No. 23

HarvestPlus Working Paper | March 2016

A Technical Review of Modern Cassava Technology Adoption in Nigeria (1985-2013): Trends, Challenges, and Opportunities

Adewale Oparinde
Tahirou Abdoulaye
Victor Manyong
Ekin Birol
Dorene Asare-Marfo
Peter Kulakow
Paul Ilona

HarvestPlus
Better Crops • Better Nutrition

HarvestPlus improves nutrition and public health by developing and promoting biofortified food crops that are rich in vitamins and minerals, and providing global leadership on biofortification evidence and technology. We work with diverse partners in more than 40 countries. HarvestPlus is part of the CGIAR Research Program on Agriculture for Nutrition and Health (A4NH). CGIAR is a global agriculture research partnership for a food secure future. Its science is carried out by its 15 research centers in collaboration with hundreds of partner organizations. The HarvestPlus program is coordinated by two of these centers, the International Center for Tropical Agriculture (CIAT) and the International Food Policy Research Institute (IFPRI).

HarvestPlus Working Papers contain preliminary material and research results that have been reviewed by at least one external reviewer. They are circulated in order to stimulate discussion and critical comment.

A Technical Review of Modern Cassava Technology Adoption in Nigeria (1985–2013): Trends, Challenges, and Opportunities

Adewale Oparinde[1], Tahirou Abdoulaye[2], Victor Manyong[3], Ekin Birol[1], Dorene Asare-Marfo[1], Peter Kulakow[2] and Paul Ilona[4]

ABSTRACT

In recent times, results of various adoption studies have been mixed, raising questions regarding why some improved farm technologies are still not widely adopted several years after their first introduction. Many improved cassava varieties have been introduced to millions of farm households across Africa south of the Sahara. Using an extensive review of cassava-adoption literature focused on Nigeria, this paper discusses the uptake of improved cassava varieties. Generic measurement and methodological issues in the literature are illuminated and alternative approaches suggested. The literature can be improved to better inform policy by considering issues such as attribution constraint due to varietal identification challenges and sample selection bias that can limit interpretation of findings. Very few studies disaggregated adoption by men and women, thus the literature can provide more policy relevance by giving adequate attention to gender considerations. Also, the use of only descriptive statistics and dichotomous choice models is most common while issues of sequencing, simultaneity, endogenity, and social learning effects in adoption decisions are under-evaluated. The local germplasm at research institutions in the country is not exhaustive and thus efforts should focus on improving the database for an effective use of a DNA fingerprinting technique in the varietal identification process.

Lessons are also drawn for the effective introduction and dissemination of biofortified provitamin A cassava in Nigeria. Historically, public institutions and international agencies have been the drivers of Nigeria's cassava sector. A market-based approach focusing on attracting private sector investment would be important to ensuring sustainability in the adoption of provitamin A cassava. Farmers' fields have always been characterized by a mix of improved cassava varieties and landraces, suggesting that several varieties of provitamin A cassava should be promoted simultaneously in order for a significant replacement of landraces to take place over time on farmers' fields.

Keywords: Technology adoption, improved cassava varieties, Nigeria, methodological issues

[1]International Food Policy Research Institute (IFPRI), Washington, DC, USA

[2]International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria

[3]International Institute of Tropical Agriculture (IITA), Dar-es-Salaam, Tanzania

[4]HarvestPlus, International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria

CONTENTS

1. INTRODUCTION

Food insecurity is a widespread problem in several African countries where growing population pressure, combined with climate change, presents a global challenge associated with social and economic costs. About 50 percent of Africa's rural farm households and 20 percent of the urban poor are food insecure (Heidhues et al. 2004). Food insecurity arises as a result of deficiencies in three aspects: food availability, food access[1], and food adequacy[2]. Food availability involves productivity and other factors in the food supply chain. Innovations in agriculture have been one of the main methods for addressing food insecurity through increased productivity of common staple crops. Cassava is the second most important food staple in Africa after maize, and it is consumed by more than 200 million people in Africa south of the Sahara, who derive more than 50 percent of their calories from the crop (Manyong et al. 2000). Nigeria leads the global market share with about 21 percent of world cassava production (FAOSTAT 2013).

The development and introduction of improved cassava varieties has long been recognized as one of the key strategies for transforming the cassava industry and for enhancing the wellbeing of Nigeria's rural population (Dixon and Ssemakula 2008). The other key strategies applied include value addition, as well as markets and an enabling policy environment. Cassava breeding programs in the country initially addressed viral disease epidemics. With close and strategic collaborations between the International Institute of Tropical Agriculture (IITA), the International Center for Tropical Agriculture (CIAT), and national agricultural research programs, about 59 early-bulking, disease-resistant, and high-yielding cassava varieties have been officially released since 1977 (Dixon et al. 2010). These varieties include the Tropical Manioc Selection (TMS) varieties from the IITA and the National Root Crop Research Institute, Umudike (NRCRI) materials (or NR varieties). From 1990 to 1998, about 14 percent of the germplasm incorporated into the development of varieties released from IITA across Africa was sourced from landraces, while 2 percent and 80 percent were sourced from CIAT and IITA, respectively (Manyong et al. 2000).

With the implementation of the cassava transformation agenda in the country, cassava adoption in Nigeria has come to the fore in the policy debate. Policymakers, donors, and research institutions have many questions about producers' adoption of modern cassava technologies, especially with regard to the use and diffusion of improved varieties. These questions include how farmers perceive improved cassava varieties and whether they will be willing to experiment with, evaluate, and adopt a new variety. In addition, policy interest has risen around constraints to adoption and the impact of improved cassava varieties on commodity production, poverty, and input use. Therefore, agricultural economists and agronomists must address whether or not farmers are adopting these technologies, at what rate, where, and how adoption impacts farmers' wellbeing, as well as the countrywide economy. Several studies in Nigeria have attempted to address these areas since the 1980s (for example, Ikpi et al. 1986; Udensi et al. 2011; Alene et al. 2012).

This paper has two objectives. First, it provides a synthesis of adoption rates (discrete choices) and intensity (referred to here as extent of adoption)[3] in Nigeria using an extensive review of literature on the economics of improved cassava varietal adoption in the country. Second, study approaches were synthesized and various issues and limitations are discussed in order to assess how adoption has been empirically measured in cassava research in Nigeria.

One of the constraints in illuminating the trend in improved technology uptake in Nigeria is the lack of panel data that can be used to empirically trace adoption since the 1970s. It is also difficult to conduct a meta-analysis due to lack of commonality in conceptualization across studies. However, this paper contributes to the adoption literature by shedding light on current practices in Nigeria's cassava adoption literature while identifying various measurement, attribution, and generalizability issues that can limit interpretation of results for policy. The paper also suggests approaches to help improve estimation of improved cassava technology adoption in the Nigerian context.

Recent innovations in cassava breeding have enabled new varieties to be released to address food inadequacy in Nigeria. In close collaboration with HarvestPlus, IITA and NRCRI recently released six new biofortified yellow cassava varieties that are conventionally bred to have high beta-carotene content (TMS 01/1371, TMS 01/1412, TMS 01/1368, TMS 07/593, TMS 07/539, NR 07/0220) as a strategy to address vitamin A deficiency in Nigeria. Dissemination of these varieties is ongoing. The goal is to promote adoption and consumption of provitamin A yellow cassava among farming households in the country. Therefore, this paper also attempts to draw lessons from a review of the cassava adoption literature to inform the provitamin A yellow cassava dissemination strategy in Nigeria.

[1] For example, an individual or household's access to food.

[2] For example, access to and consumption of adequate diets.

[3] Smale, Heisey, and Leathers (1995) also defined intensity as the quantity of seeds applied per hectare of land. While we recognize this, for simplicity, adoption intensity here is referred to as the share of cassava land area allocated to improved varieties.

The rest of the paper is organized as follows: Section 2 provides a historical perspective on cassava technology adoption in Nigeria since 1958. Various public and private investments in cassava technology development and promotion are identified while examining the adoption trends in section 3. Opportunities for future research and recommendations for improvements in study design are discussed in section 4, and conclusions are drawn in section 5.

2. HISTORICAL PERSPECTIVES ON THE INTRODUCTION AND DIFFUSION OF TMS VARIETIES

Although cassava breeding activities in Africa date back to 1920 starting at the Amani research station in Tanzania, they only commenced in Nigeria in 1958 at Moor Plantation. The point of departure from this genetic research level investment occurred in 1977 when high-yielding mosaic-resistant varieties (TMS 50395, 63397, 30555, 4(2)1425, and 30572) were released by IITA. One of the key strategic objectives of the IITA Root and Tuber Program is to improve the productivity of cassava-producing farming households in Nigeria. The Collaborative Study of Cassava in Africa (COSCA) has shown that progress was made (Table 1); Around 1988, for instance, improved cassava varieties were found to yield significantly more than local varieties in sub-humid areas under both intercropping and monocropping management practices (Nweke, Ugwu, and Dixon 1996; Raji, Ladeinde, and Dixon 2007).

COSCA is a multi-country cassava adoption study funded by the Rockefeller Foundation with the aim of collecting authoritative information over a wide area on cassava production systems, processing methods, market prospects, and consumption patterns. COSCA commenced in 1989 in six countries (Côte d'Ivoire, Ghana, Nigeria, Tanzania, Uganda, and Zaire), and it was implemented in three phases in Nigeria (1989–91). Phase I involved the collection of data on environmental factors, production, processing, marketing, and consumption. Phase II collected information on cassava production details including yield and land area measurements. Phase III involved areas such as product quality assessment. The study was designed to be nationally representative using a multi-stage sampling procedure where, in the first stage, three maps—climate, population density, and market access conditions—were overlaid and divided into grids of cells with less than 10,000 hectares of cassava area. In the second stage, 65 grids of cells were randomly selected along each climate/population density/market access zone proportionate to the zone size. In the third stage, a village was randomly selected per grid and in each village three farm-holder units with less than 10 hectares of cultivated land area were selected for the study. Thus, COSCA was conducted in 65 villages and 195 farm units across all of Nigeria's agroecological zones (Nweke, Ugwu, and Dixon 1996). This collaborative study represents the first effort to systematically evaluate cassava adoption nationally in Nigeria.

In 1989, COSCA reported an adoption rate of about 60 percent for improved varieties across cassava producing areas in Nigeria (Nweke, Ugwu, and Dixon 1996).

By the late 1980s, the TMS diffusion in Nigeria had become an African success story par excellence! The TMS varieties were grown in both the forest and the savanna zones of Nigeria. The TMS 30572 variety was the most popular, especially among farmers who process it as *gari*[4] for sale in urban markets (Nweke 2009).

A positive policy environment and enhanced extension services, among other factors, influenced this adoption success (Nweke 2009). Therefore, the spread of improved cassava varieties in Nigeria likely correlates with various forms of policy, institutional, and private investments in the sector over the years. To shed some light on this area, Figure 1 summarizes various forms of investments and events that might have impacted the sector (see Appendix for details).

Two key lessons can be drawn from a chronological review of the various investments and events presented in Figure 1. First, most of the investments went into diffusion in

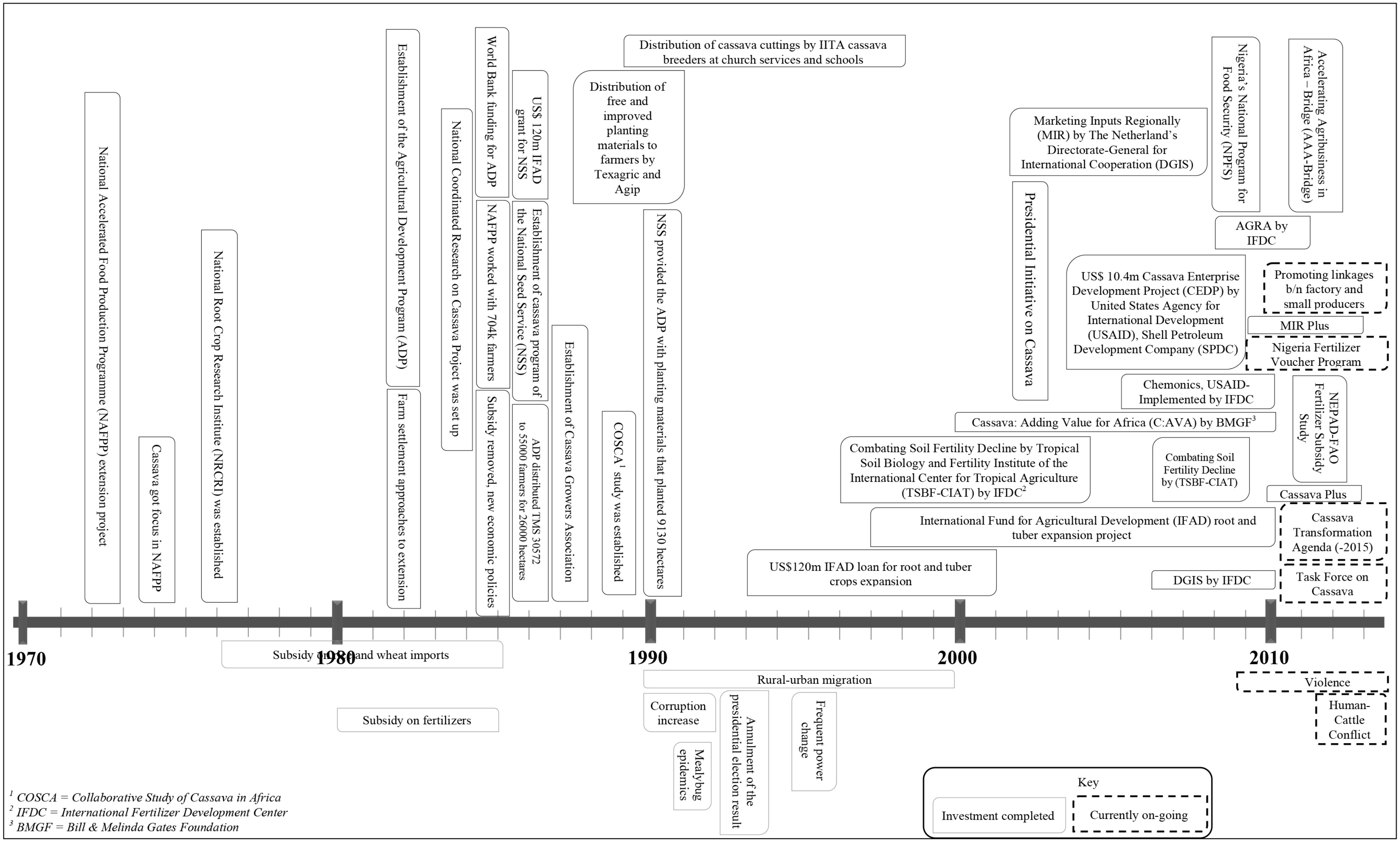
Table 1. Farm-Level Yields for Local and Improved Cassava Varieties Under Different Management Practices

	Local variety (mean ton/ha)	Improved variety (mean ton/ha)	Difference in yield between local and improved
Intercropping	14.1	16.5	17%
Monocropping	13.7	23.5	72%

Source: Nweke, Ugwu, and Dixon (1996).

[4] *Gari* is a cassava flour product.

Figure 1. Trends in Investments in Cassava Technology Development and Diffusion Promotion in Nigeria



Source: Authors, based on review of available evidence.

the mid-1980s, a period close to the year of first release of TMS varieties in Nigeria. This period coincided with an era of relatively stable government, with lower rates of military coups, and with changes in economic policies, thus attracting more support from the international community, in addition to oil revenue. An example of this is the World Bank's support of the Agricultural Development Project (ADP) and the International Fund for Agricultural Development's (IFAD) $120 million grant to promote diffusion of TMS varieties in the 1980s. Other factors, such as the advent of structural adjustment policy, decline in petroleum revenue, corruption, and increased poverty levels, brought cassava into the limelight in the 1980s. The combined effect of these factors resulted in increased urban demand for cassava products, particularly gari, while also shifting government attention toward the enhancement of food security through cassava production (Nweke 2009).

Various policy and political changes occurred between 1990 and 2000 that could have influenced cassava adoption, including incomplete markets and market access infrastructure (Nweke, Ugwu, and Dixon 1996; Nweke, Spencer, and Lynam 2002). In a Tobit regression model, Omonona, Oni, and Uwagboe (2006) showed that farmers who are more likely to adopt a higher number of the improved cassava varieties are male, educated, and have better access to input supply and extension services. Policy transformations, such as the withdrawal of World Bank funding from the extension program ADP, could have led to a reduction in farmers' level of contact with extension agents, reducing access to information. Although limited by measurement and conceptual issues, recent studies, such as Ajala, Ogunjimi, and Farinde (2012), show that about half of the 312 cassava farmers surveyed in Osun State did not have contact with extension services. Likewise, Bankole et al. (2012) reported that about 50 percent of cassava farmers surveyed in the Igbabi local government area (LGA) in Kaduna State lacked access to regular extension services. Onu and Ohajianya (2005) also noted that farmers' limited contact with extension agents contributed to low adoption of improved varieties among 120 households surveyed in six LGAs in Imo State.

In 1992 when the country became increasingly politically unstable and the resulting insecurity led to frequent military coups, adoption studies were few. Also, not much investment was reported between 1992 and 1999 (see Figure 1 and the Appendix). With the return of democracy in 1999, significant policy changes and donor investments have perhaps increased and are being refocused on cassava adoption and production in Nigeria (Figure 1). For instance, the Presidential Initiative on Cassava was launched in July 2002 to promote cassava as a foreign exchange earner for the country and a way to achieve self-sufficiency in food production. Under the initiative, the government set a 10 percent inclusion of cassava flour in wheat flour and a 10 percent blending of ethanol with premium spirit. It also made use of cassava starch a requisite ingredient for industries. During the first and second democratic government administrations since 1999, cassava farmers across the country were encouraged to cultivate improved varieties to meet the upcoming market demand. The 10 percent cassava inclusion policy, however, suffered from a transition in government, lack of support from the industry, and lack of enforcement. A new government (2008–11) contradicted the policy goal when the ban on importing cassava and cassava products, such as chips and starch, was relaxed.

This policy change could have had both positive and negative effects on adoption. Using a stochastic frontier function, a cross-section analysis of 290 farmers in Ido LGA in Oyo State compared outputs of both participants and non-participants under the Presidential Initiative on Cassava program. The study suggested a significant and positive effect of the initiative on cassava farmers' productivity (Awoyinka 2009). On the other hand, it is possible the Presidential Initiative attracted many smallholder farmers to rush investments into increased cultivation of improved varieties in anticipation of market demand for raw tubers. Meanwhile, since the initiative did not deliver on its promises, the policy change may have also resulted in a heteroskedastic nature of farmers' choice of improved varieties where, for instance, poorer farmers may have stopped using improved materials in later years since cultivation of improved varieties requires more agro-inputs than traditional varieties.

In contrast, relatively wealthier farm households were more likely to maintain the cultivation of improved varieties irrespective of the failure of the Presidential Initiative on Cassava. This is consistent with the findings of Omonona, Oni, and Uwagboe (2006) and Nwakor et al. (2011), which indicate that the adoption of improved varieties is higher among farmers of high social class who are literate, and who can easily find their way out to markets. The demand-pull mechanisms created by the new Ministry of Agriculture's Cassava Transformation Agenda beginning in 2011 may have positively shifted farmers' interest in improved varieties. The policy aims to attract foreign direct investment (FDI) in cassava processing by 2015. Nigeria has also received more than $200 million in financing from China for the installation of 18 large-scale cassava flour processing plants. This trend of policy changes (shown in Figure 1), and the resulting shifts in demand and other market variables, may have caused farmers to move into and out of adoption.

3. RATES OF ADOPTION OF IMPROVED CASSAVA VARIETIES OVER TIME (1985-2013)

An article search was conducted using international and national journal databases, search engines, and the IITA library. The total number of articles found was small, but they provide useful insights into improved cassava adoption in Nigeria. Of the 24 cassava-adoption studies found and reviewed, 4 percent were conducted at local government area (LGA) level, 52 percent at state level, and the remaining 44 percent at regional or zonal level. Table 3 presents the methodology, sampling, and results of these studies. They were all conducted between 1985 and 2013. Twelve out of 13 studies conducted at state level adopted a multi-stage sampling procedure where the first stratum was usually LGAs, senatorial districts, or ADP extension blocks, followed by communities or villages, and then random sampling of farm households. Table 2 shows that for this category of studies, households were randomly drawn from anywhere from 1 to 17 LGAs, while the number of households usually selected per community or village ranges from 10 to 45. Studies (n = 10) conducted at regional levels usually cover at least one agroecological zone or more than one state. These studies have also adopted a multi-stage sampling procedure where the number of states surveyed was 5 or more and the number of households sampled was between 68 and 840.

A summary of studies reviewed is provided in Table 3. With the exception of those conducted in the 1980s and early 1990s, most of the studies conducted at the state level have focused on adoption rate (proportion of subjects) rather than adoption intensity (proportion of land area). On account of their design, these studies generally provide descriptive information and apply probit or logistic models. While this approach provides useful and static information on patterns of adoption and attrition, it is a common notion in the literature that the reason for technology adoption goes beyond dichotomous choices (Doss 2006). In terms of methodology and survey design, a majority of these studies are based on interviews at individual or household levels while using Probit and Tobit econometric approaches.

Attempts were made to categorize the Nigeria cassava adoption literature based on area of study focus, such as input, output, constraints, and facilitating factors. The following six broad areas are the best meaningful categorization of the studies reviewed based on the study's contribution, research methodology, and sampling coverage. These categories are also referred to in Table 3.

1. Contributions of research institutions to the development and diffusion of improved cassava varieties
2. Qualitative and historical description of adoption trends
3. Discrete choice of improved cassava varieties based on localized data collection
4. Empirical analysis of the welfare effect/profitability and production efficiency relating to the use of improved cassava varieties but based on localized data collection
5. Cross-sectional analysis aimed at generalizing adoption rates at the regional level
6. Applications of econometric techniques in predicting adoption rates for cross-country generalization

Table 2. Description of Nigerian State-Level Cassava Adoption Studies Reviewed

Variable	Range (n = 13)
Sample size	40–360
Number of LGAs/senatorial districts sampled per state	1–17
Number of communities sampled per LGA/senatorial district	2–6
Number of households/respondents sampled per LGA/senatorial district	15–30
Number of households/respondents sampled per community	10–45

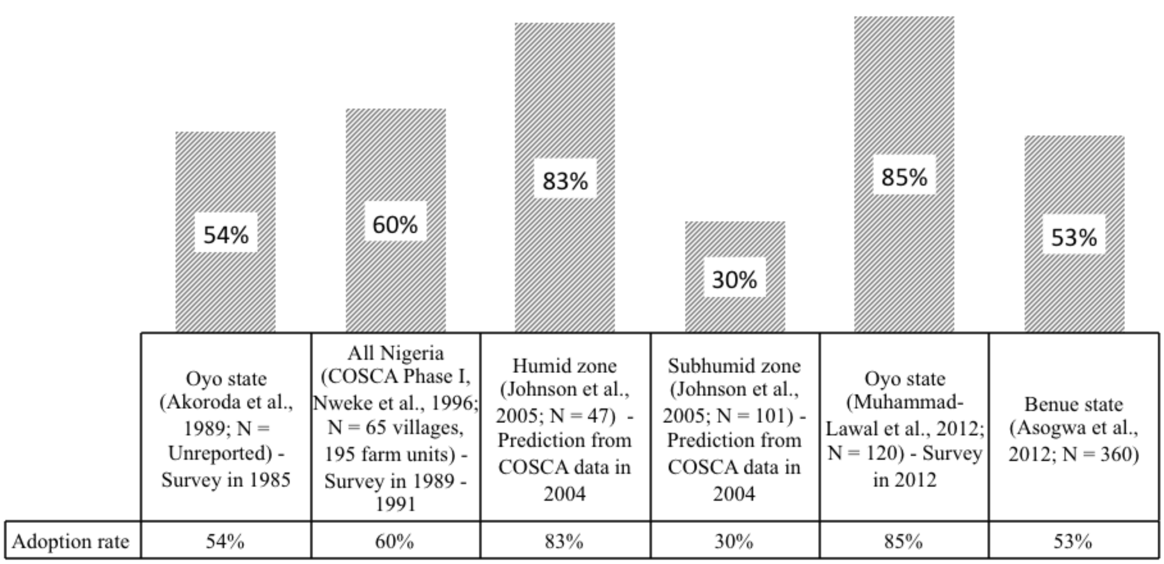
Source: Authors' estimate (2013).
Note: LGA = local government area

Adoption rates and intensity reviewed in this paper are difficult to compare due to differences in sampling approaches and coverage. While multi-stage sampling design for some studies covered both rural and peri-urban areas, others covered only rural areas. For instance, Ikpi et al. (1986) purposely included semi-urban towns in their sample in order to obtain information on rural–urban transition in cassava production. Likewise, the recent Diffusion of Improved Crop Varieties in Africa (DIVA) study on adoption intensity in the southwest excluded urban LGAs in the sampling design (Alene et al. 2012). While Ikpi et al. (1986) explicitly reported the coverage of peri-urban areas, other studies have not described the level of remoteness of the study areas covered. Major cassava processing centers are usually located in the peri-urban areas to serve as hubs for raw cassava from remote villages. Since the literature on adoption in Nigeria has shown that literate farmers are more likely to cultivate improved cassava varieties (Omonona, Oni, and Uwagboe 2006), it is important that adoption studies report proximity of study sites to peri-urban areas.

Authors have also reported differences in results based on study areas and sampling design (Figure 2). Akoroda, Gebremeskel, and Oyinla (1989) reported an adoption intensity of about 63 percent in Oyo State in 1985, while Ikpi et al. (1986) reported an adoption intensity of about 25 percent in the same state in 1986 (see Table 3). Ikpi (1988), however, reported that cassava area allocated to improved varieties kept increasing at an annual rate of 16.5 percent in the southwestern region.

Since the study by Johnson, Masters, and Preckel (2005) is based on the COSCA data, one can assume that the adoption intensity is comparable to that of Nweke, Ugwu, and Dixon (1996). Although Nweke, Ugwu, and Dixon's COSCA study is reported to be regionally representative based on their multi-stage sampling procedure discussed in section 2, the following discussions need to be cautiously interpreted as they are only based on estimates and arbitrary comparisons. Based on the studies, it may be deduced that adoption intensity remained constant for the humid zone between 1992 and 2004, while it changed negatively for the sub-humid zone within the same time frame (Figures 3 and 4). The humid zone includes states in the southwest, southeast and south-south; the sub-humid zone includes mostly states in the north-central while the non-humid zone includes states in the northwest and northeast. Although this comparison is arbitrary, Alene et al. (2012) suggests that the adoption intensity for the southwest (52 percent) in the humid zone has reduced over time since 1992 when Nweke, Ugwu, and Dixon (1996) reported that 60 percent of cassava land area was cultivated under improved varieties (Figures 3 and 5). This trend could be a reflection of the variation in investments in adoption and diffusion promotion caused by changes in political power and agricultural policies. Manyong et al.'s (2000) estimate of about 23 percent adoption intensity in 1998 from an expert survey of cassava-producing areas in Nigeria could suggest a depression in investments in the 1990s, especially when the result reported is compared to those of COSCA in 1992 (Figures 6).

Figure 2. Adoption Rate Reported across Regions in Nigeria (1985–2012)



Using data from the COSCA study, Nweke, Ugwu, and Dixon (1996) also reported an adoption rate of 60 percent representative of cassava-producing areas in Nigeria (Figure 2). The authors indicated, however, that due to the low multiplication rate of cassava planting materials, farmers usually cultivated local and improved materials side by side on the same field and gradually phased out undesired varieties. As a result, farmers' fields had a mixture of local and improved varieties. With farmers using this strategy, one could expect that farmers would have phased out several local varieties during the three decades since 1977. However, as noted by Udensi et al. (2011), mixing of local and improved varieties on the same cassava field is still a common practice among farmers in Nigeria, which is beneficial to biodiversity. In their study covering 17 LGAs in Abia State, about 61 percent of 510 farmers surveyed planted both local and improved varieties on the same field, while 12 percent planted improved varieties only and 26 percent planted local varieties only.

This particular practice is as old as the cassava-breeding program itself, and it has become a key challenge to the accuracy of micro-adoption studies based on cross-sectional analysis and localized data. Thus, Johnson, Masters, and Preckel's (2005) estimation of 83 percent adoption rate in Oyo State might have omitted this issue in the conceptualization of variables for predicting adoption under the heterogeneous agent model applied without taking into account current farmers' management practices. Ikpi et al. (1986) reported this problem of varietal identification and noted that Ege dudu (a local variety called black cassava), which is very similar morphologically to TMS 30572, is the second most popular local variety after Odongbo (another local variety) in Oyo State. The authors indicated that these local varieties might bear different names in different areas. TMS 30572, TMS 30555, and TMS 30211 selected by the IITA were spreading all over Nigeria in the 1980s (Ikpi et al. 1986). As such, it is more likely that farmers could have named many of these improved varieties after Ege dudu and vice versa, since farmers usually name cassava cultivars after their colors, sources of stem, or yield potential (Oparinde et al. 2012).

In addition, Alene et al. (2012) have shown that expert opinion[5] on adoption rate or intensity differs significantly

Figure 3: Zonal Adoption Intensity (% Cassava Land Area) Reported (Humid Zone: SE, SS, and SW)

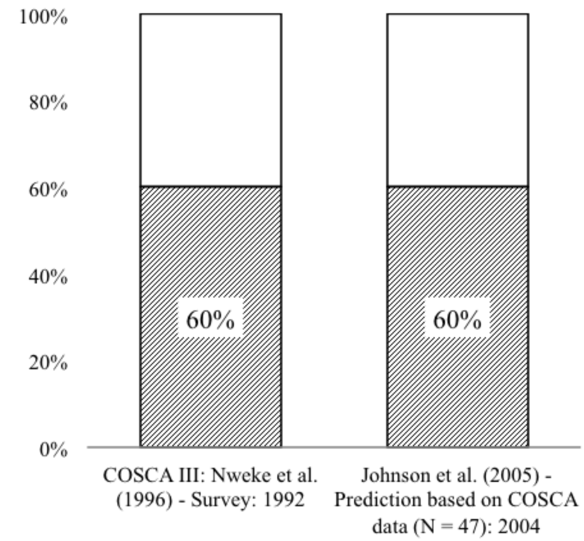
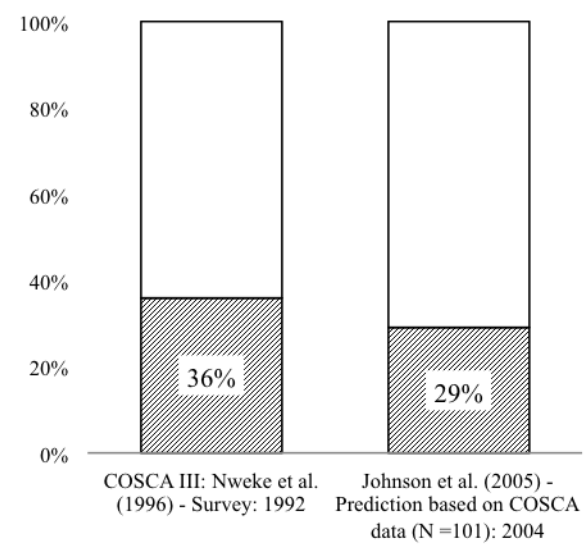


Figure 4: Zonal Adoption Intensity (% Cassava Land Area) Reported (Subhumid Zone: NC)



[5] This is when authors directly ask experts in the field of cassava (for example, breeders) their opinions on the percentage of farmers (or percentage of cultivated land area) cultivating improved cassava in a locality, state, or region without scientific field measurement for varietal identification.

Figure 5: Adoption intensity (% cassava land area) reported (Southwest vs. Southeast)

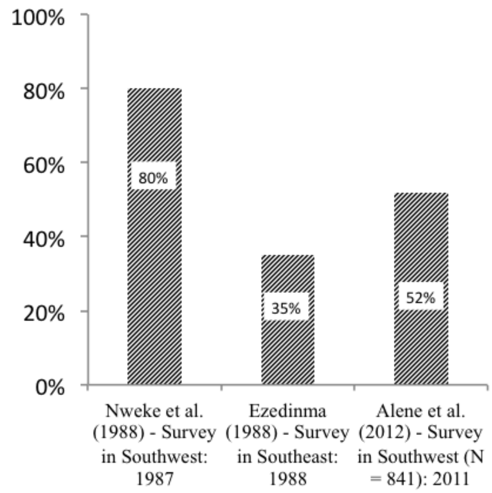
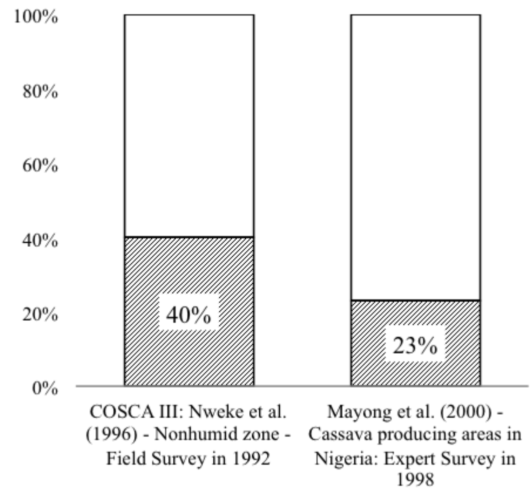
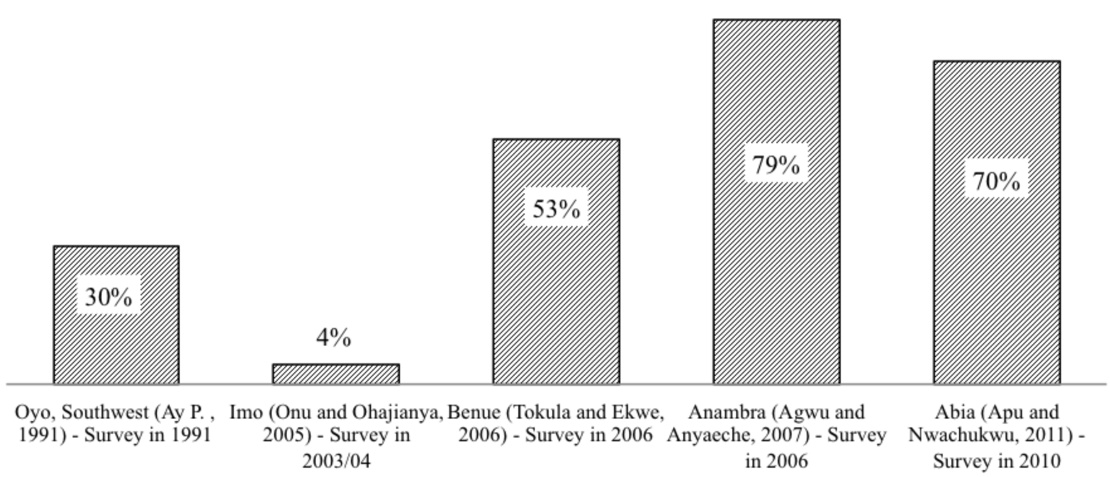


Figure 6: Adoption intensity (% cassava land area) Reported (Nonhumid Zone vs. National Level)



from those of farmer groups[6] and farming households.[7] For instance, in the DIVA study, while experts stated that the cassava area allocated to improved varieties as a whole and TMS 30572 only are 70 percent and 42 percent respectively, in Oyo State farmer groups stated that the adoption intensity for improved varieties is about 44 percent. At the household level, the reported adoption intensity for improved varieties as a whole is 26 percent and for TMS 30572 only is 4 percent in Oyo State. This disparity could have led to subjectivity of a multimodal Bayesian distribution in stakeholders' beliefs regarding the adoption of improved cassava varieties in Nigeria. Figures 7 and 8 also show adoption rates reported based on farmers' opinion across states for TMS 30572 and NR 8082, which are the varieties usually perceived to be most popular among farmers in Nigeria.

Figure 7: Adoption Rate: Percentage of Farmers that Cultivated TMS 30572 by State

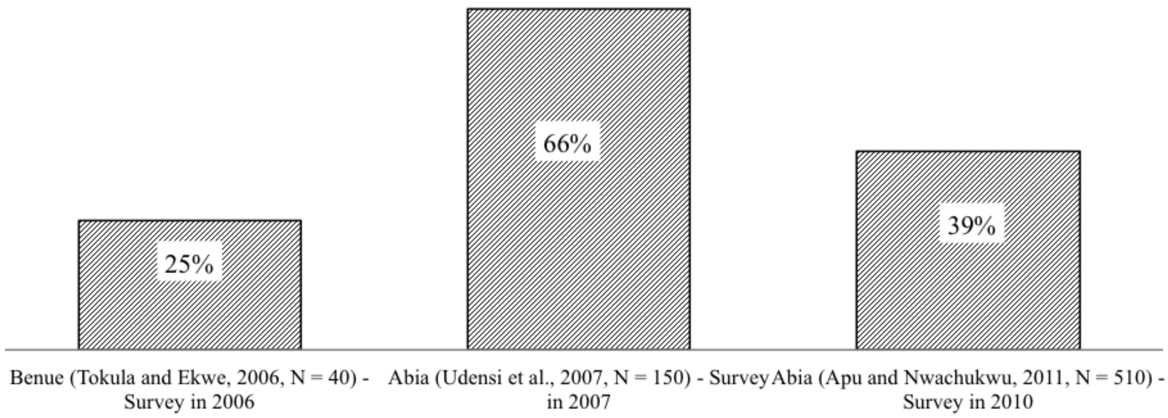


---

[6] Similar to footnote 5, this is also when authors directly ask groups of farmers their opinions about adoption rate without scientific field measurement for varietal identification.

[7] Similar to footnote 5, this is when authors directly ask farmers/farming households whether or not they cultivate improved cassava varieties (or a particular improved variety) without scientific field measurement for varietal identification.

Figure 8: Adoption Rate: Percentage of Farmers that Cultivated NR 8082 in Abia and Benue States (2006, 2007, and 2010)



4. IMPLICATION & RECOMMENDATIONS

Studies on adoption of improved cassava varieties in Nigeria have been widely based on cross-sectional analysis and have provided useful information on patterns and trends in adoption. Policy considerations of findings from these adoption results range from the priority setting for research to evaluation of the distributional impact of improved varieties on poverty to the minimization of adoption constraints. Such studies can be improved to better inform policy by giving consideration to certain issues that can limit interpretation of findings.

4.1 Limitations

Various limitations of the cassava adoption literature in Nigeria are highlighted here. First, across all studies reviewed, very few disaggregated adoption by men and women (Omonona et al. 2006 and Ibitoye 2011)[8]. The literature has not given adequate attention to gender considerations. Second, study and sampling designs lack commonality, which limits the opportunity for meta-analysis or synthesis of the dynamics of cassava adoption in Nigeria. Comparing adoption across studies depends on sampling design, coverage, definitional concept, and unit of analysis.

Most studies were conducted in southern Nigeria, but the number of administrative locations covered varied across studies. This has direct implications on the extent to which results can be extrapolated and compared. Reported adoption rates may be limited by selection bias because study objectives primarily dictate sampling designs. It is likely that Tokula, Asumugha, and Ibeachi (2009) reported a high adoption rate because the study was conducted among beneficiaries of a program that directly received TMS 92/0326 cassava varieties during their initial dissemination. There is no direct way to harmonize sampling designs. In addition, the conceptualization of the meaning of adoption intensity is not clearly established in the cassava adoption literature. A majority of the studies reviewed do not differentiate between area of land cultivated and volume of stands per area. Further, underreporting on definitional issues surrounding adoption and study-area remoteness limits the comparability of estimates.

Third, attribution constraints and measurement issues limit the accuracy of the adoption estimates reviewed. With the exception of Agwu and Anyaeche (2007), Udensi et al. (2011), and a few others, most of the micro-level studies reviewed have relied on farmers' knowledge to identify varieties as either "improved" or "landrace." For instance, Ibitoye (2011) asked farmers in Kogi State whether or not they had made a dichotomous decision to cultivate three classes of varieties. In the study, varieties were classified into variety A (TMS varieties from IITA), variety B (NR varieties from NRCRI) and variety C (local varieties). Similarly, in other studies, such as Apu and Nwachukwu (2011)—which reported a 70 percent adoption rate—farmers were asked whether or not they had planted TMS 30572. However, it is not clear how TMS 30572 was described to the farmers or whether or not researchers confirmed the accuracy of farmers' responses. The same was observed in Nwakor et al.'s (2011) study, which reported that 81 percent of farmers surveyed were aware of NR 8082. Also, since IITA and other research institutions have conducted many on-farm trials over the years, farmers' fields could contain different improved varieties that were not officially released.

[8] More details on these studies are available in Table 3.

Similar to Nweke, Ugwu, and Dixon (1996), Raji, Ladeinde, and Dixon (2007) already noted that identification of improved cassava among local varieties requires experience since cassava is open pollinated and farmers do retain resulting plants from wild crosses. Therefore, there could be several cassava materials on farmers' fields that may become difficult to identify. A recent study on varietal identification in Oyo State has also shown that farmer's knowledge is not sufficient for the identification process since one local name can refer to different varieties within the same village and even within the same cassava field (Oparinde et al. 2012). This suggests that the 77 percent adoption rate reported for Udukanani (considered as local material in Agwu and Anyaeche [2007]) may refer to different varieties across communities.

Fourth, there is a need for genetic fingerprinting data that can enhance the varietal identification process for landraces. Since Dallas (1988) demonstrated the usefulness of the DNA fingerprinting technique for cultivar identification in rice, advances in the method have made DNA markers a very useful tool in obtaining unambiguous characterization of cultivars. This technique provides a genotypic and distinct profile of cultivars, which makes varietal identification less difficult. In the case of cassava in Nigeria, where there has been an intergenerational practice of cultivating local and improved varieties on the same field, DNA fingerprinting can enhance precision of adoption results. This method is less laborious and less time consuming than morphological and biochemical methods. Besides this, local germplasm at IITA comprises more than 2,200 cassava accessions, but this collection is not an exhaustive list. The collection of local materials should be an ongoing exercise at IITA and other research institutions in Nigeria. The lack of exhaustive reference profiles of local materials will diminish the advantage of DNA fingerprinting for varietal identification. Efforts have been made to describe the genetic diversity and genetic structure of landraces in Ghana (Parkes 2011) and IITA germplasm in Nigeria (Moyib, Kodunola, and Dixon 2007; Raji et al. 2009), but this is not exhaustive since several landraces on farmers' fields remain uncharacterized.

Generalization is another limitation identified in the cassava adoption literature in Nigeria. Johnson et al. (2005) used the COSCA data to estimate the spillover effect of adoption rates in Nigeria for predicting adoption of improved cassava in Côte d'Ivoire and Ghana. The COSCA data collected between 1989 and 1991 from which the prediction was made showed that out of 47 households in the humid zone of Nigeria, 70 percent adopted improved varieties. Similarly out of 101 households in the sub-humid zone of Nigeria, 34 percent adopted improved varieties. Even though the heterogeneous agent model applied is econometrically interesting, the analysis is limited by data constraints. The sample size used for predictions is too small to yield a reliable estimate that can be generalized for a country as large as Ghana or Côte d'Ivoire. This lack of statistical footprint and masking of the aggregation bias can be overcome if sample size is larger than the current average and a careful survey design is applied.

Finally, this paper draws attention to several methodological issues. Simple descriptive statistics and dichotomous choice models of technology adoption offer limited insight into the process of improved cassava adoption. This is the dominant trend in the literature on cassava adoption in Nigeria (for example, Tokula, Asumugha, and Ibeachi 2009 and Babasanya et al. 2013). Issues such as incomplete markets and policy changes have not been well investigated in the cassava adoption literature. This could provide information important for policies to reduce barriers to adoption of new technologies in the country. As indicated previously, recent micro-studies on improved cassava adoption in Nigeria have generally failed to align with the current trend in global literature on technology adoption. Most of the recently published studies now focus on improvement in econometric applications to address the problems of sequencing, simultaneity, and endogeneity in adoption decisions as well as social learning effects (see Khanna 2001 and Conley and Udry 2010).

4.2 Future Research

Several opportunities for research exist in advancing the Nigeria cassava adoption literature. Simultaneity and sequencing in adoption are important areas that have not received significant attention. Since up to 59 improved cassava varieties have been officially released in Nigeria (Dixon et al. 2010), farmers have had access to multiple options and, as such, improved cassava varieties could be adopted as a package. Byerlee and de Polanco (1986) and Smale, Heisey, and Leathers (1995) have modeled adoption as simultaneous, step-wise, or double-hurdle choice decisions. It is surprising that this aspect has not been widely explored in the cassava adoption literature in Nigeria. Omonona, Oni, and Uwagboe (2006) study is one of the few to address simultaneity and sequencing. They use the Tobit regression approach to model the level of adoption as the share of the number of technology packages adopted by a farming household. In addition to this, a cost–benefit analysis of the different cassava technology packages from the smallholder's perspective would be necessary since several packages of management plans have been developed in addition to improved varieties over time. It is important that farmers' demand for these technologies be analyzed under a cost-benefit framework so as to shed light on why certain improved cassava varieties have not been widely adopted by farmers over time. Adoption could be hindered by poor management practices that cause improved cassava production to have yield levels that may not differ significantly from those of local varieties.

A countrywide analysis of adoption is important for Nigeria after such a long experience with improved cassava technology. A consideration of non-dichotomous and computable general equilibrium models can enhance wider-level generalization. Other aspects that would benefit from empirical analysis include (1) the role of women in cassava adoption; (2) the impact of non-farm income in the adoption of improved cassava and its relationship with input use; (3) the role of processing technology in promoting adoption of improved cassava varieties, which is crucial in view of the current objective of the Government's cassava transformation agenda, as demonstrated in a recent paper by Rusike et al. (2012); (4) the role of social networks in the diffusion-network analysis, which is crucial since cassava stems are exchanged mostly through farmer-to-farmer diffusion channels (Oparinde et al. 2012);[9] and (5) complementarities in the adoption of improved cassava varieties, which is an important aspect for investigation since it has been shown that farmers still keep preferred local varieties. An empirical analysis of the farmers' trade-offs between various cassava agronomic, processing, and consumption traits is necessary to better inform the cassava breeding and delivery program.

5.CONCLUSION & LESSONS FOR PROVITAMIN A CASSAVA DISSEMINATION

The literature on cassava adoption in Nigeria is widely characterized by cross-sectional analyses that have provided useful information on patterns and trends in adoption of improved cassava varieties in the country. Policy considerations of findings from these adoption studies range from the setting of priorities for research to the minimization of adoption constraints. A review of the historical perspective of the cassava sector in Nigeria suggests that adoption of improved cassava technology has been conditional on various policy and political changes that have occurred since the 1980s. The literature can be improved to better inform policy by giving consideration to certain issues such as attribution constraints that can limit interpretation of findings. Key lessons for effectively promoting provitamin A cassava adoption in Nigeria include the following: First, the cassava sector in Nigeria has been historically driven by public institutions and international agencies. Therefore, a market-based approach focusing on attracting private sector investment is important to sustaining the adoption of provitamin A cassava in the country. Second, the fact that farmers' fields have always been characterized by a mix of both improved varieties and landraces suggests that several varieties of provitamin A cassava should be promoted simultaneously for a significant replacement of landraces to take place over time on farmers' fields. Third, organizations introducing and promoting provitamin A cassava should adopt fingerprinting techniques to address the measurement issues that currently limit Nigeria's cassava adoption literature. Fourth, gender dimensions in the adoption of improved cassava have not received significant attention. Therefore, it is crucial that gender-differentiated dissemination and adoption strategies be used to promote provitamin A cassava since women have unique roles along the cassava value chain in Nigeria.

[9] Maertens and Barret (2012) and Munasib and Roy (2011) exemplify frameworks for analyzing network effect in technology adoption.

Table 3. Results of Studies Examining the Adoption Rate and Intensity for Improved Cassava Varieties in Nigeria

Year of Study	Author(s)	Location in Nigeria	Survey/analytical method	Level of investigation	Sample size (n)	Adoption rate (% adopters)	Adoption intensity (% cassava land area)	Study category*
1985	Akoroda et al. (1989)	Oyo State	Quantitative	Household	-	54	63	5
1986	Ikpi et al. (1986)	Oyo State	Quantitative	Household	-	-	25	1
1987	Ikpi (1988)	Oyo, Ondo, and Kwara states (southwest)	Quantitative	Household	360	-	Mean annual rate of increase in hectare cultivated to improved - Oyo in Oyo State: 22; Owo in Ondo State:11; average increase: 16.5	5
1987	Nweke et al. (1988)	Humid zone, southwest	Quantitative	Farm	-	-	80	1
1988	Ezedinma (1989)	Subhumid zone, southeast	Quantitative	Farm	-	-	29	5
1989 - 1991	COSCA phase I (Nweke et al. 1996)	Cassava producing areas across Nigeria	Qualitative: Rapid rural appraisal	Village	65	Reported that many/most farmers in the village grew improved varieties: 60	-	2
1990	Ay (1991)	Subhumid zone, southwest	Qualitative	Farmer	429	Planted TMS 30572 from IITA: 30	-	2
1992	COSCA phase III (Nweke et al. 1996)	Cassava producing areas across Nigeria	Quantitative/plot measurement	Household	-	-	Humid zone - improved: 60; local: 40 Subhumid zone - improved: 35; local: 65 Nonhumid zone - improved: 40; local: 60	6
1998	Manyong et al. (2000)	The study involved 20 African countries in which Nigeria is one	Quantitative (Structured Questionnaire)	Expert (leaders of the national cassava breeding programs)	-	-	23	1

2003	Omonona, Oni, and Uwagboe (2006)	3 LGAs from each senatorial district in Edo state, 4 villages per LGA, 15 respondents per village	Quantitative (Structured Questionnaire)/ Tobit regression model to explain determinants of level of technology package adoption & poverty level	Household	180	95 (Male: 81 Female: 19)	-	4
2003/04 cropping year	Onu and Ohajianya (2005)	6 out of 27 LGAs in Imo state; 2 communities per LGA, 10 households from each community	Quantitative (Structured Questionnaire)/ Agricultural Household Model to explain low adoption of improved cultivars	Household	120	The use of only improved varieties is not widespread; low extension contact contributes. Local only: 0.0; improved only: 5.0; TMS 30572 and local: 4.2; TMS 30555 and local: 5.8	-	4
2004	Johnson et al. (2005)	Humid zone	Spillover effect prediction from heterogeneous-agent model based on COSCA 1989/1991 data	Households	47	83	60	6
2004	Johnson et al. (2005)	Sub-humid zone	Spillover effect prediction from heterogeneous-agent model based on COSCA 1989/1991 data	Households	101	30	36	6
2006	Tokula and Ekwe (2006)	4 LGAs in Benue State (Makurdi, Gwer, Gwer East and Guma), 10 extension agents per LGA, 40 in total	Quantitative (structured questionnaire)/ /linear regression	Extension agent	40	TMS 30572: 53; TMS 4(2)1425: 32; NR 8082: 25; NR 8083: 10	-	5
2006	Agwu and Anyaeche (2007)	6 rural communities in Nnewi South LGA of Anambra State, 20 cassava farmers per community	Quantitative (Structured Questionnaire)/ Descriptive statistics	Farmer	118	Local only: 14; improved only: 22; Local & improved: 64; TMS 30572: 79; TMS 30555: 57; TMS 4(2)1425: 10; Akpuocha: 12; Udukanani: 77; Achirinaka: 6	-	5

Table 3 cont'd. Results of Studies Examining the Adoption Rate and Intensity for Improved Cassava Varieties in Nigeria

Year of Study	Author(s)	Location in Nigeria	Survey/analytical method	Level of investigation	Sample size (n)	Adoption rate (% adopters)	Adoption intensity (% cassava land area)	Study category*
2007	Udensi et al. (2011)	17 LGAs in Abia State, 30 farmers per LGA	Quantitative (Structured Questionnaire)/ probit estimation of determinants of adoption	Farmers	510 (30 per LGA)	Local only: 26.4; Improved only: 12.4; Mixed 61.2, NR8082: 38.6; TME 419: 36.7; TMS 98/0505: 12.9; TMS 98/0581: 6.7; TMS 98/510: 5.1; TMS 97/2205: 4.9	-	5
2009	Tokula, Asumugha, and Ibeachi (2009)	2 LGAs in Kogi State (Ankpa and Olamaboro or Ayangba and Alloma ADP zones)	Quantitative (Structured Questionnaire)/ Descriptive statistics	Farmers	60	Cultivated TMS 92/0326 on scattered plots: 90	-	3
2009	Nwakor et al. (2011)	5 LGAs in Abia State, 2 communities per LGA, 15 farmers per LGA	Quantitative (Structured Questionnaire)/ probit estimation of determinants of adoption of two improved varieties (TME 419, NR 8082, NR 8083)	Farmer	150	Adoption of improved variety studied is higher among farmers of high social class who are literate. Adoption rate was not reported but % of farmers aware of the variety are as follows: NR 8082: 81; NR 8083: - ; TME 419: 97	-	3
2010	Apu and Nwachukwu (2011)	Ohafia agricultural zone in Abia State, 5 extension blocks, 30 housholds from each block	Quantitative (Structured Questionnaire)/ Descriptive statistics	Household	150	TMS 30572: 70; NR 8082: 66	-	3
2011	Ibitoye (2011)	4 senatorial districts in Kogi state, 1 LGA per district, 2 communities per LGA, 45 respondents per community	Quantitative (structured questionnaire)/ customer buying behavioral model with an application of dynamic programming	Household	360	Varieties were categorized into 3 aggregates: TMS (Variety A); NR (Variety B); Local (Variety C) and farmers were asked for the number of cassava stands planted per variety category	TMS: 32; NR varieties: 38; Local varieties: 30. Quantity of improved variety cuttings cultivated by gender - male: 69.5; female: 30.5	1

2011	Ibitoye (2011)	4 senatorial districts in Kogi state, 1 LGA per district, 2 communities per LGA, 45 respondents per community	Quantitative (structured questionnaire)/ customer buying behavioral model with an application of dynamic programming	Household	360	Varieties were categorized into 3 aggregates: TMS (Variety A); NR (Variety B); Local (Variety C) and farmers were asked for the number of cassava stands planted per variety category	TMS: 32; NR varieties: 38; Local varieties: 30. Quantity of improved variety cuttings cultivated by gender - male: 69.5; female: 30.5	1
2011	Alene et al. (2012)	DIVA project covering 5 states in Southwest, 10 farmers per state, covering 80 villages across all the five states	Quantitative: household survey Qualitative: data collection involved focus group interviews, farmer's interview, field observation of varieties and plot measurement. However, number of FGD per location as well number of expert interviews are not reported	Expert, farmer groups, household	841 households	Ekiti: 88; Ogun: 125; Ondo:175; Osun: 209; Oyo: 244	Overall mean (household): 52 Overall mean for TMS 30572 (household): 8 Expert opinion - Ekiti: 60; Ogun: 75; Ondo: 65; Osun: 60; Oyo: 70 Farmers' FGDs - Ekiti: 73; Ogun: 78; Ondo: 77; Osun: 58; Oyo: 44 Household level survey - Ekiti: 51; Ogun: 58; Ondo: 50; Osun: 59; Oyo: 54	1
2012	Babasanya et al. (2013)	Igbabi LGA in Kaduna, 3 out of 14 districts, 3 villages per district, 10 cassava farmers per village	Quantitative (structured questionnaire) & qualitative (focus group discussion)	Household	67	Prefer TMS 01/1412: 66; undecided: 11	-	2
2012	Asogwa et al. (2012)	9 LGAs selected based on cassava production data, 360 cassava farmers were randomly drawn from these LGAs	Quantitative (structured questionnaire)/ descriptive statistics	Farmer	360	Improved variety: 52.78 Local variety: 47.22	-	4

REFERENCES

Agwu, A. E., and C. L. Anyaeche. 2007. "Adoption of Improved Cassava Varieties in Six Rural Communities in Anambra State, Nigeria." African Journal of Biotechnology, 6(2): 089–098.

Ajala, A. O., S. I. Ogunjimi, and A. J. Farinde. 2012. "Assessing the Effectiveness of Improved Cassava Production Technologies among Cassava Farmers in Osun State, Nigeria." Journal of Agricultural Research, 1(7): 281–288.

Akoroda, M. O., T. Gebremeskel, and A. E. Oyinla. 1989. "Impact of IITA Cassava Varieties In Oyo State, Nigeria, 1976–1985." Tropical Agriculture (Trinidad), 66(2): 113–120.

Alene, A. D., T. Abdoulaye, P. Kulakow, and V. M. Manyong. 2012. "Adoption of Improved Cassava Varieties in Southwestern Nigeria. Diffusion and Impact of Improved Varieties In Africa (DIVA)." Objective 2 Technical Report, IITA-Malawi, October.

Apu, U., and I. Nwachukwu. 2011. "Effect of Adoption of Improved Cassava Varieties on Farmers' Income in Abia State, Nigeria." Journal of Agriculture and Social Research, 11(2): 155–160.

Asogwa, B. C., J. C. Umeh, and V. A. Okwoche. 2012. "Agricultural Policy in the Cassava Sub-Sector: Implications for Welfare of Cassava Farmers in Nigeria." British Journal of Science, 6(2): 81–98.

Awoyinka, Y. A. 2009. "Effect of Presidential Initiatives on Cassava Production Efficiency in Oyo State – Nigeria." Ozean Journal of Applied Sciences, 2(2): 185–193.

Ay, P. 1991. "New Cassava Varieties and Their Impact: An Assessment with Qualitative Data from Farmers Memories, Results from a Sample Survey in Western Nigeria." UTA Seminar, October 31, 1991, Ibadan, Nigeria.

Babasanya, B., O. G. Oladele, O. O. Odidi, L. Ganiyu, E. Apene, J. Etim, S. O. Olafemi, and A. Sirajo. 2013. "Farmers' Perception and Knowledge Need For Adoption of New Cultivars of Cassava in Igbabi Local Government Area (LGA), Kaduna State." Journal of Biology, Agriculture and Healthcare, 3(2): 45–53.

Bankole, O., O. G. Oladele, B. Bridget, L. Ganiyu, and E. Apene. 2012. "Farmers' Perception and Knowledge Need for Adoption of New Cultivars of Cassava in Igbabi Local Government Area (LGA), Kaduna State." Journal of Agricultural Science, 2(12): 314–318.

Byerlee, D., and E. de Polanco. 1986. "Farmers' Stepwise Adoption of Technological Packages: Evidence from Mexican Altiplano." American Journal of Agricultural Economics, 68(3): 519–527.

Conley, T. G., and C. R. Udry. 2010. "Learning about a New Technology: Pineapple in Ghana." American Economic Review, 100(1): 35–69.

Dallas, J. F. 1988. "Detection of DNA 'Fingerprints' of Cultivated Rice by Hybridization with a Human Minisatellite DNA Probe." Proceedings of the National Academy of Science (USA), 85(18): 6831–6835.

Dixon, A. G. O., and G. Ssemakula. 2008. "Prospects for Cassava Breeding in Sub-Saharan Africa in the Next Decade." Journal of Food, Agriculture & Environment, 6(3–4): 256–262.

Dixon, R. U., et al. 2010. Improved Cassava Variety Handbook. Ibadan, Nigeria: International Institute of Tropical Agriculture.

Doss, R. D. 2006. "Analyzing Technology Adoption Using Microstudies: Limitations, Challenges, and Opportunities for Improvement." Agricultural Economics, 34: 207–219.

Ezedinma, C. I. 1989. "Impact of Some Improved Varieties on Cassava in Anambra State, Nigeria." In Contributions from the Second Annual Meeting of the Collaborative Group in Cassava-Based Cropping Systems Research. Cassava-Based Cropping Systems Research II, Resource and Crop Management Program. Ibadan, Nigeria: International Institute of Tropical Agriculture.

FAOSTAT. 2013. Food and Agricultural Organisation of the United Nations Online Statistics Database. http://faostat.fao.org/site/339/default.aspx. Accessed January 7, 2013.

Heidhues, F., A. Atsain, H. Nyangito, M. Padilla, G. Ghersi, and J-C. Le Vallée. 2004. Development Strategies and Food and Nutrition Security in Africa: An Assessment. 2020 Discussion Paper No. 38. Washington, DC: International Food Policy Research Institute.

Ibitoye, S. J. 2011. "The Influence of Socio-Economic Variables of Farmers on Their Choice of Cassava Varieties in Kogi State, Nigeria." International Journal of Agricultural Science, Research and Technology, 1(4): 185–193.

Ikpi, A. 1988. "Monitoring and Evaluating Household Food Security and Nutrition Projects." IITA-UNICEF Collaborative Program Report, IITA, Ibadan, Nigeria.

Ikpi, A. E., T. Gebremeskel, N. D. Hahn, H. Ezumah, and J. A. Ekpere. 1986. "Cassava – A Crop for Household Food Security. A 1986 Situation Analysis for Oyo Local Government Area- Nigeria." IITA-UNICEF Collaborative Program on Promotion of Household Food Production and Nutrition, Socio-economic unit, IITA, Ibadan, Nigeria.

Johnson, M. E., W. A. Masters, and P. V. Preckel. 2005. "Diffusion and Spillover of New Technology: A Heterogeneous-Agent Model for Cassava in West Africa." Agricultural Economics, 35: 119–129.

Khanna, M. 2001. "Sequential Adoption of Site-Specific Technologies and Its Implications for Nitrogen Productivity: A Double Selectivity Model." American Journal of Agricultural Economics, 83(1): 35–51.

Maertens, A., and C. B. Barret. 2012. "Measuring Social Networks' Effects on Agricultural Technology Adoption." American Journal of Agricultural Economics Papers and Proceedings.

Manyong, V., A. Dixon, K. Makinde, M. Bokanga, and J. Whyte. 2000. "The Contribution of IITA-Improved Cassava to Food Security in Sub-Saharan Africa: An Impact Study." International Institute of Tropical Agriculture: Ibadan, Nigeria.

Moyib, O., O. A. Kodunola, and A. G. O. Dixon. 2007. "SSR Markers Reveal Genetic Variation between Improved Cassava Cultivars and Landraces within a Collection of Nigerian Cassava Germplasm." African Journal of Biotechnology, 6(23): 2666–2674.

Muhammad-Lawal, A., S. A. Salau, and S. A. Ajayi. 2012. "Economics of Improved and Local Varieties of Cassava among Farmers in Oyo State, Nigeria" Ethiopian Journal of Environmental Studies and Management, 5(2): 189–194.

Munasib, A. and Roy, D. 2011. "Socializing Interactions and Social Attitude Formation." A paper under review at Journal of Urban Economics, Department of Economics and Legal Studies, Oklahoma State University. http://spears.okstate.edu/ecls-working-papers/files/0802_Munasib_SocAttitude.pdf.

Nwakor, F. N., G. E. Ifenkwe, B. C. Okoye, F. N. Onummadu, H. N. Anyaegbunam, T. O. Ekedo, and C. E. Onyia. 2011. "Socio-Economic Factors Affecting Adoption of Improved Cassava Varieties among Farmers in Abia State." Journal of Agriculture and Social Research, 11(1): 63–71.

Nweke, F. 2004. New Challenges in the Cassava Transformation in Nigeria and Ghana. EPTD Discussion Paper No. 118. Washington, DC: International Food Policy Research Institute, Environment, Production, and Technology Division.

Nweke, F. 2009. Controlling Cassava Mosaic Virus and Cassava Mealybud in Sub-Saharan Africa. IFPRI Discussion Paper 00912. Washington, DC: International Food Policy Research Institute.

Nweke, F. I., D. S. C. Spencer, and J. K. Lynam. 2002. The Cassava Transformation: Africa's Best Kept Secret. East Lansing: Michigan State University Press.

Nweke, F. I., B. O. Ugwu, and A. G. O. Dixon. 1996. "Spread and Performance of Improved Cassava Varieties in Nigeria." Collaborative Study of Cassava in Africa (COSCA) Working Paper No. 15, Resource and Crop Management Division. Ibadan, Nigeria: International Institute of Tropical Agriculture.

Nweke, F. I., H. C. Ezumah, and D. S. C. Spencer. 1988. "Cropping Systems and Agroeconomic Performance of Improved Cassava in a Humid Forest Ecosystem." RCMD Research Monograph. No. 2, Resource and Crop Management Program. Ibadan, Nigeria: International Institute of Tropical Agriculture.

Omonona, B. T., Oni, O. A., Uwagboe, A. O. 2006. "Adoption of Improved Cassava Varieties and Its Welfare Impact on Rural Farming Households in Edo State, Nigeria" Journal of Agricultural and Food Information, 7(1): 39–55.

Onu, D. O., and D. O. Ohajianya. 2005. "Variety Characteristics and Cassava Adoption among Rural Households in Imo State." Journal of Agricultural and Social Research, 5(1): 33–40

Oparinde, A., S. Bamire, A. Adepitan, A. Ajayi, M. Ala, E. Birol, D. Asare-Marfo, A. Tahirou, and P. Ilona. 2012. "Situation Analysis of Cassava Farmers' Current Varieties and Practices in Oyo State, Nigeria." HarvestPlus Qualitative Draft Report. Washington, DC: International Food Policy Research Institute.

Parkes, E. Y. 2011. "Assessment of Genetic Diversity, Combining Ability, Stability and Farmer Preference of Cassava Germplasm in Ghana." Degree Philosophiae Doctor Thesis, Department of Plant Sciences (Plant Breeding), Faculty of Natural and Agricultural Sciences at the University of the Free State.

Raji, A. A. J., I. Fawole, M. Gedil, and A. G. O. Dixon. 2009. "Genetic Differentiation Analysis of African Cassava (Manihot Esculenta) Landraces and Elite Germplasm Using Amplified Fragment Length Polymorphism and Simple Sequence Repeat Markers." Annals of Applied Biology, 155: 187–199.

Raji A. A, T. A. O. Ladeinde, and A. G. O. Dixon. 2007. "Agronomic Traits and Tuber Quality Attributes of Farmer Grown Cassava Landraces in Nigeria." Journal of Tropical Agriculture, 45(1–2): 9–13.

Rusike, J., T. Abdoulaye, G. Asumugha, A. Dixon, V. Manyong, and P. Ilona. 2012. "Does cassava processing research-for-development have an impact on fabricator, processor and farm level outcomes? Evidence from Nigeria." In Proceedings of Pre-conference Workshop, "Assessing Impacts of Agricultural Research," 28th International Conference of Agricultural Economists: The Global Bio-Economy, August 18–24, 2012.

Smale, M., P. W. Heisey, and H. D. Leathers. 1995. "Maize of the Ancestors and Modern Varieties: The Microeconomics of High-Yielding Variety Adoption in Malawi." Economic Development and Cultural Change 43(2): 351–368.

Tarawali, G., C. Iyangbe, U. E. Udensi, P. Ilona, T. Osun, C. Okater, and G. N. Asumugha. 2012. "Commercial-Scale Adoption of Improved Cassava Varieties: A Baseline Study to Highlight Constraints of Large-Scale Cassava Based Agro-Processing Industries in Southern Nigeria." Journal of Food, Agriculture and Environment, 10(3–4): 689–694.

Tokula, M. H., G. N. Asumugha, and O. O. Ibeachi. 2009. "Adoption of Improved Cassava Varieties in Kogi State, Nigeria." Global Approaches to Extension Practice: A Journal of Agricultural Extension, 5(1). http://www.ajol.info/index.php/gaep/issue/view/6820

Tokula, M. H., and K. C. Ekwe. 2006. "Utilization of Improved Cassava Varieties among Extension Agents in Benue State, Nigeria." Journal of Agriculture and Social Research, 6(2): 80–85.

Udensi, U. E, G. Tarawali, E. U. Favour, G. Asumugha, C. Ezedinma, B. C. Okoye, C. Okarter, P. Ilona, R. Okechukwu, and A. Dixon. 2011. "Adoption of Selected Improved Cassava Varieties among Smallholder Farmers in South-Eastern Nigeria." Journal of Food, Agriculture & Environment, 9(1): 329–335.

APPENDIX

Table A. Investments and Policy Changes Affecting Cassava Technology Development and Adoption Promotion in Nigeria

Timeline	Source of change	Definition of problem/policy change	Description
1976–1985	Federal government	Subsidy on rice and wheat imports	The effect of this policy on cassava production was made worse by oil boom. Resulted in unstable growth in cassava production. This depressed the price of gari and acted as a constraint on the spread of the TMS varieties.
1972	Federal government	NAFPP (National Accelerated Food Production Programme) extension project established	It covers all of Nigeria but cassava was added to the list of crops of focus in 1974.
1976	Federal government	National Root Crop Research Institute (NRCRI) established	Initially established in Eastern Nigeria but is now national.
Early 1980s	Federal government	Government fertilizer subsidy	Cassava did not benefit from the fertilizer subsidy as it was not one of the focus crops at that time. It instead depressed the cassava production.
1982	Federal government	Agricultural Development Project (ADP) established	Effects seen across all of Nigeria.
1982	Federal government	Farm settlement approaches to extension	Focusing on cassava farmers in Eastern and Western region
1984	Federal government	In 1984, the NCRCP (National Coordinated Research on Cassava Project) was set up	The project coordinates the on-farm adaptive research on cassava by the NAFPP, ADPs, research institutes, and universities across Nigeria
1985	Federal government	Government removed subsidy on grains import, banned importation, and introduced new economic policies.	Affected all of Nigeria.
1985	Federal government	NAFPP	NAFPP was working with 704,000 farmers in the 12 major cassava producing states of Nigeria.
1985	Federal government and World Bank	World Bank funding was secured to support; Cassava was also added to the project as a crop of focus.	ADP multiplied and distributed TMS materials across Nigeria.
1986	Federal government and World Bank	ADP distributed TMS 30572 to 55000 farmers to plant about 26000 hectares.	Varieties were distributed in Oyo State.
1986	IFAD (International Fund for Agricultural Development) - Implemented by the Federal government	Cassava program of the National Seed Service was established.	The program has the objective of multiplying and distributing the stem cuttings of the TMS varieties free to farmers to stimulate rapid diffusion It had US$120 million grant.
2004–2009	USAID/SPDC/NDDC	Cassava Enterprise Development Project (CEDP)	Supported by IITA with $29 million, contributed by United States Agency for International Development (USAID), Shell Petroleum Development Company (SPDC), International Institute of Tropical Agriculture (IITA) and the Federal Government of Nigeria.
2005–2010	Chemonics, USAID-Implemented by IFDC	Maximizing Agricultural Revenue and Key Enterprises in Targeted Sites (MARKETS)	Goal was to help transform Nigerian subsistence agriculture into commercially competitive market, improving sale of improved seeds, fertilizer and crop protection products.
2006–2009	Tropical Soil Biology and Fertility Institute of the CIAT (TSBF-CIAT) - Implemented by IFDC	Combating Soil Fertility Decline to Implement Smallholder Agricultural Intensification in Sub-Saharan Africa (CSD_ISFM)	Goal was agricultural intensification and providing technical backstopping to IFAD projects in Africa south of the Sahara.

Table A (cont'd). Investments and Policy Changes Affecting Cassava Technology Development and Adoption Promotion in Nigeria

2006–2010	The Netherland's Directorate-General for International Cooperation (DGIS)-Implemented by IFDC	From Thousands to Millions(1000+)	Goal was improving livelihoods of one million farm households through scaling up of IFDC's Competitive Agricultural Systems and Enterprise (CASE) Approach in the entire Nigeria.
2008–2009	Nigeria's National Program for Food Security (NPFS)	Agro-Dealer Network Development (AND)-Implemented by IFDC	The project educated and empowered extension officers who then trained 100 agro-dealers in each of 10 states (Anambra, Bauchi, Bayelsa, Cross River, Imo, Jigawa, Kano, Ondo, Sokoto, and FCT) during a 12-month period.
2008–2011	AGRA - Implemented by IFDC	Nigeria Agro-Dealer Support (NADS) project	NADS provided credit and support (training of field demonstration, soil testing, etc.) to rural agro-dealers across Nigeria.
2009–2013	Marketing Inputs Regionally (MIR Plus)-Donor: ECOWAS, West African Economic and Monetary Union (UEMOA) and DGIS	MIR Plus is improving policy and regulatory environments in the 15 nations of ECOWAS	The project increased the use and efficiency of agro-inputs, improving the availability of technical and market information and using technology to link producers' organizations with agro-dealers.
2009–ongoing	USAID, Alliance for a Green Revolution in Africa (AGRA) and Nigerian National Food Reserve Agency (NFRA)	Nigeria Fertilizer Voucher Program	Enables farmers to obtain agro- inputs in a timely fashion (using vouchers in lieu of cash). It was proposed that 600,000 smallholder farmers in five states will be reached with vouchers by the end of 2010
2010–2013	IFDC/DADTCO/Dutch foreign aid program - Donor: The Netherland's Directorate-General for International Cooperation (DGIS)/Schokland Fund	Cassava Plus – a public-private partnership between IFDC and the Dutch Agricultural Development and Trading Company (DADTCO) - Initiative on mobile cassava processing technology	Goal was to commercialize the cassava production of 160,000 farmers in 3 Nigerian states by linking them to markets more efficiently. The program assisted farmers in planting, harvesting, and transporting crops using a mobile processing unit.
2011–2012	FAO and AGRA – Implemented by IFDC	NEPAD-FAO Fertilizer Subsidy Study	Fertilizer subsidy program in eight African countries including Nigeria
2011–2012	IFDC - Donor: DGIS	Accelerating Agribusiness in Africa – Bridge (AAA-Bridge)	To extend activities of the Strategic Alliance for Agricultural Development in Africa (SAADA-B) and these include fertilizer resource assessments and market information systems (MIS)
2011–2015	Cassava Transformation Agenda	Aimed at modernizing the agricultural sector through deregulation and infrastructure investments, attracting foreign direct investments	Across the country. The program has involved collaborations with the Chinese biotechnology company (Yuan Long Ping High-Tech Agricultural Co. Ltd) Nigeria has secured more than $200 million financing from China for the installation of 18 large-scale cassava flour processing plants
Ongoing	USAID	Promoting links between Matna Starch factory and small oriented producers	Niger Delta region
Ongoing	Federal Ministry of Agriculture and Rural Development	Task Force on Cassava	Unknown
Ongoing	WASCO	Japanese company using cassava as raw materials for manufacturing	Promoting large scale cultivation of cassava in Kogi and Kwara states
Unknown	USAID	Program supporting SMEs	Supported more than 12 SMEs processing industries in Niger Delta region.
Uknown	Shell/IFDC/the Dutch Foreign Aid Program	Shell cassava program	Targeted at helping increase production in Port Harcourt or Niger Delta Region

Source: IFDC; Nweke (2004; 2009); Nweke, Ugwu, and Dixon (1996); Nweke, Spencer, and Lyman (2002), and search engines.