farmers in different competitive cassava production techniques (including demonstration events on the mechanical planters, sprayers, stem and brush cutters), linked farmers to services providers such as agro-dealers and mechanization service providers and developed and distributed to farmers, six extension publications on competitive cassava production. A total of 8 production technologies associated with land clearing, soil fertility management, stem handlings, weed management, spacing, herbicides application, fertilizer application, and harvesting and post-harvest handlings. In addition to these, 22 weed control groups were established resulting to job creation for 219 farmers. The program has successfully increased yield from the baseline figure of 13.56 ha to an average yield of 35 ha (about 158% increases in yield) in the 2009/2010 planting season. These capacity building efforts will not only encourage cassava productivity at the farm level for the industries (producing mainly glucose syrup and starch) which at the moment are operating far below their optimum capacity but will also generate more income and jobs for the farmers. Following the successes of this program, the agro-processors demanded for additional 2700 ha (EKHA 2000 ha; MATNA 2000 ha; NSM 200 ha and NOVUM 200 ha), which is already being implemented for 2010 planting season. Summary of the achievements in this program is presented in table 1 below.

Table 1: Achievement in IITA-MARKETS cassava value chain project

Activity	Output
Number of direct farmers mobilized/networked for large scale industries	1085
Number of indirect farmers mobilized/netwo rked for large scale industries	3000
Number of training conducted	4
Number of demonstration events	3
Number of farmers trained	4049
Number Demo Trials established	40
Area under improved management practices established	1304 ha
Number of farmers that received improved cassava cuttings	1304
Number of weed control business groups created	22
Number of jobs created as a result of weed control business groups	219
Number of extension publication developed	6
Number of farmers that received extension publi cations	>4000
Number of improved management practices made available to farmers	8
Number of farmers adopting new technologies or management practices as a result of project intervention	>4000
Number of people trained on private sector development training	291
Number of extension publication developed	6
Number of farmers that received extension publi cations	>4000
Number of improved management practices made available to farmers	8
Number of farmers adopting new technologies or management practices as a result of project intervention	>4000
Number of people trained on private sector development training	291
Change in productivity of cassava production	158%

The past and present scenarios

This cassava value chain development approach built on the efficiency of private-led businesses encouraged the best agronomic practices *and* guaranteed an effective and sustainable supply of raw materials to large scale industries (Figures 2 and 3).

Figure 2: Before IITA's intervention (2008)

Figure 3: After IITA's intervention (2010)

Conclusion

The community value chain development approach has been proved as an effective model for making cassava agribusiness work in an evolving consumer preference driven system. The effective linkages and participation among major actors in the cassava agribusiness value chain have enhanced the reliability and efficiency of the input supply system, adoption of yield enhancing production technologies in productivity increase and better income for cassava farmers, and processors. According to the US Ambassador Robin Renee Sonder, during her recent visit to EKHA Agro factory, "*small-scale farmers will double their productivity and increase their net income by over 150 percent, thanks to better yield and higher prices*".

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Ex-ante economic impact of the biotechnological research on cassava brown streak disease in eastern and southern Africa

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Abstract

Cassava brown streak disease (CBSD) is a major threat to cassava production in eastern and southern Africa. While the conventional breeding approach is being used to address the problem, biotechnology can also be an option.

This paper presents results from an ex-ante assessment of returns to biotechnological research to control CBSD in three countries of eastern and southern Africa (Malawi, Mozambique, and Tanzania) worse affected by the virus. Returns to research can yield benefits as high as US$ 260 million at 10% discount rate over a projected period of 25 years. Mozambique share of the benefits was the biggest because of its largest share in the cassava producing area. Among the parameters used in the surplus economic model for data analysis, the maximum adoption rate has most influence on the results. The other main challenge consists in collecting accurate data to run such analyses. Despite these challenges, biotechnology should be considered as an option in the control of CBSD or other biotic stresses on agricultural commodities in Africa.

Keywords: Biotechnology, economic evaluation, cassava, Africa

Introduction

Cassava (*Manihot esculenta* Crantz) is one of the widely grown staple crops in sub Saharan Africa. Total production is estimated to be more than 90 million tones (FAO, 2001), which is greater than for any other crop in Africa. The crop is grown in 39 African countries, of which Nigeria, Democratic Republic of Congo, Ghana, Tanzania and Mozambique are among the top ten producers in the world (FAO, 2007).

The average cassava fresh root yield in eastern and southern Africa is still low at about 8 t/ha (FAO, 2005). This is well below the continent's average of 10 t/ha and the average yield of 14 t/ha of Africa's (and the world's) largest producer, Nigeria. The low yield is caused by many factors including susceptibility of commonly grown varieties to major diseases and pests such as Cassava Mosaic Disease (CMD), caused principally by the East African Cassava Mosaic Virus (EACMV), its Ugandan variant (UgV), and the African Cassava Mosaic Virus (ACMV), Cassava Brown Streak Disease (CBSD), Cassava Bacterial Blight (CBB), Cassava Green Mite (CGM) and Cassava Mealy Bug (CMB). Low soil fertility and drought are also yield-limiting factors of cassava in the country (Manyong et *al*. 2007).

CBSD is one of the most important biotic constraints on cassava production. In Tanzania, Mtunda et *al*. (2002) found a mean incidence of 30% and mentioned average yield losses of 34%. For the aggregate production of cassava in Tanzania using the data from FAO (2005), it was estimated that 48% of this production is produced in coastal areas (Mtunda *et al.,* 2002). Using these estimates and assumptions of 30% of incidence and 34% of yield losses, about 350,000 Mt is presumably lost in coastal regions due to CBSD. In economic terms, Kanju (2004) gave estimates of USD16.5 million losses due to CBSD. In Malawi, extensive surveys were conducted in 2001 and 2002 (Gondwe *et al*., 2003). CBSD was found along the shores of Lake Malawi at low altitudes between 400-1000m asl. Over 40% of the crops were infested. The mean loss in production was estimated to range between 20-25% of the harvest. In Mozambique, the incidence of CBSD is mainly in the Nampula and Zambezia provinces with a mean incidence of 30% and 40% respectively (Tresh, 2001). These two provinces account for the majority of cassava production in Mozambique.

While a substantial effort has been dedicated to the management and control of other cassava pests and diseases (such as CMD, CGM and CMB) CBSD has received little attention. An initiative to tackle CBSD has been engaged at the International Institute of Tropical Agriculture (IITA) and its collaborators from 2002, supported by Rockefeller Foundation. Other comprehensive interventions are supported by National Resources Institute (NRI-UK) to elucidate the nature, patterns of infection, and methods of spread and field dynamics of CBSD using both conventional and biotechnological tools in order to build effective and sustainable programs. Some of these efforts are paying off as "field tolerant varieties" have been identified and on-farm trials show very good promises (IITA-Tanzania, 2007).

While conventional breeding efforts are attempting to address many cassava constraints (bacterial and viral diseases, insect pests, weeds and drought all combined) progress has been slow, partly because of the crop's complex genetic makeup, which makes it difficult to develop new strains efficiently. According to Mantel (2002), many scientists think that new tools such as biotechnology offer useful approaches to cassava improvement. There is potential to efficiently identify beneficial traits in wild and domesticated cassava plants and then transfer these traits to farmer-preferred cassava varieties. This could be the case for biotechnology research to control the devastating CBSD. Two research questions need to be addressed: Is it worth investing in biotechnology for the control of CBSD and what are the challenges of conducting research on ex-ante impact of returns to research on biotechnological interventions against CBSD? The objectives of this study were therefore to calculate the streams of benefits associated with the development of a transgenic CBSD cassava resistant variety at IITA in order to predict ex-ante the profitability of investing in biotechnology research for the control of CBSD, to identify research challenges brought about by this study, and to recommend future areas for research in this area

The paper is organized into four sections. After the introduction, the second section describes materials and methods. The third section presents major results and their discussion. The last section reports on conclusions and areas for future research.

Materials and Methods

Theoretical approach

We applied the conventional economic surplus model (ESM) that is used to assess returns from technical change in agriculture (Alston, 1995). ESM are used extensively in economic literature to compare alternative investment options or the profitability of a single investment. The approach is to capture the average yield gain from technical change. The effect of a technical change is to shift the surplus curve (yield increase) to the right from a "before period" (So) to the "after period" (St) and to increase the consumer surpluses (through lowering the price from Po to Pt) and producer surpluses (from increasing the quantity supplied from Qo to Qt). The combined total benefit to consumers and producers represents the change in economic surplus. More details about the graphic representation of an ESM and equations to compute consumer and producer surpluses for this study can be found in Vercauteren (2005). The net present value (NPV) was applied to evaluate the total gains. In general, an investment with a positive NPV is considered profitable.

Empirical model

The computation of the empirical ESM model requires data on various factors, which were collected from literature.

Current cassava areas affected by CBSD and yields

The study area includes the cassava producing regions of three countries where CBSD has been reported (IITA, 2005). The three countries are Malawi, Mozambique, and Tanzania. In Malawi, the study covered the shores of Lake Malawi made of eight agricultural development divisions (ADDs) of Karonga, Mzuzu, Kasungu, Salima, Lilongwe, Machinga, Blantyre, and Shire Valley covering an area of about 154,000 ha with an average yield of fresh roots of 13.5 mt/ha. Gondwe et *al*. (2003) estimated an incidence rate of 40% and mean loss in production ranging between 20-25% of harvest. In Mozambique, the cassava regions are in the northern provinces of Cabo Delgado, Nampula, and Zambezia covering about 940,000 ha with an average yield of 10 mt/ha. Incidences rates of CBSD were about 40% in Nampula and 30% in Zambezia (Hillocks *et al*. 2001). We applied a conservative estimate of 20% in Cabo Delgado and the average yield loss of Malawi to Mozambique as a whole, in the absence of any other alternative source of information. In Tanzania, the study covered the regions of Tanga, Coast, Dar es Salaam, and Mtwara on an area of about 660,000 ha and an average yield of 10.4 mt/ha. Mtunda *et al*. (2002) found a mean incidence of 30% and mentioned average yield losses of 34% in the coastal areas where it was assumed that 48% of cassava is produced in the country.

Yield gains through biotechnology intervention

The effects of CBSD on cassava roots are on the weight reduction of fresh roots and quality loss for severely damaged roots. In this study we assumed that the above mentioned percentages yield losses account for the two parameters. As a conservative approach, the possible yield gains through biotechnology intervention were raised with a percentage equal to the current yield losses.

Exogenous growth in demand of cassava, acreage and yield gain

We considered that cassava is mostly used as a food crop for local subsistence that is a closed economy. Therefore, population growth was the only exogenous factor driving the demand of cassava. It was assumed that the population in Malawi, Mozambique and Tanzania approximately doubles in 2050 (reaching 25, 31, and 69 million persons), compared to current figures. Scott *et al*. (2000) projected an annual increase in area planted to cassava at 1.09% and that of cassava yield at 1.34%. These rates were kept during the first ten years in all the countries, letting it stabilize after 2016 because the uncertainty would make longer estimates very hard and unreliable.

Elasticity of supply and that of demand

The elasticity of supply and that of demand have an important influence on the consumer and producer surpluses and affect the overall outcome. Alston *et al*. (1995) advise to apply a supply elasticity of 1 if no better information is available, as it is the case in this study. However, since there is a limited possibility for cassava production growth, we assumed a supply elasticity of 0.8 in our empirical model. As to the elasticity of demand, we adopted that of -0.6 for Africa that was used by Gottret and Wood (1997) in their global impact assessment model for cassava.

Time frame

Carliene (2004) mentioned that the time frame for moving transgenic crops from the lab to farmers' fields is typically 10-15 years. At IITA, scientists developed a 3-year project proposal to complete the transformation and molecular analysis of transgenic plants together with the laboratory and greenhouse testing (IITA, 2005). If a 3-year research period is considered, and another five years for field test adoption, then a conservative approach of 10 years for the research phase was used in the basic model. The projections are that the adoption of CBSD resistant varieties would start in 2015 up to 2040 when the full benefit of the CBSD technology is expected. Therefore, the time frame for the projections of streams of benefits and costs in this study runs from 2005 to 2040.

Maximum rates of adoption of improved cassava varieties

Reliable data are not often available on the adoption of cassava varieties in the study area. Manyong *et al*. (2000) estimated adoption rates of 10% for Malawi and 38% for Tanzania (no figure for Mozambique) in 1998. Nweke et al. (2001) estimated that improved clones cover between 20% and 50% of the cassava acreage in Tanzania. Haggblade and Zulu (2003) mentioned that 60 to 70% of the cropped area is planted with improved cassava varieties in Malawi while Jumbo *et al*. (2007) recently reported adoption rates of 40% only from a sample of 834 households in the same country. Due to uncertainty about the coverage rate, we considered conservative maximum adoption rates of 40% for Malawi and Mozambique and 50% for Tanzania in this study. We applied an S-shaped adoption path as recommended by Alston *et al*. (1995) over the 25-year of the adoption period and results are depicted in Figure 1.

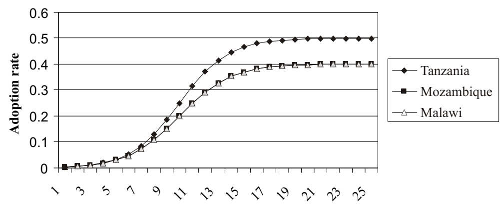

Figure 1: Computed adoption rates of CBSD resistant varieties

Costs for research and deployment of the technology

Qaim and von Braun (1998) considered five stages along the path of a transgenic crop for which costs and benefits should be computed: basic research, applied research, technology development, technology diffusion and technology application. Costs are incurred over all the phases while the stream of benefits begins to be perceived at the end of the third phase. The cost considered in this study would apply to three stages only of the above path and it was based on the project proposal by IITA (2005) for the development of CBSD resistant varieties, which amounts to about half a million of US dollar over the period of three years. This cost should not be regarded as the total cost of a transgenic cassava because it does not take into account the costs of basic research, costs of field testing, or costs of extension work. The cost is important in estimating the cost-benefit ratio or the internal rate of return. In this study, we only estimated the possible benefits of increasing cassava production to achieve our objective of priority setting. We also neglect the costs involved in bio-safety testing and compliance with country regulations on the introduction of transgenic crops. These costs could be very substantial, particularly if there is a negative attitude towards transgenic varieties. At this stage, it is impossible to reasonably estimate the costs of compliance. We make the assumption of not taking them into consideration in this study.

Cassava prices and discount rates
Two discount rates were considered at 5% and 10% for the computation of net present values (NPV). The prices of cassava were from Manyong *et al*. (2000) and applied in each country as follows: US$70/ton for Tanzania, US$71/ton for Malawi, and US$83/ton for Mozambique.

Uncertainty
Modelling of future returns to investments always involves levels of uncertainty during the research stage, for the time taken to complete research, uncertainty about the outcome, and uncertainty in calculating the expected benefits. Therefore, a sensitivity analysis was performed on some of the technical parameters of the ESM to identify those that significantly affect the outcome from the exercise. Another issue is about the riskness of alternative solutions from the model. Arrow and Lind (1970) argue that risk caused by intrinsic uncertainty of doing research from public investments is insignificant and should not be taken into account because the decision takers should be risk-neutral.

Data analysis
Secondary data from published documents were analysed using a template developed in Microsoft Excel. The sensitivity analysis was performed using the @ RISK software. The details of excel model can be found in Vercauteren (2005).

Results and Discussion

Cassava production lost due to CBSD
The estimated losses due to CBSD on the affected cassava regions indicate an aggregate loss of fresh cassava roots of about 1 million tons (Table 1). Mozambique has the largest share of loss (60%) due to its large share in areas grown to cassava, followed by Tanzania (30%) and Malawi (10%). The lost production is worth providing adequate energy intake for up to 1.5 million persons.

Table 1: Estimates of current losses due to CBSD

Cassava Regions	Cassava production (1000 Mt)	CBSD incidence (%)	Loss estimate (%)	Cassava production loss (1000 Mt)
Malawi	1,711			
Lake Malawi area	1,711	40	20-25	137-171
Mozambique	11,458			
Nampula	4,800	30	20-25	288-360
Zambezia	2,970	44	20-25	261-327
Cabo Delagado	2,080	20	20-25	83-104
Tanzania	7,000			
Coastal regions (Mtwara, Lindi, Tanga, Coast, and Dar es Salaam	3,360	30	30-35	302-353
Total				1,071-1,315

Gains from CBSD resistant cassava
We calculated the equilibrium price in the case there is successful development of a transgenic cassava. The results show that the projected price will initially decrease in all the regions due to higher projected growth in supply than in demand. This pattern will continue until the projected growth in supply disappears in the year 2015. The equilibrium quantities were also computed and the surplus generated thanks to the new CBSD resistant cassava were calculated for each region. From this information, the estimated NPV of the benefits from the increased production using all data in the basic model accrue to more than US dollar 880 million at 5% discount rate over the period 2005-2040 (Table 2). Not surprisingly the greatest benefits are to be expected in Mozambique since the CBSD affected regions are very large. Even at a stiffer discount rate of 10%, the expected benefits of increased cassava production are still very attractive. Spill over effects from such an investment would be expected from other regions where CBSD is also present but less damaging than in the areas considered in this study. More important, the availability of such CBSD resistant varieties would save several other millions ha of cassava land where CBSD could migrate in the future. Those results provide a strong economic evidence for investments in the biotechnological program for the control of CBSD.

Table 2: Expected benefits from CBSD resistant cassava varieties

Country	Benefits at 10% discount rate (million US$)	Benefits at 5% discount rate (million US$)
Malawi	22	75
Mozambique	153	518
Tanzania	85	289
Total	260	883

A sensitivity analysis was conducted to assess the effects of changes in some of the key parameters used in the analysis. The analysis was done for each cassava region separately and using the same discount rate of 5%. The results on NPV from sensitivity analysis lay between US dollar 472 and 1312 million, indicating the profitability of investing in the biotechnological control against CBSD. The parameters that have most influence on the results are maximum adoption rate, followed by the elasticity of supply as shown in Table 3 for Nampula province. The uncertainty related to other exogenous parameters (growth in area and yield and elasticity of demand) seem to be of a lesser importance. These findings for the Nampula province also apply to other regions as the ranking on the parameters remains identical.

Table 3: Sensitivity analysis on Nampula province: Results on the ranking of important parameters of the model

Rank	Parameter	Regression coefficient	Level in the base scenario (BS)
1st	Maximum adoption rate	0.651	40%
2	Elasticity of supply	-0.452	0.8
3	Expected yield gain	0.38	130% of BS
4	Years of research	-0.379	10 years
5	Exogenous yield growth	-0.029	1.34
6	Elasticity of demand	-0.017	-0.6
7	Exogenous area growth	0.016	1.09

Therefore, it can be argued that collecting accurate information on areas planted to improved varieties of cassava would lead to smaller intervals for this parameter and help better forecast benefits from investing in new cassava varieties. In another study about the expected benefits from *Nikwaha*, a CBSD tolerant cassava variety in coastal Mozambique, McSween *et al*. (2006) also found out that the adoption rate of improved varieties was the most important parameter affecting the streams of benefits.

Conclusion and future areas for research

Investing in biotechnology for the control of CBSD would result in high benefits. Therefore there is a niche for biotechnology in developing new cassava varieties. The larger the cassava areas infested with the disease, the larger the benefits to investments. Therefore, proper targeting of the new CBSD resistant varieties to areas most affected is needed in order for biotechnology to yield high benefits. It is clear from the findings of this study that the success of biotechnology would depend very much on the coverage of the new technology. Even areas with currently low levels of infestation would also benefit from current investments if the coverage rate increases. The spread of a new technology depends on the technology specific attributes and researchers need to take into consideration agronomic traits, consumers and market preferences. The spread of a new technology also requires conducive policy and institutional arrangements that fuel the rapid dissemination of the technology such as efficient extension systems and approaches. The shorter the research lag to make the breakthrough and the higher the yield gains, the higher the expected benefits from biotechnological research on CBSD. Research institutions are tasked to adopt the most efficient biotechnology tools that lead to quick and sustainable results.

This study has also highlighted challenges in conducting ex-ante impact studies on biotechnological research, which need to be addressed in future research. The availability and accuracy of secondary data is a major factor for success in ex-ante impact studies. Lack or unavailability of robust data comes from the lack of an impact culture whereby research activities are often designed without the conscious aim of ultimately measuring impact. Such studies often miss to collect meaningful data during the research process that could be needed in impact studies. The need for an impact culture within institutions needs to be re-emphasized. Adoption studies to collect accurate data on areas planted to improved cassava varieties must be generalised. Likewise consumption studies need to be initiated in order to have good data on elasticity of demand. The cost of deployment of new CBSD resistant varieties needs to be included in future studies about the evaluation of benefits from biotechnological research. This is a major limitation for the current study although one can argue that the cost of extension would be low compared to that of cereals for example (in particular for hybrid varieties) since the new cassava varieties do not require a costly seed system for continuous production of planting materials at each cropping season. The inclusion of costs for deployment of new CBSD resistant cassava would lower down the magnitude of expected benefits but it will not alter the general recommendation about the profitability of investments from biotechnological research to control CBSD in cassava production.

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Improving urban markets supply with Kponan yam for poverty alleviation: Case analysis in Abidjan, Côte d'Ivoire

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Abstract
In Côte d'Ivoire, Kponan (*Dioscorea cayenensis rotundata*) yam variety is the most appreciated and consumed in urban centre but for the reason of high selling prices, this product is inaccessible to poor residents. A socio-economic survey was conducted in Abidjan to analyse the efficiency of the market supply chain. The study is based on weekly data collected on prices and quantities sold on markets. Analyses revealed that the most important part (54 %) of Kponan yam supply is provided by the production zone of Bouna-Bondoukou (located within 400 to 600 kilometers from Abidjan). High selling prices of Kponan yam are mainly due to high charges of transport (43 to 74 % of the total cost of commercialization), commissions (12 to 20 % of the total cost of commercialization) taken by middlemen and high profit margins (47 to 63 % of the consumption price) earned by actors. It's was also found that wholesale markets are more competitive than retail ones. Retailers obtain the highest profit margin (23 to 43 % of the consumption price) whereas they don't improve final quality distribution of yams to consumers. For a better access to Kponan yam by consumers, producers and wholesalers should make sale cooperatives and policy makers have to develop markets information system.

Keywords: Kponan yam variety, urban markets, supply chain, poverty, Côte d'Ivoire

Introduction

In Côte d'Ivoire, yam (*Dioscorea spp*) constitutes the basic food crop for population (Sawadogo, 1977). Kponan (*Dioscorea cayenensis rotundata*) yam variety in particular, is the most appreciated and consumed in urban centers (Nindjin and *al*., 2003) but for the reason of its high price, this product is inaccessible to poor residents. Abidjan is the main urban center for yam consumption in view of the relative importance of its population. In order to analyze the efficiency of the Kponan yam's supply chain of Abidjan, a socio-economic survey was undertaken.

Materials and Methods

Efficiency analysis of Kponan yam's supply chain was based on a weekly data collection on prices and quantities sold on various markets in Abidjan. A survey was conducted on twenty-five (25) wholesalers for two campaigns (July 2000 to June 2001 and July 2001 to June 2002) of yams commercialization. Analyses consist firstly in determining contribution of each yam's supply chain to Abidjan' markets. For the Kponan yam's supply chain, commercial actors were identified. The typology of theses actors was established and the role of each one was described. The structure of commercialization's costs and margins in the supply chain were analyzed. With price series, markets' integration was measured by calculating Pearson correlation coefficient. Cointégration of markets was tested by Augmented Dickey Fuller's test (Engle and Granger, 1987). The markets' integration indicates the competitiveness (or efficiency) in the distribution system.

Results

Yams' supply chains of Abidjan: Three different yams' supply chains exist in Abidjan (Figure 1). The contribution of the chain of Bouna-Bondoukou-Abidjan (54 %) is highest than those of Bouaké-Abidjan (28 %) and Korhogo-Abidjan (18 %). The first one is specialized for the commercialization of Kponan (*Dioscorea cayenensis*) yam variety. The second one is specialized for the commercialization of Bètè-Bètè (*Dioscorea alata*) yam and the third one for Krènglè (*Dioscorea cayenensis*) yam (Figure 2).
The efficiency of a supply chain is related to the importance of quantities of goods and services put on markets for consumers. In view of quantities sold on markets, the chain of Bouna-Bondoukou-Abidjan is more efficient than the chains of Bouake-Abidjan and Korhogo-Abidjan.

Typology and role of actors of Kponan yam's supply chain: The Kponan (D. c. r.) yam variety is produced by the Lobi ethnic group in the production zone of Bouna-Bondoukou. This region is situated within 400 to 600 kilometers from Abidjan. Producers are 25 to 68 years old with an average age of 45. Educational level of a major part (81.8 %) of producers is illiteracy. The others (18.2 %) are of secondary school level. Producers are also traders. After the harvest, yams are conveyed directly to Abidjan by producers or stocked in a warehouse for rural wholesalers. In Abidjan, producers solicit help of middlemen (named coxers) to sell yams to urban wholesalers. As remuneration, these middlemen take commission on each kilogram of yam sold to wholesalers on market. According to producers, commissions taken by these middlemen induce rise in price. Beside the producers, collectors are also in charge of the supplying of Abidjan' markets with yams. Collectors are 23 to 58 years old and the average of age is 35. The majority (45.5 %) of theses actors are illiterate. The others are of secondary school level (27.3 %), primary school level (18.2 %) and koranic school level (9.1 %). Major ethnic groups of collectors are Lobi (63.6 %) and Doula (18.2 %).

In the production zone of Bouna-Bondoukou, the yam's supply is scattered. Thus, collection of yams is made by collectors in collaboration with yams' trackers. Trackers are young and native from the region of Bouna or Bondoukou. Their role consists in prospecting villages for yams' producers. After the prospection and collection of yams, a charge of 20 tons is loaded in a lorry of 16 tons capacity. This overweight induces injuries and breakage of yams which are bargain away on markets. For any food product commercialized in Côte d'Ivoire, traders have to pay a free pass at OCPV (Office for commercialization of food crops). Incidental expenses are also required by policemen. According to wholesalers, the high selling price of Kponan (D. c. r.) yam in Abidjan is due to incidental expenses paid to policemen and commissions taken by middlemen.

In the urban zone of Abidjan, principal actors are wholesalers and retailers. There are two types of wholesalers: primary wholesaler and secondary wholesaler. The first one is able to buy all of the charge of 20 tons of yams coming from the production zone. The second one buys yam with the first one and resells it on markets.

Primary wholesalers are men in majority (96 %), less old than 40 years (53 %) and are non-Ivorian (57 %). Principals' ethnic groups of Ivorian primary wholesalers are Dioula (43%) and Sénoufo (39%). Secondary wholesalers are also men in majority (99 %), less old than 40 years (87%) and are non-Ivorian (66 %). Ethnic groups of Ivorian secondary wholesalers are also Dioula (42%) and Sénoufo (35%). The proportion of non-Ivorian wholesalers (42 % for primary wholesalers and 44% for secondary ones) is native from bordering countries (Niger, Mali, Burkina-Faso and Ghana).

Contrary to the wholesale activity, the retail one is monopolized by women (77 %). Retailers are 18 to 57 years old and a great part (56 %) of them is less than 30 years. In majority, retailers are Ivorian (77 %) and ethnic groups are Dioula (35 %), Baoulé (14 %), and Sénoufo (11 %). The proportion of non-Ivorian retailers (23 %) is also native from bordering countries (Mali, Niger, Benin, Burkina-Faso and Togo). It was also found that a major part of retailers is illiterate (72%). The other part is of primary school level (23 %) and of secondary school level (5%). Retailers are in charge of the distribution of yams on markets in Abidjan.

Costs and profits margins of Kponan yam's commercialization: Analyses revealed that an important part (71 à 78 %) of the total cost of Kponan yam's commercialization occurs during collection (Table 1). This great part of costs is due to charges of transport (40 à 57 %) and commissions taken by middlemen (12 à 20 %). In relation to the consumption price, this proportion varies from 13 to 21 %. Out of the price consumption, the transport cost goes from 4 to 12 % and commissions taken by middlemen, from 2 to 3 %. Margins analyses revealed that a great proportion (47 à 63 %) of the consumption price constitute profits margins of commercial actors. It was also found that the highest profit margin (23 à 43 %) is taken by retailers whereas they don't improve the final quality of the distribution of yams to consumers.

Markets Integration: The markets' integration is tested with price series of wholesale markets (Treichville, Abobo, Adjamé and Yopougon) and retails markets (Abobo-Avocatier, Adjamé-Complex, Yopougon- UTB and Treichville-Gare Bouna). Pearson correlation coefficients showed that wholesale markets (0.391 to 0.901) are more competitive than retails ones (0.477 à 0.511) (Table 2). The degree of influence within markets goes from 15 to 80 % for wholesale markets and from 23 to 26 % for retail ones.

Augmented Dickey Fuller' (ADF) tests revealed that the wholesale market of Treichville is co-integrated with all of the others wholesales markets of Abobo, Adjame and Yopougon (Table 2). The Treichville wholesale market constitutes the central market of Kponan yam in Abidjan. Prices of this central market influence secondary ones. ADF tests revealed a weak co-integration within retails markets.

Correlation and cointégration analyses confirm that wholesale markets are more competitive than retail ones.

Discussion

This study of efficiency of the Kponan yam's supply chain revealed that the high price of this variety on markets of Abidjan is due to high operating costs and profit margins taken by actors. Prices could be reduced by reducing costs and profit margins. In order to reduce transport costs, producers and wholesalers should make sale cooperatives and policy makers have to develop markets information system. This political economy should reduce the consumption price of Kponan yam in Abidjan markets for a better access to poor residents.

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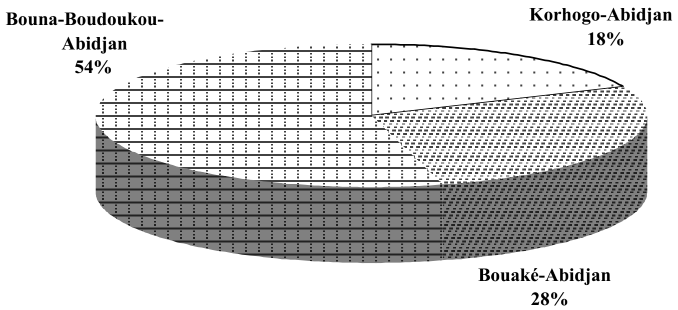

Figure 1: Contribution of different yams' supply chains of Abidjan.

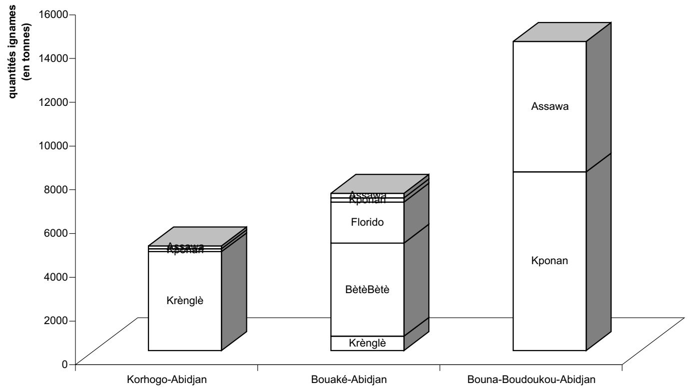

Figure 2: Varieties of yams commercialized by supply chain in Abidjan

Table 1: Commercialisation's costs and margins in Kponan yam supply chain

		July to August				September to November				December to January			
Actors	Rubric (F CFA/Kg)	Mean	%TAC	%TC	% FSP	Mean	%TAC	%TC	% FSP	Mean	%TAC	%TC	% FSP
Collector	Purchasing price	91,50				64,67				78,50			
	Selling price	235,50				121,67				132,00			
	Gross margin	144,00			36,59	57,00			27,58	53,50			17,66
	Costs												
	Yams tracker commission	3,50	8,78	6,84	0,89	1,13	3,35	2,58	0,55	3,50	9,76	6,97	1,16
	GVCcommission	2,00	5,02	3,91	0,51	2,00	5,92	4,58	0,97	2,00	5,58	3,98	0,66
	Lading to store	0,60	1,51	1,17	0,15	0,75	2,22	1,72	0,36	0,60	1,67	1,19	0,20
	Transportto store	6,00	15,06	11,73	1,52	0,00	0,00	0,00	0,00	6,00	16,74	11,94	1,98
	Unloading to store	0,60	1,51	1,17	0,15	0,00	0,00	0,00	0,00	0,60	1,67	1,19	0,20
	Renting store	1,50	3,76	2,93	0,38	0,00	0,00	0,00	0,00	1,50	4,18	2,99	0,50
	Lading to Abidjan	0,75	1,88	1,47	0,19	0,00	0,00	0,00	0,00	0,75	2,09	1,49	0,25
	Transport to Abidjan	16,00	40,15	31,28	4,07	25,00	74,01	57,30	12,10	16,00	44,63	31,84	5,28
	OCPVs free pass	0,15	0,38	0,29	0,04	0,15	0,44	0,34	0,07	0,15	0,42	0,30	0,05
	Rackets	1,25	3,14	2,44	0,32	1,25	3,70	2,86	0,60	1,25	3,49	2,49	0,41
	Coxers commission	7,50	18,82	14,66	1,91	3,50	10,36	8,02	1,69	3,50	9,76	6,97	1,16
	Total Actor Costs (TCA)	39,85	100,00	77,91	10,13	33,78	100,00	77,41	16,34	35,85	100,00	71,34	11,83
	Profit margin	104,15			26,47	23,22			11,24	17,65			5,83
Wholesaler	Purchasing price	235,50				121,67				132,00			
	Selling price	272,00				154,00				166,50			
	Gross margin	36,50			9,28	32,33			15,64	34,50			11,39
	Costs												
	Unloading to store	1,10	17,35	2,15	0,28	1,10	16,47	2,52	0,53	1,10	11,93	2,19	0,36
	Renting store	2,06	32,49	4,03	0,52	2,19	32,78	5,01	1,06	3,18	34,49	6,33	1,05
	Monthly Tax	0,23	3,63	0,44	0,06	0,24	3,59	0,55	0,12	0,35	3,80	0,70	0,12
	Annually Tax	0,07	1,10	0,14	0,02	0,08	1,20	0,18	0,04	0,11	1,19	0,23	0,04
	Guarding	0,44	6,94	0,86	0,11	0,47	7,04	1,07	0,23	0,68	7,38	1,36	0,22
	Salaries for employees	1,32	20,82	2,59	0,34	1,41	21,11	3,22	0,68	2,05	22,23	4,07	0,68
	Packages	0,51	8,04	1,01	0,13	0,54	8,08	1,25	0,26	0,80	8,68	1,58	0,26
	Phone facture	0,37	5,84	0,72	0,09	0,39	5,84	0,90	0,19	0,57	6,18	1,13	0,19
	Electricity facture	0,24	3,79	0,47	0,06	0,26	3,89	0,59	0,13	0,38	4,12	0,75	0,13
	Total Actor Cost (TCA)	6,35	100,00	12,41	1,61	6,68	100,00	15,00	3,23	9,21	100,00	18,33	3,04
	Profit margin	30,15			7,66	25,65			12,41	25,29			8,35
Retailer	Purchasing price	272,00				154,00				166,50			
	Selling price	393,50				206,67				303,00			
	Gross margin	121,50			30,88	52,67			25,49	136,50			45,05
	Costs												
	Ladingto market place	2,00	40,32	3,91	0,51	2,00	62,89	4,58	0,97	2,00	38,54	3,98	0,66
	Tax	2,25	45,36	4,40	0,57	0,90	28,30	2,06	0,44	2,43	46,82	4,84	0,80
	Guarding	0,08	1,61	0,15	0,02	0,03	0,94	0,07	0,01	0,08	1,54	0,16	0,03
	Packages	0,63	12,70	1,22	0,16	0,25	7,86	0,57	0,12	0,68	13,10	1,34	0,22
	Total Actor Cost (TCA)	4,95	100,00	9,68	1,26	3,18	100,00	7,29	1,54	5,19	100,00	10,33	1,71
	Profit margin	116,55			29,62	49,49			23,95	131,31			43,34
Total chain	Purchasing Price	91,50				64,67				78,50			
	Final Selling Price (FSP)	393,50				206,67				303,00			
	Total Gross margin	302,00			76,75	142,00			68,71	224,50			74,09
	Total Costs (TC)	51,15		100,00	13,00	43,63		100,00	21,11	50,20		100,00	16,57
	Total Profit margin	250,85			63,75	98,37			47,60	174,30			57,52

Legend:

TAC= Total Actor Cost; TC = Total Cost; FSP= Final Selling Price or Consumption Price

Table 2: Tests of markets integration

Wholesale markets	Pearson correlation coefficient	ADF statistical Value	ADF Critical Value (5 %)
Treichville/Abobo	0,657**	-4.496496*	-3.544284
Treichville/Adjamé	0,576**	-3.887026*	-3.544284
Treichville/Yopougon	0,391*	-4.620396*	-3.544284
Abobo/Adjamé	0,901**	-2.713216	-3.544284
Abobo/Yopougon	0,225	-5.224221*	-3.544284
Adjamé /Yopougon	0,240	-4.813384*	-3.544284
Retails markets			
Abobo Avocatier/Adjamé complex	0,133	-2.669095	-3.574244
Abobo Avocatier/Treichville Gare Bouna	0,072	-	-
Abobo Avocatier/Yopougon UTB	0,184	-4.639847*	-3.574244
Adjamé Complex/Treichville Gare Bouna	0,511**	-	-
Adjamé Complex/Yopougon UTB	0,477**	-1.994324	-3.574244
Treich Gare Bouna/Yopougon UTB	0,320	-	-

** Significant at the level of 1 % * Significant at the level of 5 %