Adoption and Impacts of Modern Groundnut Varieties in Nigeria

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Summary

This paper compares 3 methods of monitoring and evaluating adoption including expert opinions, community and household surveys, identifies the drivers of adoption and assesses the impacts of modern groundnut varieties on rural livelihoods in Nigeria. Results indicate that adoption rate of modern groundnut varieties are estimated to be 51.2% through expert opinions, 52.87% through community surveys and 31% when using household surveys. There are differences between experts and community and household surveys. There are seemingly no differences between estimates from community groups and expert opinions. Expert opinions are over-estimated by more than 20% compared to household surveys. The visual consistency between expert opinions and focus groups hide the differences in the number of varieties reported and the adoption estimates at variety level. The inconsistency between expert opinions, community estimates and household surveys may partially be explained by some methodological issues related to expert opinions and community group surveys. Household surveys remain the best method of evaluating adoption.

Household survey data of 2,732 households was used to assess the drivers of exposure, adoption and impacts of modern groundnut varieties released less than 20 years ago on household poverty and food security. Results showed that adoption is largely explained by knowledge of modern varieties known, age and education of household head, the total work force and household size. This is consistent with many other adoption studies. In addition, assess to seed was significant while and access to markets was not. Results showed that the current adoption rate for modern groundnut varieties is estimated to 22.44% of the farmers accounting for 13% of the groundnut area planted. Using the treatment effect estimation framework, the potential adoption rate for groundnut is estimated to 78.44% leading to an adoption gap of 55.99% implying that there are potential to increase adoption of modern groundnut varieties based on awareness or promotion. The propensity score matching and other econometric methods indicate that the effects of modern groundnut varieties on yield are estimated between 155.05 kg per ha and 202 kg/ha between adopters and matched non-adopters. The estimated impacts of adoption on the score of consumption and coping strategy index (proxy for food security) are significantly different between adopters and matched non-adopters. There are impacts on food security and no proven impacts on poverty. Investment on promotion and seed projects are essential to boost uptake of groundnut varieties in Nigeria and generate more impacts.

Key words: method of monitoring adoption, technology adoption, groundnut, West Africa, Average Treatment Effect

1. Introduction

The role of agricultural technologies and innovations in alleviating and reducing poverty and contributing to economic development has been well documented (Just and Zilbermann, 1988, Binswanger and von Braun, 1991). The benefits from adopting new technologies and innovations are viewed directly through productivity increases that can translate into higher farm incomes and food security. Indirect benefits can accrue to other farmers and consumers through lower food prices, increased in food availability, accessibility and consumption and potentially non-farm employment (de Janvry and Sadoulet, 2001). This is likely to be true in the dryland regions of West Africa and Nigeria in particular where groundnut is a major staple and cash crop and where donors and governments have invested in the development and dissemination of groundnut varieties.

Nigeria is the largest groundnut producing country in West Africa accounting for 51% of the production in the region. The country produces 10% and 39% of the World and Africa's total production respectively. Prior to 1980s, groundnut production declined significantly due to rosette incidence and drought. However, since 1984, production has been increasing at a growth rate estimated to 8% resulting both from area expansion (6%) and increased productivity of 2% (Ndjeunga and Ibro, 2010). It is a major cash crop for many households accounting for 21% of rural cash earnings and is a major source of employment. The roles of groundnut in enhancing rural household livelihood outcomes are important and have been well documented. Groundnut increases the total value of production per hectare by increasing cereal production (intensifying cereal based cropping systems through intercropping, relay cropping and rotation cropping) with biological nitrogen fixation (BNF). By raising food production through BNF of cereal crops, they also increase food security. Groundnut is a nutritious and safe food and contributes to improved health of the rural population. It is rich in protein, oil and micronutrients such as iron and zinc. Their amino acid profiles complement those of cereals, such that consuming them together raises the nutritional effectiveness of both. High iron and zinc contents are especially beneficial for women and children at risk of anemia and have proven to be genetically malleable.

Groundnut contributes to the sustainability of the natural resource base with positive externalities. On average groundnut contributes to about 60 kg nitrogen per hectare. By fixing nitrogen in biological forms that are more slowly released over time than chemical fertilizers they can improve nitrogen use efficiency in farming systems fostering healthier soils richer in biological activity and higher inorganic matter content. By substituting for manufactured chemical fertilizers that are usually insufficiently available to meet the needs of the rural poor, they contribute directly to reducing cultivation costs while also increasing the productivity of other crops the following season (cereals, roots/tubers).

Since 1990, the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), the Institute for Agricultural Research (IAR) in Nigeria, the University of Georgia and the Peanut CRSP developed and tested or adapted 44 groundnut varieties less susceptible to foliar diseases and most importantly resistant/tolerant to rosette disease. These varieties were tested in multi-location trials in partnership with the State Agricultural and Rural Development Authorities (ADRAs) of Kaduna, Kano, Katsina and Jigawa states. From this program, three varieties (UGA 2 (SAMNUT 21) M 572.80I (SAMNUT 22) and ICGV-IS 96894 (SAMNUT 23) were formally released in 2001. Likewise, further research efforts in the same states led to the identification of 3 other promising varieties not formally released but that are currently being planted by farmers (ICIAR 19BT, ICIAR 7B, ICIAR 6AT). The adoption of these varieties will contribute significantly to reducing poverty, increasing food security, improved health, enhanced sustainability of natural resource base of adopters. So far, few studies in WCA have examined the adoption and impacts of modern groundnut varieties and the few have been undertaken in and around project/program intervention sites. As part of the monitoring and evaluation of the Groundnut Seed Project in WCA, baseline results were conducted and results indicate that the adoption of modern groundnut varieties is estimated to 14% in Niger, 44% in Mali and 32% in Nigeria (Ndjeunga et al., 2008). Expert opinions carried out in July 2011 indicate rough estimates of 22% of area planted with modern groundnut varieties in Northern Nigeria (Ndjeunga et al. 2011). In another project, the Tropical Legumes 2 program, baseline data indicate adoption rates of 24% in Niger, 8% in Nigeria and 3% in Mali (Ndjeunga et al. 2010). Expert opinion surveys showed adoption rate of 51.2% in Nigeria for all improved varieties but 21% of recently released varieties[1]. The discrepancies in the adoption rates are largely explained by the non-representativity of samples at national level.

Few studies in Africa have used nationally representative samples. A study from Uganda by Kassie et al. [2010] estimated that 53% of the groundnut area is planted with modern varieties consistent with expert surveys of 56%. Other expert opinion surveys in East and Southern Africa, indicate adoption rates of 47% in Kenya, 32% in Tanzania, 57% in Malawi or Zambia and 56% in Uganda. So far no study has actually assessed the adoption and impacts of modern groundnut varieties in Nigeria (Simtowe, 2011).

In many research and development organizations, monitoring and evaluation are an integral part of the assessment of performance and tools that can be used to take corrective actions when necessary. The evaluation of uptake is an essential part of the process which may be costly. The search for alternative less costly options to assess adoption is likely to enhance the M&E process. In this study, 3 assessment methods will be compared namely the expert opinion, community and group surveys. Therefore the major objectives of the study will be to: (1) compare the 3 methods of evaluation adoption rates of varities, (2) assess the factors explaining farmers' exposure and adoption of improved varieties, and (3) assess the impacts of adoption of modern

[1] Varieties released since 1996

varieties on the livelihood of rural households including poverty reduction, food security and sustainability of natural resource base.

This paper is organized as follows. Section II presents the groundnut research and development process in Nigeria and Section III highlights the methodology and the data. Section IV presents the results and discussions and Section VI concludes with options for increasing adoption and impacts of modern varieties in Nigeria.

2. Groundnut research and dissemination process in Nigeria

Groundnut research and promotion evolved through 3 main phases. Prior to 1992, breeding work was undertaken by IAR. About 20 varieties were developed or adapted and were officially released in Nigeria. Most of the varieties released were medium- to late maturing varieties and were grown in the dry savannah region of Northern Nigeria. Three of these varieties (55-437, RRB and RMP 12) remain widely grown and are very susceptible to the rosette virus. During the second phase, given that most of the varieties could not escape drought and were susceptile to the rosette virus, the focus was placed on the development of early maturing varieties tolerant/resistant to the rosette virus. ICRISAT and IAR engaged in a series of variety trials involving early maturing varieties from ICRISAT material in partnership with ADPs in Kano, Gigawa, Katsina and Sokoto states. After three years of testing, 3 varieties namely ICGV 86015, ICGV 86124 and ICGV 85045, were found promising for further diffusion. At the same time, crosses between early maturing susceptible lines and resistant late maturing lines were developed. Subsequent selection at IAR's Samaru research station led to identification of short-duration (90-110 days), high-yielding rosette resistant breeding lines.

From 1997-onwards, ICRISAT scaled-up its research intervention. A series of variety trials with newly developed rosette resistant breeding lines in the Guinea and dry savanna zones of Nigeria was undertaken. It involved essentially ICRISAT varieties. In effect, more than 95% of IAR-ICRISAT breeding program involved essentially ICRISAT material or germplasm. In 1998, on-farm trials were conducted in collaboration with the extension services (ADPs) and Sasakawa Global 2000 in the states of Kano, Gigawa, and Katsina involving newly developed early and medium maturing rosette resistant varieties. Thus, all new groundnut varieties developed in Nigeria since 1992 contain ICRISAT germplasm.

Since the 1990s, the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), IAR, the University of Georgia, ADPs and Sasakawa developed, tested or adapted with partners a range of groundnut varieties suitable for the different agro-ecological zones resulting in the availability of 44 groundnut varieties. These varieties were tested in multi-location trials in many states including Kaduna, Kano, Jigawa and Katsina. The specific locations for on-farm testing included Samaru (1996-97, 1998-99) in the state of Kaduna, Bagauda (1997-98), Minjibir (1996-98), Shika (1998-99), Kano (1998-99) in the state of Kano, Katsina (1998-99) in the state of Katsina and Maiduguri (1998-99) in Borno State. Following the on-farm testing program, three groundnut varieties (UGA 2 (SAMNUT 21), M 572.80I (SAMNUT 22) and ICGV-IS-96894 (SAMNUT 23) were formally released in 2001. Currently other varieties ICIAR 19BT, ICIAR 7B, ICIAR 6AT are in the pre-release stage but are currently grown by farmers in Nigeria.

Following the release of these varieties, ICRISAT and partners initiated projects to promote and increase access and availability of seed of the preferred varieties to end-users. From 2003 to 2007, a groundnut seed project funded by the Common Fund of Commodities (CFC) was implemented in the states of Kano, Kaduna, Katsina, and Jigawa with major objective to promote varieties and empower communities, seed companies in seed production and delivery of preferred varieties. These efforts were further enhanced by the implementation of the Tropical Legumes II program in other villages in the same states from 2007 to 2010. This resulted in the selection by farmers of 6 varieties though participatory variety selection, and in the production of more than 10 tons of breeder seed, and 125 tons of foundation and 1000 tons of certified seed have been produced and sold to end-users. In addition, more than 1500 farmers have been trained in groundnut seed production technologies, more than 75 farmers have been trained in small-scale business skills and marketing;

3. Methods and data

3.1. Sampling procedure

In order to determine a nationally representative sample size and given the paucity of reliable agricultural statistical information, we solely relied on information on groundnut area in all the 36 states of Nigeria from the FAO National Country Statistics, 2012. Then, all states with zero groundnut production such as Bayelsa, Osun, Ogun, Akwa Ibom, Anambra, Ekiti, Imo, Delta, Ondo, Enugu, Rivers and Abia states were excluded from the list of states. All states not located in the semi-arid zone were also excluded from the list such as Lagos, FCT Abuja, Edo, Cross River, Ebonyi, Kwara, Oyo, Plateau, Benue, Taraba, Nassarawa and Kogi. A total of 13 states located in the semi-arid tropics were retained. These are Kebbi, Gombe, Adamawa, Sokoto, Jigawa, Yobe, Borno, Katsina, Bauchi, Zamfara, Kaduna, Niger and Kano. Out of these, 3 states were removed due funding constraints and the remaining 10 states accounted for about 92% of groundnut area located in the semi-arid tropics (Annex 1). The sample size was computed as a function of the prior probability of uptake from expert opinions, sampling design effect set to 2, and confidence level (error margins) to 0.05 and an adjustment ratio of 10%. The following formula was applied to obtain the sample size:

Table 1: Distribution of villages and households by State in Nigeria

	Number of				
State	Estimates of adoption	Villages originally drawn	Villages surveyed	Households surveyed	LGA surveyed
Bauchi	0.05	8	12	119	8
Borno	0.05	6	10	100	6
Gombe	0.05	2	3	30	2
Jigawa	0.15	45	41	499	21
Kaduna	0.05	12	18	185	10
Kano	0.35	80	72	820	31
Katsina	0.15	45	41	524	22
Niger	0.05	18	29	297	19
Yobe	0.05	3	5	42	5
Zamfara	0.05	9	12	123	7
Total	1	228	243	2739	131

Source: ICRISAT survey, 2011.

$$Sample\ size = \frac{4 \times GAR \times (1 - GAR) \times DEF}{(EMARG \times EMARG)} \times (1 + ADJRAT)$$

where GAR is the guess-estimate of adoption rate in the state, DEF is the design effect, $EMARG$ is the confidence level (error margins) and $ADJRAT$, an adjustment ratio of 10% in case of missing household heads and other reasons. The study was then carried out in 10 major groundnut producing states in Nigeria namely Bauchi, Borno, Gombe, Jigawa, Kaduna, Kano, Katsina, Niger, Yobe and Zamfara. These regions encompassed the Sahelian and Sudanian-savanna zones. These sites span a range of socioeconomic and demographic settings and are representative of agro-ecologies suitable for groundnut production. Based on a ratio of 10 households per village, a total of 228 villages were to be selected. In each state, the villages to be surveyed were randomly selected. Table 1 below summarises the guess-estimates of adoption used, the number of villages to be selected and actually surveyed, the number of households selected and the number of LGA per state.

3.2. Data collection

Expert meetings were organized both at individual and group levels in 5 countries. In the case of Nigeria, individual interviews were carried out with scientists (breeders and agronomists of IAR and ICRISAT) and Directors of Extension services of ADPs of Kano, Katsina and Jigawa. The major 2 questions are to elicit the first 5 groundnut varieties used and then to pin-point the villages or LGA where those varieties can be found and in what percentage. Potential areas occupied by the varieties are summed up and divided by the total groundnut area grown. Then these estimates were valided in a meeting of experts held in Niamey, Niger from 05 and 06 August 2012.

In order to evaluate the adoption of varieties through community group and household levels, a survey was carried out from December 2011 to January 2012 in Nigeria in 245 villages and 2739 households. Data entry was completed by end of February 2012. However, data cleaning took almost 4 months due multiple data entry problems. Figure 1 below depicts the map of the surveyed villages by state and rainfall zone. The survey was implemented at village and household levels using 2 types of survey instruments. Village level information was collected using focus groups tools and structured survey questionnaires. Information was be gathered on village socio-demographic profile, infrastructure and natural resources, land use and tenure system, varieties known and planted, program and projects that have promoted variety evaluation and/or seed production, type and price of inputs, crops and livestock prices, labor/wage prices and credit source and costs, weights and units of measurements. Participatory rural appraisal tools were used to probe farmers on the knowledge and uptake of varieties at village level.

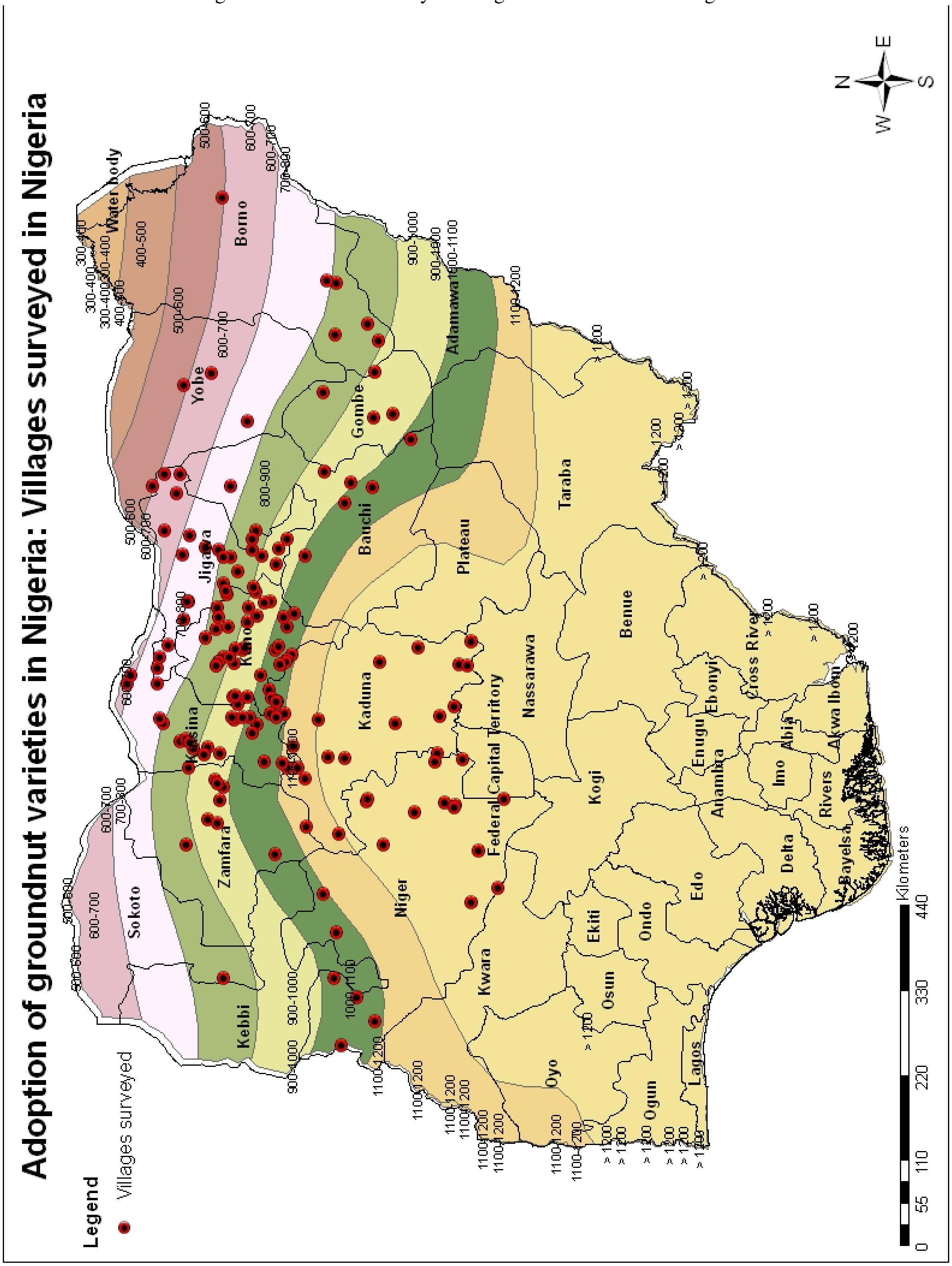
At household level, household data was collected using essentially structured questionnaires. Survey questions included modules on (1) socio-economic and demographic profile of the households [household characteristics, agricultural equipment, land stocks, livestock], (2) knowledge of varieties and sources of first information, (3) adoption and dis-adoption of groundnut varieties, (4) household crop production and livestock (5) utilization, consumption and commercialization of groundnut, (6) input/output at plot level (7) household transactions, (8) household expenditures, (9) household durable assets and (10) finally households' perception of changes in welfare resulting from the use of modern groundnut varieties. The quantitative indicators on poverty and food security indices include the per capita expenditure and the proxy in food security is the score of consumption. The modern varieties under investigation include SAMNUT 21, SAMNUT22, SAMNUT23, ICIAR 19BT, ICIAR 6AT and ICIAR 7B. These varieties are tolerant / resistant to the rosette virus and are early maturing ad were released since 1996.

3.3. Profile of varieties under investigation

The modern varieties under investigation are SAMNUT 21, SAMNUT 22, SAMNUT 23, ICIAR19BT, ICIAR6AT, and ICIAR7B and are characterized below (Table 2).

(1) SAMNUT 21 (UGA 2). This variety, also known as UGA 2, was developed jointly by the University of Georgia in the USA and the Institute of Agricultural Research (IAR) in Nigeria. It results from a cross between (RMP 12 × ICGS (E) 52). It is a medium-maturing variety with vegetative cycle between 115 and 120 days. It is a Virginia type and is resistant to groundnut rosette disease (GRD) and foliar diseases. It has high oil content estimated to 51%. The potential pod yield is about 2.5 tons and 4 tons of haulm on-station and about 1.5 tons on-farm under the best agronomic practices. It was officially released in 2001 but was introduced in on-farm trials in many northern states since 1996. The adaptation zone is between 700 mm to 1000 mm annual rainfall.

Figure 0.1: Selected surveyed villages in the 10 states of Nigeria



(2) SAMNUT 22 (M572.80 I). This variety is also known as M572.80 I under IAR nomenclature. It was selected in 1980 under irrigation at IAR's Mokwa research station in Central Nigeria. It results from a cross between RMP 91 x (4753.70 x 3520.71). It is a medium maturing variety with a vegetative cycle of between 115 to 120 days. It is of Virginia type, resistant to GRD and tolerant to cercospora leafspots. It has moderate oil content estimated to 45%. The potential on-station pod yield is about 2.5 tons/ha and 1.5 tons on-farm. It was officially released in 2001 but was already introduced in on-farm trials in many northern states since 1996. The adaptation zone is the Sudan and Guinea savannah zones (which have average annual rainfall of 700-1500 mm).

(3) SAMNUT 23 (ICGV-IS 96894). This variety is also known as ICGV-IS 96894 under ICRISAT nomenclature. It results from a cross between ICGV-SM 85048 and RG 1. It was developed by ICRISAT in partnership with IAR. It is an early maturing variety with vegetative cycle between 90 and 100 days. It is of Spanish type, resistant to GRD and foliar diseases. It has high oil content estimated to 53%. The on-station potential pod yield is about 2.0 tons and 4 tons of haulm. On-farm yield potential is about 1.5 tons. It was officially released in 2001 but was already introduced in on-farm trials in many northern states since 1996. The adaptation zone is between 700-1000 mm annual rainfall.

(4) ICIAR 19 BT This variety was developed in 1996 by IAR and ICRISAT and results from the crossing between ICGM 751/754 and ICGV 87922. It is an early maturing variety with vegetative cycle between 90 and 100 days. It is a rosette resistant variety with potential yield varying between 2 and 2.5 tons per ha. It is very sensitive to drought stress.

Other important varieties being grown by farmers include 55-437, RMP 12, RMP 91, RRB and other local varieties. The variety 55-437 is the most popular but is highly susceptible to rosette which nearly wiped out the entire groundnut industry in Nigeria in the mid 1970s. On the other hand RMP 12 and RMP 91 though resistant to GRD, are very late maturing (more than 120 days) and are no longer adapted to the short-season environment of the dry savanna zone of Nigeria, where most of the crop is grown. However, farmers still grow these varieties even in the drier areas hoping for a high probability of rainfall.

3.4. Data analysis

Analysis of the data included the use of matching methods, multivariate econometric methods, stochastic dominance methods, and methods of economic cost benefit analysis to estimate the impacts and the discounted gross benefits of investments. We discuss each of these methods briefly.

Table 2: Characteristics of groundnut varieties planted in 10 states of Nigeria

	Characteristics of groundnut varieties planted by farmers in 10 states of Nigeria			
Variety	Crop cycle (days)	Average yield (tons/ha)	Year released	Institution
SAMNUT 21	110-115	2.5	2001	IAR/UGA
SAMNUT 22	110-120	2.5	2001	IAR
SAMNUT 23	90	1.5-2.5	2001	ICRISAT-IAR
ICIAR 19BT	100	2.5	2011	ICRISAT-IAR
ICIAR 6AT	90	2.0	NYR	ICRISAT-IAR
ICIAR 7B	90	2.0	NYR	ICRISAT-IAR
NYR Not yet released				

3.4.1. Matching methods

The basic problem in assessing the impact of a technology on the participants is that the counterfactual situation – what would have happened to the participants had they not participated – is not observed. For example, if a project's outcome indicator is household income, the average impact of a technology on the beneficiaries referred to as the average effect of the treatment on treated (ATT) is defined as the difference between the expected income earned by technology beneficiaries while participating in the project and the expected income they would have received if they had not participated in the project:

$$ATT = E(Y_1|p=1) - E(Y_0|p=1) \quad (eq.1)$$

Where $p = 1$ participation in the project ($p = 1$ if participated in the project and $p = 0$ if did not participate in the project); Y =outcome (household income in this example) of the project beneficiary after participation in project; Y_0 = outcome of the same beneficiary if he/she had not participated in the project; and $E(\ )$ refers to expected value.

Unfortunately, we cannot observe the counterfactual income of the beneficiaries had they not participated in the project $E(Y_0|p=1)$. Simply comparing incomes of households that are participating in the project and those that aren't can result in serious biases, since these two groups may be quite different and hence likely to have different incomes regardless of their participation in the project. For example, adding and subtracting $E(Y_0|p=0)$ on the right hand side of equation (1), we have:

$$ATT = [(E(Y_1|p=1) - E(Y_0|p=0)) - (E(Y_0|p=1) - E(Y_0|p=0)) \quad (eq.2)$$

The first expression (in the first square bracket) in equation (2) is observable since it is the simple difference of mean income between the beneficiaries and non-beneficiaries. The second expression (which is unobservable because $E(Y_0|p = 1)$is unobservable) represents the bias resulting from estimating ATT using the first expression. This bias results because the income or outcome that non-beneficiaries receive without adoption groundnut varieties may not be equal to the income that beneficiaries would have received without adopting modern varieties. Two common sources of bias are program placement or targeting bias, in which the location or target population of the program is not random (e.g., if poorer regions or households are targeted by the program); and self-selection bias, in which households choose whether or not to adopt, and thus may be different in their experiences, endowments and abilities.

The most accepted method to address these problems is to use an experimental approach to construct an estimate of the counterfactual situation by randomly assigning households to treatment (beneficiary) and control (non-beneficiary) groups. Random assignment assures that both groups are statistically similar in both observable and unobservable characteristics, thus avoiding program placement and self-selection biases. Such an approach is not feasible in the present study since program placement and participation decisions were already made prior to design of this study, and are unlikely to have been random.

The quasi-experimental method used is the propensity score matching (PSM), which selects project beneficiaries and non-beneficiaries who are as similar as possible in terms of observable characteristics expected to affect adoption as well as outcomes. The difference in the mean outcomes between the two matched groups can be interpreted as the ATT; i.e., the impact of the project on the beneficiaries.

A key assumption necessary for matching estimators to consistently estimate the impacts of a treatment on the treated is that the outcome that would occur without adopting is independent of whether or not the household adopts, conditional on observed characteristics of households (conditional independence assumption) (Rosenbaum and Rubin [1983]). This assumption assures that the expected value of the outcome variable for group of non-adopters is equal to the expected value of what the outcome of the group of adopters would have been, had it not adopted (i.e., that $E(Y_0|p = 1) - E(Y_0|p = 0)$.

Matching can be done on individual covariates, but if there is more than one continuously distributed covariate, some type of distance metric is needed to aggregate differences between observations of multiple variables into a scalar measure to identify closely matching observations. PSM uses a particular distance metric – the propensity score – which is measured by estimating the probability of adoption (usually using a probit or logit model) as a function of observed covariates that jointly affect the probability of adoption and the impact of the program. In measuring the "distance" between adopters and non-adopters, PSM implicitly gives greater weight to covariates that have a greater impact on the probability of adoption. This is useful, since the variables that have a stronger influence on adoption are the ones that have more potential to bias the estimated impact if not adequately matched.

There are several ways to select the matching observations using propensity scores, including selecting the nearest neighbor (i.e., select for each treated observation the matching non-treated observation with the closest propensity score), the nearest N neighbors, all neighbors within a certain radius (radius matching), or calculating a matching observation based on a weighted mean of its neighbors, with the weights declining as the distance increases (kernel matching). The choice of method involves tradeoffs between bias and efficiency, with nearest neighbor matching minimizing bias, since it uses the best available match, but having lower efficiency than other methods because it discards information about other near matches. An additional issue is estimation of correct standard errors. Since the propensity scores are based on estimated coefficients rather than the true coefficients, this first stage estimation causes additional errors that are not accounted for by standard calculations. A common practice is to use bootstrapping to estimate standard errors, but it has been shown in a recent paper (Abadie and Imbens, 2006) that for nearest N neighbor matching, this does not estimate correct standard errors. Considering this problem, and the greater efficiency of kernel over nearest neighbor matching, we decided to use kernel matching but will report the NN matching as well.

In the matching procedure, we dropped observations that do not have “common support”; meaning observations that are not within the ranges of values of the covariates for which both adopters and non-adopters are represented. This resulted in dropping relatively few observations. Requiring common support reduces a potential bias that can exist in regression models resulting from comparing observations that are from completely different regions of the space of covariates (e.g., if the wealthiest program participants are wealthier than any non-participants or the poorest non-participants are poorer than any participants, including those participants can bias the results of regression models). This helps to avoid biases from comparing non-comparable observations.

The results of the PSM may be biased as a result of imperfect matches. We tested for statistical differences in the covariates between the participants and non-participants in the unmatched and matched samples and found statistically insignificant differences in the matched samples for almost all covariates, though there were many significant differences in the unmatched samples. We also found that the mean levels of the covariates were more similar in almost all cases in the matched samples than the unmatched samples. These results indicate that PSM has reduced potential biases, but it may not have eliminated them, since some differences remain in the matched samples.

To address possible bias in the PSM results, we also used the bias corrected N nearest neighbor matching estimator developed by Abadie et al., 2004. This estimator has the advantages that it corrects for the bias using auxiliary regressions and estimates the analytically correct standard error for the ATT. Unfortunately; the distance metric used by this estimator is more arbitrary than the PSM metric. The distance metric used by this procedure is based on the sum of the magnitudes of differences in values of the covariates, weighted by the inverse of the standard errors of these variables. Unlike the PSM metric, this metric does not account for which covariates have a greater impact on the probability of adoption. Given that each matching estimator has disadvantages as well as advantages, we decided to use and report the results of both estimators.

The covariates that we used in the matching estimations for impacts on the household response and outcome variables (e.g., average household crop yield, per capita crop production per hectare) include variables reflecting the household's endowments of natural, physical, human and social capital, and the quality and tenure of the plot. These were amount of land owned (in ha) in 2006, average quality of the soil of plots used by households (soil fertility, soil texture), tenure of the plot (family vs. individual plot, means of plot acquisition), value of livestock owned in 2006, value of farm equipment owned in 2006, value of household assets (transportation equipment, other durable goods) owned in 2006, age and education of the household head in 2006 and dependency ratio in 2006.

The models also included state fixed effects (different intercepts for each state), which account for all state level factors affecting adoption (e.g., agro-ecological zone, access to markets and infrastructure, etc.). In the matching estimations for gross income per capita we used the same explanatory variables, except that we used household level aggregate versions of the plot variables (e.g., share of land of particular qualities or tenure). We used the values of endowments and other time-varying covariates in 2006, rather than in 2010/11, as determinants of the propensity scores, because of concern about reverse causality. By using earlier levels of endowments, these levels are less likely to have been affected by adoption. There still may be problems of reverse causality for older programs, but we are unable to do more to address this problem with our data. Interpretation of the coefficients of the propensity score regression may be affected by this reverse causality. Fortunately the validity of the results of PSM does not depend upon the exogeneity of the covariates used to predict the propensity scores, as long as the conditional independence assumption is satisfied (Heckman et al., 1988).

Matching methods have some advantages over econometric regression methods since they compare only comparable observations and rely less on parametric assumptions to identify the impacts of projects (Heckman et al., 1988). However, matching is subject to the problem of "selection on unobservables", meaning that the adopters and non-adopters groups may differ in unobservable characteristics, even though they are matched in terms of observable characteristics. This could lead to violation of the conditional independence assumption underlying matching. Econometric instrumental variables regression methods have been devised to address this problem, although these suffer from the problems noted above. We used econometric methods to address these concerns and check robustness of the conclusions from the matching methods. These methods are described further below.

3.4.2. Econometric analysis

We use econometric models to estimate the impacts and other factors on adoption of groundnut varieties on the gross value of crop production at household level, on gross household income per capita, on the per capita expenditures, on the per capita groundnut sales, on the per capita wealth and on score of consumption. The explanatory variables included in these regression models included the adoption of modern groundnut varieties , plus the same covariates used to estimate propensity scores in the PSM model. The only difference is that 2009/10 values of household endowments and other time varying covariates were used in the per capita total value crop production and per capita gross revenues regressions, rather than 2006/07 values, as in the PSM model. The reason for this is that the concern about reverse causality does not apply in these regressions, since the endowments were measured as of the beginning of the current crop and income year, so would not be affected by crop production and gross revenues in 2009/10. As in the PSM model, we used household level aggregates of the plot level covariates in the model for household income per capita.

As mentioned above, instrumental variables methods are available to deal with problems of selection on unobservables. We use instrumental variables (IV) (also known as two-stage least squares) regressions to test whether there are such problems in the econometric models. The instrumental variables we used for adoption of varieties are the predicted probabilities of awareness on varieties from the probit models used in the PSM. Tests of the relevance of these instrumental variables in the IV versions of the models determining adoption of varieties and ln(per capita value of crop production) found that these instruments are strong predictors of awareness, and that under-identification of the IV model is rejected (Davidson and MacKinnon, 2004). A "C-test" was used to test the exogeneity of the program participation variables (Baum et al., 2003), and was found to support in almost all exogeneity of these variables, meaning that concerns about selection on unobservables are statistically rejected. Hence, the probit models (in the case of adoption of varieties) and ordinary least squares model (in the case of per capita value of crop production) is preferred, as they are more efficient than the IV model. This also helps to support the conditional independence assumption of the matching estimators.

We estimated the outcome models (per capita value of crop production, etc..) including adoption of varieties as explanatory variable, to be able to assess the direct impacts of varieties on productivity, controlling for other factors. We also estimated a reduced form version of the model without adoption included; in this case the total impacts of adoption, considering the effects of adoption of varieties, are estimated. We first estimated an unrestricted ordinary least squares (OLS) version of the regression, including all of the explanatory variables mentioned above, plus the adoption of varieties. Then we used a Wald test to test the joint statistical significance of several household level variables that were hypothesized to affect production only by adoption of varieties. These variables were found to be jointly statistically insignificant and were removed from the model to improve model efficiency and identification in an IV version of the restricted model. Restricted OLS and IV models were estimated, excluding the jointly insignificant household level variables and using them as instrumental variables, which may be subject to endogeneity bias, in the IV model. Other instrumental variables used in the IV model included the value of endowments and other time-varying covariates as of 1999. A Hansen's "J" overidentification test was conducted to test the validity of the instruments used, and the test supported their validity (Davidson and MacKinnon, 2004). The strength of identification of the IV model was tested using Anderson's canonical correlation likelihood ratio statistic, and weak identification was found to be a problem, suggesting that the results of the IV model could be seriously biased (Bound et al., 1995). The C test for exogeneity of adoption of varieties failed to reject exogeneity of varieties, so the restricted OLS model is preferred to the IV model.

For per capita gross revenues or total value of crop production, we estimated 3 regressions: an unrestricted OLS model, including all of the explanatory variables, a restricted OLS model in which the household head's social status variables were dropped (these were found to be jointly statistically insignificant in the unrestricted model), and an IV version of the restricted model. The social status variables and the household's endowments in 1999 were used as instrumental variables for the adoption variables in the IV model. Identification tests supported the validity of the instrumental variables used, but showed that weak identification of the model is a problem. The C test failed to reject exogeneity of the program participation variables, so the restricted OLS model is preferred.

3.4.3. Stochastic dominance analysis

Using the matched samples, we plotted the cumulative density functions (cdf) of the average groundnut yield, per capita total value of production, per capita total wealth of households and per capita total sale of sorghum or pearl millet for adopters and matched non-adopters. This allowed us to investigate the impacts of adoption of modern varieties on the entire distribution of yield, total value of crop production per household, and not only on the mean value. In comparing these cdf's we assess whether the distribution with adopters (first order) stochastically dominates the distribution without adoption, which means that the probability of average groundnut yield, per capita wealth and per capita value of sales falling below any threshold level is lower with the practice than without it (Mas-Colell et al., 1995). When this occurs, adoption of modern varieties reduces risk as well as increasing mean yield. Simple comparison of cdf's using unmatched samples could lead to biased conclusions, since other factors besides adoption in question could be responsible for differences in the distributions. We use the matched samples for this in order to reduce this potential bias.

Table 3: Mean characteristics of focus group participants in the villages

Characteristic	State										
	Bauchi	Borno	Gombe	Jigawa	Kaduna	Kano	Katsina	Niger	Yobe	Zamfara	Overall
Group size	6	19	14	16	13	17	15	18	16	17	16
Number female	0	0	0	0	1	0	1	1	1	0	0
Mean age	50	47	45	51	42	46	52	42	49	42	47
Agriculture-main	92.5	92.8	84.1	94.9	87.8	86.73	95.3	84.6	77.6	92.9	90.1
Village head	11.32	8.7	0.0	33.3	9.3	12.0	14.3	7.1	20.6	7.5	14.8
Religious leader	8.68	19.3	18.6	13.9	9.9	3.5	9.9	6.4	1.3	12.9	8.5
Opinion leader	41.7	23.4	54.3	12.8	14.6	21.9	29.9	10.8	7.5	11.7	20.5
Other status	38.3	48.6	27.1	40.0	66.3	62.7	45.9	76.8	70.7	67.9	56.2

Source: Groundnut adoption survey in Nigeria, ICRISAT 2011

IV. Results and discussions

This section presents the results including the human capital ie. the socio-demographic profile of villages and households surveyed, the physical capital ie. the stock of land owned and cultivated, the financial assets ie. the major sources of household liquidity or cash, the number of households who have access to credit and the amount of credit contracted, the social capital ie. the number households with a member affiliated to an institution and the average number of members in the households affiliated to one or more institutions, and the durable assets as proxies for wealth. Then factors explaining exposure to modern groundnut varieties are identified and discussed, drivers of adoption of modern varieties are elicited, and impacts of groundnut varieties on household livelihoods are assessed.

4.1. Socio-demographic and economic profile of villages and households

4.1.1. Socio-demographic and economic profile of villages

Table 3 presents the mean characteristics of focus group participants by State. A total of 243 communities were interviewed with one in each village surveyed. The average group size was estimated to 16 members with significant differences between States. Bauchi had the lowest number of members in the groups while Borno had the hghest ie. 19 members. There were almost no female in the groups reflecting the social fabrics in the Northern part of Nigeria. The average age of the members of the group was estimated to 47 years old, reflecting the potential knowledgeable that members may have on adoption related issues. Agriculture is the main occupation for 90% of the group interviewed. Overall, in 15% of the groups, a village head was present, in 8.5% a religious leader, in 20.5% an opinion leader and the remaining sample was made of farmers without a specific social status.

4.1.2. Socio-economic and demographic profile of households

Table 4 presents the socio-economic and demographic profile of households including human capital, physical capital, financial capital and social capital assets.

Survey results showed that the average age of the household head is estimated to about 48 years with a median of 48 years, that about 98% of household heads are married and that there are few female headed households, less than 2%. The average household size is estimated to 10 members with a total work force of 6. There dependency ratio is estimated to about 2 and only about 38% of household heads are literate. On average, in each household, there are 6 members who receive a formal education and a household member has about 6 years of schooling. About 71% of respondents belong to the Hausa ethnic group. Agriculture is the main occupation for 90% of respondents. Overall, these results are consistent with those reported in Nigeria (Ndjeunga et al., 2008).

On average, households own 7 ha of land and they cultivate on average about 6 ha. Grounndut is cropped on about 36% of the cultivated area ie. 2.16 ha. The average value of agricultural equipment owned by households is estimated to about US$521 without draught animals and US$779 with draught animals. Land is mostly owned by inheritance for 78% and by purchase for 17% of respondents. Seventy-one percent of the plots are individually owned. The proportion of households using inorganic fertilizers on groundnut fields is estimated to about 46%, and 11% are using organic fertilizers, 6% pesticides, 76% used corralling. Fertilizer use intensities are estimated to about 2 bags ie. 94 kg/ha.

The value of durable assets is estimated to about US$383. Most of the households surveyed are well connected to information supply sources. In effect, about 51% of households surveyed owned cellular phones, 74% of the households own a radio and 18% have a TV set. As for means of transport, 59% of households have a bicycle, 59% have a motorcycle and 10% owned a vehicle.

About 32% of households surveyed have access to formal credit. It is estimated that about 2% of households contracted loans from commercial banks, 1% from micro-finance institutions, 0.15% from NGO and projects. Most farmers contract with informal institutions. In effect, 25% of the households contract loans from family, neighbors or friends, 6.64% from village traders ...etc. The amount of credit contracted through commercial banks is lower than that of infomal institutions. On average, in 2010, households contracted on average about US$20.24 from commercial banks, US$75.37 from family, friends and relatives and US$175.30 from traders. Other

Table 4: Household socio-economic and demographic profile

	Basic statistics				
Variable	Mean	Stdev.	Min	Max	Median
Human capital					
Age of household head (years)	48.44	11.26	20	90	48
Sex of household head (0=female, 1=male)	0.98	0.13	0	1	1
Household size (number)	8.99	4.20	1	20	8
Work force (number of adult equivalents)	5.28	2.62	0.5	19	4.75
Dependency ratio	2.16	1.75	0.00	16.00	1.75
Illiteracy (0=illiterate, 1=literate)	0.38	0.49	0	1	0
Number of years of schooling of HH	6.39	5.95	0	25	6
Number of educated members of HH	4.92	3.73	0	20	4
Marital status (0=not married, 1=married)	0.98	0.15	0	1	1
Major ethnic group					
Hausa	0.71	0.45	0	1	1
Fulani	0.09	0.28	0	1	0
Agriculture as main occupation (0=No, 1=Yes)	0.89	0.32	0	1	1
Physical capital					
Land owned (ha)	7.01	7.66	5.00	100.00	5
Cultivated land (ha)	5.78	4.91	0.00	100.00	5
Fallow land (ha)	0.58	1.88	0	25	0
Value of equipment (US$)	343	435	0	7,168	154
Value of equipment (Naira)	47,984	60,937	0	1,003,500	21,500
Value of draft animal - traction (US$)	746	1,322	0	6,857	0
Value of draft animal - traction (Naira)	104,471	185,132	0	960,000	0
Financial capital					
Total cash sales (US$)	2,037	1,984	0.00	12,025	1432
Total cash sales (Naira)	282,231	277,850	0.00	1,683,452	200,546
Total groundnut sales (US$)	1,069	1,260	0.00	11,576	642
Total groundnut sales (Naira)	149,963	176,388	0.00	1,620,600	89,936
Proportion of HH with access to credit in 2010 (%)	32	46	0	100	0
Amount of credit contracted by HH (US$)	109	331	0	4,286	0.00
Amount of credit contracted by HH (Naira)	15,318	46,356	0.00	600,000	0.00
Social capital					
Percent HH with at least a member affiliated to an association	25	43	0	100	0
Percent HH with at least one male affiliated to an association	29	45	0	100	0
Average number of HH members affiliated to at least an association	42	82	0	5	0
Average number of HH male members affiliated to at least an association	38	73	0	5	0
Durable assets					
Ownership of cellular phones	0.50	0.50	0	1	1
Ownership of radio	0.74	0.44	0	1	1
Ownership of television	0.18	0.38	0	1	1
Bicycle ownership	0.59	0.49	0	1	1
Motorcycle ownership	0.59	0.49	0	1	1
Vehicle ownership	0.10	0.31	0	1	0
Value of durable assets (US$)	402	486	0.80	13,704	371
Value of durable assets (Naira)	56,218	67,973	112	1,918,500	52,000

sources of cash include the direct sales of crops and livestock. The value of groundnut sales in 2010 was estimated to about US$1,177 accounting to more than half the household total sales estimated to about US$2,184.

Social capital is defined as the proprotion of households whose members are affiliated at least to one institution ad the number of household members who are affiliated to at least one institution or associated. However users of modern varieties belong significantly to more associations on average than non-users, ie, 1.39 against 0.867. Similarly the number of household members that are connected to different associations is significantly higher for users, 9 members against 4 members for non-users. Overall, it can be noted that in the three countries, adopters of modern groundnut varieties are better connected to institutions than non-adopters.

4.2. Awareness, adoption and dis-adoption of groundnut varieties

Exposure or awareness can be defined as the degree at which technologies are known to the users. The rate of exposure is a critical variable explaining adoption. It is the proportion of farmers that have been exposed to the technology. Adoption is defined as the degree of use of a new technology and its potential. The rate of adoption is a critical variable in estimating the returns to research and development investments. It is the relative speed with which an innovation is accepted and utilized by members of a social system (Rogers 1962). It is defined as the proportion of the area planted with modern varieties over the total area planted to the crop. Many scientists have hypothesized factors driving adoption decisions to include: (1) human capital involving socio-personal characteristics such as age and education, household size, total work force etc, (2) technological attributes; for instance, varieties may not have characteristics sought by farmers or required by the market, or farmers perhaps cannot afford to implement the recommended technological package, (3) socioeconomic factors such as farm size, endowments in physical assets, access to credit, and (4) poorly functioning input supply and delivery systems, underdeveloped product markets, poor access to credit facilities etc (Feder et al. 1985). Exposure or awareness to modern technologies/varieties is one of the critical drivers and the first step to adoption of technologies. Farmers must first know about the technology and after take the decision to adopt or not.

Awareness of varieties was assessed through focus group interviews at community level and then at household levels. Table 5 below summarizes the exposure and adoption rates of varieties reported through expert opinions, community and household surveys. It can be noted that with respect to knowledge of varieties, they are fewer varieties reported to be known at

Table 5: Knowledge and adoption of groundnut varieties reported at community and household levels

	Knowledge of varieties		Adoption of varieties				
Name of variety	Community	Household	Community	Expert opinion	Household		
			% area	% area	% HH	% area	% seed
55-437	53.56	41.82	9.40	40.63	32.40	14.79	14.84
69-101	0.42	0.07	0.00	nr	0.08	0.00	0.00
F452.2	0.84	0.37	0.05	nr	0.08	0.04	0.04
ICIAR19bt	2.09	2.50	0.25	3.53	1.40	0.45	0.41
ICIAR6at	1.26	1.01	0.03	nr	0.45	0.11	0.06
ICIAR 7b	0.84	0.86	0.03	nr	0.23	0.01	0.01
RMP 12	3.77	2.61	0.34	9.02	2.38	1.14	1.12
RRB	7.11	5.89	0.81	nr	4.38	1.24	1.30
SAMARU?	8.79	5.03	1.96	nr	4.00	2.09	2.07
SAMNUT21	7.95	7.12	0.70	2.45	5.70	3.20	3.20
SAMNUT22	12.55	7.60	2.10	2.45	5.73	3.21	3.17
SAMNUT23	10.88	10.06	1.42	4.48	7.66	4.21	4.22
PRP	0.42	0.78	0.00	nr	0.45	0.00	0.15
M 318.74	nr	0.86	nr	nr	0.04	0.02	0.03
M 25.68	nr	0.04	nr	nr	nr	0.28	nr
M 412.801	nr	0.04	nr	nr	nr	0.04	nr
M 95.71	nr	0.15	nr	nr	nr	0.00	nr
MK 374	nr	0.56	nr	nr	0.34	1.24	0.29
RMP 91	nr	0.26	nr	nr	0.15	2.09	0.04
Spanish 205	nr	0.07	nr	nr	nr	0.00	nr
M 554-76	nr	nr	nr	nr	0.11	nr	0.00
Others	nr	nr	nr	0.67	nr	nr	nr
Varieties less 20 years ago	28.08	24.82	6.50	21.92	20.86	13.28	13.15
All modern varieties	71.97	59.86	59.38	62.55	50.06	31.00	31.07
All local varieties	95.40	93.63	40.63	48.81	87.06	69.00	68.93
nr. not reported							

community level compared to household level. However, the relative magnitude of adoption is higher through the community survey than the household survey. The proportion of local varieties reported to be known through community survey is estimated to 95.40% against 93.63% at household levels. Similarly the proportion of households reporting to have known improved varieties is about 72% at community level against 60% at household level. And for varieties released since 1996, the rate of exposure is estimated to about 28% at community level and 25% at household level. There are differences between community and household estimates with respect to exposure to modern groundnut varieties.

When comparing adoption estimates, it is noted that adoption rates through expert opinions and community surveys are closer than that of household surveys. In effect, adoption estimates of all modern varieties are 63% and 59% from expert opinions and community survey respectively. The adoption of local varieties is 41% in community surveys against 49% by expert opinion. As for the adoption rates of varieties released less than 20 years ago, estimates from community surveys are 6.50% far lower than 22% from expert opinion signaling less knowledge

Table 6: Proportion of producers having adopted improved varieties reported by producers

AEZ (mm rainfall)	Proportion of households			
	Community		Household	
	All modern varieties	All recent varieties	All modern varieties	All recent varieties
500-600 mm	100	0.00	100	5
600-700 mm	95	15	83	28
700-800 mm	98	32	80	28
800-900 mm	86	23	50	25
900-1000 mm	92	32	45	24
1000-1100mm	92	20	48	20
More than 1100	84	7	18	15

Recent varieties are varieties released less than 20 years ago, and all modern varieties include all the improved varieties released since independence

of names of varieties at community level. There seemed to be an underestimation of adoption of local varieties, and overestimation of all modern varieties when compared to household estimates. When comparing adoption rates based on agro-ecological zone, it is also noted that community groups tend to over-estimate adoption of innovations when compared to household surveys. Table 6 below show the percentage of farmers reporting having adopted improved varieties by agro-ecological zone.

The next section presents the factors explaining exposure and adoption of modern varieties.

4.3. Determinants of exposure to modern groundnut varieties at household level

Survey results showed that about 59.86% of households surveyed were exposed to at least one improved variety as a whole[2]. If limited to varieties released less than 20 years ago, it is estimated that only about 25% of households were exposed. The determinants of the propensity of exposure to at least one modern variety are presented in Table 6 below. Several variables are statistically significant at less or equal to 10% probability level. The propensity score of exposure to at least on modern groundnut variety[3] is largely explained by the number of ICRISAT varieties known in the village in 2006 (+), the number of traditional varieties known in 2006 (-), the number of NARS varieties known in the village in 2006 (-), the total land owned (-), the proportion of land in fallow (-), age of the household head (+), age squared of the household head (-), the number of adult equivalents (+) as a proxy for household labor force, being for the Hausa group (+) compared to other ethnic groups, household size (-), wetter agro-ecological zones (more than 700mm rainfall) (-), training in technology use (-), household participation in on-farm trials (+), household participation in seed production (+), training at village level (+).

The coefficients on participation in on-farm trials, involvement in seed production schemes and training in technology use are significantly positive variables suggesting that farmers who

[2]Improved varieties include varieties released more than 20 years ago such as 55-437, 69-101, RMP 12, RMP 91, RRB, etc...

[3]Variety released less tahn 20 years ago

Table 7: Determinants of exposure to modern groundnut varieties

Variable	Coefficient	Std. error	P>|Z|
Number of ICRISAT varieties known in the village in 2006	0.869	0.044	0.000
Number of traditional varieties known in the village in 2006	-0.118	0.056	0.034
Number of NARS varieties known in the village in 2006	-0.205	0.024	0.000
Log of total land cultivated	-0.301	0.070	0.000
Groundnut area share in 2006	-0.001	0.002	0.623
Area in fallow in 2006	-0.005	0.003	0.090
Log of total agricultural cash income (000 Naira)	0.012	0.012	0.302
Age of household head	0.042	0.020	0.036
Age of household squared	-0.000	0.000	0.032
Level of education of household head	0.204	0.071	0.004
Number of adult equivalents in the household	0.052	0.052	0.024
Household size	-0.022	0.015	0.138
Hausa ethnic group	0.287	0.106	0.007
Fulani ethnic group	0.107	0.152	0.484
Ownership of cellular phone	-0.013	0.068	0.843
Agro-ecological zone (700-900 mm rainfall)	-0.234	0.148	0.114
Agro-ecological zone (900-1100 mm rainfall)	-0.473	0.151	0.002
Agro-ecological zone (>1100 mm rainfall)	-0.310	0.167	0.063
Number of fields days attended	0.008	0.018	0.680
Participation in on-farm trials	0.357	0.085	0.000
Participation in groundnut seed production	0.281	0.085	0.001
Existence of extension service at village level	-0.063	0.075	0.397
Existence of input shop at village level	-0.062	0.074	0.393
Existence of progressive farmers at village level	0.120	0.075	0.111
Existence of on-farm trial at village level	0.082	0.093	0.380
Training workshop on technology use at village level	0.344	0.093	0.000
Constant	-2.212	0.546	0.000
-2 log likelihood	1513.1		
Goodness f fit	1939.8		
Cox and Snell R-square	0.333		
Nagelkerke R-square	0.494		

participated in those activites through which improved seed is introduced in communities are likely to know the existence of modern varieties than farmers who did not participate. In fact, many improved technologies including varieties are tested using participatory variety selection trials by research institutes and agricultural development projects (ADP) in Nigeria creating more awareness among the producers. The results highlight the significant role of participatory trials and the involvement of producers in seed production at community level that de facto contribute to increase awareness.

The coefficients on education was found to be positive signaling that households headed by educated people are likely to be exposed than those who are less educated. This supports the well proven fact that formal education is positively associated with technology adoption (Feder et al. 1985). Similarly the coefficient on age and age squared were found to be significant and depicted a concave function implying that households with younger household heads are likely to be exposed to households and that the propensity to be exposed decreases as household heads are aging. The coefficients on adult equivalents was found significant. In effect, the adult equivalent is a proxy for total work force at household level and this is exlained by the labor requirement in groundnut production where planting, thinning and harvesting are labor demanding. Dummies on agro-ecological zones were found to be negative especially for the area of more than 900 mm rainfall suggesting that farmers in those agro-ecologies have significantly lower propensities to be exposed to modern varieties compared to producers located in the agro-ecology of 500 to 700 mm rainfall. This consistent with the fact that these varieties were bred for the relatively drier areas.

The other coefficients such as the groundnut area share, ownership of cellular phone, the number of field days attended were not found significant meaning that they are not relevant in explaining the rates of awareness.

4.4. Rates and determinants of adoption of modern groundnut varieties

Groundnut variety adoption rates

The rate of adoption remains the key impact indicator of any applied breeding research and extension program. It shows the degree of acceptance, diffusion or rejection of new research outputs. The rate of adoption is here defined as the share of farm area utilizing the new varieties (Feder et al., 1985). It is believed that this method of assessing adoption rate provides a better quantitative measure for forecasting yields and economic rates of returns to research and extension programs (Masters et al., 1996). Table 7 below shows the rate of adoption of modern groundnut varieties by state. The adoption rate is estimated to about 31% of groundnut area. However, if one targets recent varieties ie. varieties released less than 20 years ago, the rate of

Table 8: Adoption of groundnut varietes by state in Nigeria

	State										
Variety	Bauchi	Borno	Gombe	Jigawa	Kaduna	Kano	Katsina	Niger	Yobe	Zamfara	Overall
55-437	9.70	30.60	14.11	40.51	1.09	7.65	12.50	0.00	52.77	2.09	14.79
69-101	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
F452.2	0.00	0.00	0.00	0.20	0.00	0.00	0.00	0.00	0.00	0.00	0.04
ICIAR 19bt	0.00	0.00	0.00	1.08	0.00	0.53	0.47	0.00	0.00	0.00	0.45
ICIAR 6at	0.00	0.00	0.00	0.00	0.00	0.08	0.45	0.00	0.00	0.00	0.11
ICIAR 7b	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.01
M318.74	0.00	0.00	0.00	0.00	0.00	0.07	0.00	0.00	0.00	0.00	0.02
MK 374	0.00	0.00	0.00	0.00	0.00	0.07	0.39	1.71	0.00	0.00	0.28
RMP 91	0.65	0.65	0.65	0.00	0.65	0.04	0.00	0.00	0.65	0.65	0.04
RMP 12	0.87	26.39	0.00	0.32	0.00	0.89	0.00	0.00	0.00	0.00	1.14
RRB	0.00	0.00	0.00	3.34	7.97	2.07	0.00	0.00	0.79	0.00	1.24
SAMARUs	0.00	0.34	0.00	0.00	0.00	2.08	0.10	7.45	0.00	1.65	2.09
SAMNUT 21	0.00	1.71	0.00	7.52	0.00	5.47	0.20	0.00	0.00	2.27	3.20
SAMNUT 22	0.00	0.00	0.00	0.20	0.00	6.06	7.17	0.00	0.00	0.41	3.21
SAMNUT 23	0.00	0.85	0.00	3.70	3.80	5.93	7.71	0.00	0.00	0.00	4.21
M 554.76	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PRP	0.67	0.00	0.00	0.00	0.00	0.07	0.00	1.08	0.00	0.00	0.17
Recent varieties	0.00	2.90	0.00	12.51	11.78	20.18	16.09	7.45	0.00	4.34	13.28
All improved varieties	11.88	59.89	14.11	56.89	12.86	31.03	28.98	10.24	53.57	7.02	31.00
Local varieties	88.12	40.11	85.89	43.11	87.14	68.97	71.02	89.70	46.43	92.98	69.00
Recent varieties refer to SAMNUT 21, SAMNUT 22, SAMNUT 23, ICIAR 19bt, ICIAR 7b, ICIAR 6at, SAMARUs											

adoption of recent varieties is estimated to about 13.28% of groundnut area.

Results showed that the variety 55-437 is still widely used in almost all the states in Nigeria with average adoption estimated to 14.79%. This is a very old variety developed by a French research institute (CIRAD) and dependended since 1955 prior to the independence in many countries in West Africa including Nigeria. This is followed by SAMNUT 23 for 4.21%, SAMNUT 22 for 3.21% and SAMNUT 21 for 3.20%. Other improved varieties not identified are the SAMARUs which are a mix of improved varieties accounting for 2.09% of groundnut area. Varieties accounting for at least 1% of groundnut area include RMP 12 and RRB. There are differences by state[4]. The rate of adoption of modern varieties varies between 7% in Zamfara State to about 60% in Borno State.

However, for the recently introduced varieties[5], higher rates of adoption are recorded in Kano for 20.18%, then Katsina (16.09%), Jigawa (12.51%), Kaduna (11.78%), Niger (7.45%), Zamfara (4.34%), and Borno (2.90%). These rates are largely explained by the level of research and development interventions that has occurred in the respective states. In the 1996, multi-locational trials were conducted in those states and this was followed by the implementaton of 3 projects namely the Groundnut Germplasm Project (GGP) for 1996-2002, the Groundnut Seed

[4]Interpretation at the state should be take with caution because of the representativity of the data at the national level

[5]Varieties released less than 20 years ago

Project (GSP) for 2003 and 2007 and the Tropical Legumes II from 2008-2010 essentially in Kano, Katsina and Jigawa.

The reasons for not planting new varieties during the 2009/10 cropping season were reported as the non-availability of seed (37.26%), low yield (20.82%), low market value (14.66%), lack of cash to purchase seed (11.10%) and pest and diseases (6.30%). Farmers still source seed from neighbors (42.24%) and relatives (24.14%). About 21% save seed from past harvests. About 8.17% purchase seed from ADPs and very few from seed companies. The latter are uninterested to sell seed especially of groundnut. The main motivations and incentives for growing modern varieties include high productivity gains reported by 56.50%, yield stability (49.22%) and access to credit for 6.07% of households surveyed.

Determinants of adoption of modern groundnut varieties

In many adoption studies, simple logit models are often used to assess the determinants of adoption. This produces bias and inconsistent estimates of drivers of adoption. Without the corrected logit, probit or Poisson-ATE procedure, it will not be possible to produce consistent estimates of the coefficients of the determinants of the probability of adoption (Diagne, 2006). This study used the ATE corrected Poisson regression to assess the determinants of adoption of pearl millet and sorghum varieties in Nigeria.The results on the determinants of adoption of modern varieties (that have been released less than 20 years ago) for the ATE probit model are presented in Table 8 below. The most determining factors affecting adoption include the past experience in using modern varieties proxied by the number of ICRISAT varieties planted in 2006 in the village (+), the number of traditional varieties known (-), total land owned (-), the proportion of fallow land (+), age of the household head (+), age of the household head squared (+), level of education of household head (+), the total work force in the household (+), household size (-), agro-ecological zone (between 900-1100 mm rainfall and agro-ecological zone with 1100 mm and above), household participation in on-farm trials (+), household participation in seed production (+), the high proportion of progressive farmers in the village (+) and the number of training held in the village (Table 8). This is consistent with many adoption studies and largely explained by the requirement of the crop.

As in the case of exposure, the coefficients on participation in on-farm trials, involvement in seed production schemes and training in technology use are significantly positive variables suggesting that farmers who participated in those activites through which improved seed is introduced in communities are likely to adopt the of modern varieties than farmers who did not participate. The results highlight the significant role of participatory trials and the involvement of producers in seed production at community level that de facto contribute to increase adoption.

The coefficients on education was found to be positive signaling that households headed by educated people are likely to adopt than those who are less educated. This supports the well proven fact that formal education is positively associated with technology adoption (Feder et al. 1985). Similarly the coefficient on age and age squared were found to be significant and depicted a concave function implying that households with younger household heads are likely to be more receptive to modern technologies and that the propensity to adopt decreases as household heads are aging. The coefficients on adult equivalents was found significant. In effect, the adult equivalent is a proxy for total work force at household level and this is exlained by the labor requirement in groundnut production where planting, thinning and harvesting are labor demanding. Households with high work force are likely to adopt modern varieties. Dummies on agro-ecological zones were found to be negative especially for the area of more than 900 mm rainfall suggesting that farmers in those agro-ecologies have significantly lower propensities to be exposed to modern varieties compared to producers located in the agro-ecology of 500 to 700 mm rainfall. This consistent with the fact that these varieties were bred for the relatively drier areas.

The other coefficients such as the groundnut area share, ownership of cellular phone, the number of field days attended, the agricultural cash income were not found significant meaning that they are not relevant in explaining the rates of awarenessEducation is largely reported as a major driver for adoption of innvations and groundnut is labor demanding required for planting, thinning and harvesting. etc....

Current and full population adoption of modern groundnut varieties

Table 9 presents the predicted probability of adoption of modern groundnut varieties with the Average Treatment Effect (ATE) correction for non-exposure and population biases estimates. It highlights the potential adoption rates (ATE) and the current adoption rate (joint exposure and adoption rate - JEA) of modern groundnut varieties and the adoption gap (GAP). The potential adoption rate (ATE) is the adoption rate when all producers have been exposed to the modern groundnut varieties. The adoption gap (GAP) is the difference between the potential and the current adoption rate.

The results showed that the proportion of producers exposed to modern groundnut varieties is estimated at 25% and the proportion of adopters is 20% implying that 80% of those who were exposed actually adopted the modern varieties. The full population adoption rate for modern grounndut varieties is estimated to about 76.1% in year 2009/10 implying an adoption gap of 56.2% because of incomplete exposure of the population. These results indicate that there are potential for increasing adoption rate by 56% if all producers are made aware of at least one modern variety.

The results of ATE1, ie the average treatment effect on the treated, show that among the sample population, 80% of the groundnut producers exposed to modern groundnut varieties adopted

Table 9: Determinants of adoption of modern groundnut varieties

	Coefficient	Std. error	P>|Z|
Number of ICRISAT varieties planted in 2006	0.721	0.042	0.000
Number of traditional varieties known in the village	-0.110	0.025	0.000
Number of NARS varieties known in the village	-0.080	0.058	0.163
Log of total land cultivated	-0.242	0.072	0.001
Groundnut area share in 2006	0.001	0.002	0.741
Area in fallow in 2006	-0.005	0.003	0.108
Log of total agricultural cash income	0.013	0.013	0.309
Age of household head	0.052	0.021	0.015
Age of household squared	-0.001	0.000	0.012
Level of education of household head	0.370	0.072	0.000
Number of adult equivalents in the household	0.083	0.025	0.001
Household size	-0.039	0.015	0.010
Hausa ethnic group	0.091	0.110	0.411
Fulani ethnic group	-0.039	0.160	0.810
Ownership of cellular phone	-0.014	0.069	0.838
Agro-ecological zone (900-1100 mm rainfall)	-0.746	0.152	0.000
Agro-ecological zone (>1100 mm rainfall)	-0.689	0.171	0.000
Number of fields days attended	-0.017	0.021	0.420
Participation in on-farm trials	0.411	0.087	0.000
Participation in groundnut seed production	0.224	0.087	0.010
Existence of extension service at village level	-0.038	0.076	0.621
Existence of input shop at village level	0.037	0.075	0.624
Existence of progressive farmers at village level	0.217	0.076	0.004
Existence of on-farm trial at village level	0.019	0.021	0.364
Training workshop on technology use at village level	0.487	0.092	0.000
Constant	-2.661	0.577	0.000
-2 log likelihood	915.929		
Goodness of fit	1839.959		
Cox and Snell R-square	0.273		
Nagelkerke R-square	0.433		

Table 10: Current and potential adoption of groundnut varieties based on awareness

	Parameter	Robust Std Error	P>Z
Observed			
Number of exposed/number of farmers	0.248	0.008	0.000
Number of adopters/number of farmers	0.199	0.008	0.000
Number of adopters/ number of exposed	0.802	0.031	0.000
ATE			
Population adoption rate (ATE)	0.761	0.266	0.004
Adoption rate among exposed sample (ATE1)	0.799	0.287	0.005
Adoption rate among non-exposed sample (ATE0)	0.748	0.259	0.004
Joint exposure and adoption rate (JEA)	0.199	0.071	0.005
Adoption gap (GAP=ATE-JEA)	-0.562	0.195	0.004
Population Selection Bias (PSB)	0.039	0.025	0.122

at least one of them. The untreated sub-popualtion mean is estimated to 75% and the estimated population selection bias whihc is measured as the difference in the potential adoption rate in the exposed sub-population adoption rate is estimated at 4% and is statistically insignificant. This suggests that the probability to adopt modern groundnut varieties for a producer belonging to the sub-population of informed producers is the same as the adoption probability for any producer randomly selected from the whole population.

Economic impacts of modern groundnut varieties on household livelihood outcomes

The impacts of modern groundnut varieties was assessed using matching methods esp. propensity score matching and econometric methods simple regression and instrumental variable regressions. Eight outcome variables were used including groundnut yield[6], the household total value of crop production[7], the per capita total household revenues[8], the per capita value of groundnut sales[9], the per capita total wealth[10], the per capita expenditures[11], and the score of consumption[12]. In effect, one would assume that if impacts of groundnut varieties had occurred, it would have affected groundnut yield which in turn coould have affected the total value of production, the household wealth, household expenditures and score of consumption.

Matching methods

Table 10 presents the results for the impact of adoption of groundnut varieties on livelihood outcomes using 3 methods namely the propensity score matching using nearest neighborhood (PSM-NN), the propensity score matching using kernel algorithm (PSM-Kernel) and the bias-adjusted NN match estimates. All 3 estimation methods show significant and positive impacts of modern groundnut varieties' adoption on household average crop yield and the score of consumption a proxy for food security. They did not however show significant differences based on the household total value of production, per capita total revenues, per capita value of groundnut sales, per capita total wealth, and per capita expenditure proxy of poverty.

Our best estimates showed that the household average groundnut yield gains varies between 155 kg/ha to 202 kg/ha and the score of consumption gains varies between 2.25 and 5.77. The

[6]This is actually an effect variable

[7]The total value of crop production refers the value of all crops produced in 2009/10

[8]per capita household revenues refers to the total value of production, and total value of livestock and non-farm income normalized by household size

[9]The per capita groundnut sales refers to the total groundnut sales normalized by household size

[10]The per capita wealth includes the total value of durable assets, the total value of equipment and total value of livestock

[11]The per capita expenditure refers to agriculture exepnditures, and the non-agricultural expenditures and the food expenditures normalized by household size.

[12]The score of consumption is used as a proxy for food security reflecting household consumption frequency by food crops to build consumption scores (poor food consumption (<=28), borderline consumption average (28-42), Acceptance - Good (>42))

Table 11: Effects and impacts of adoption of groundnut varieties estimated by matching methods

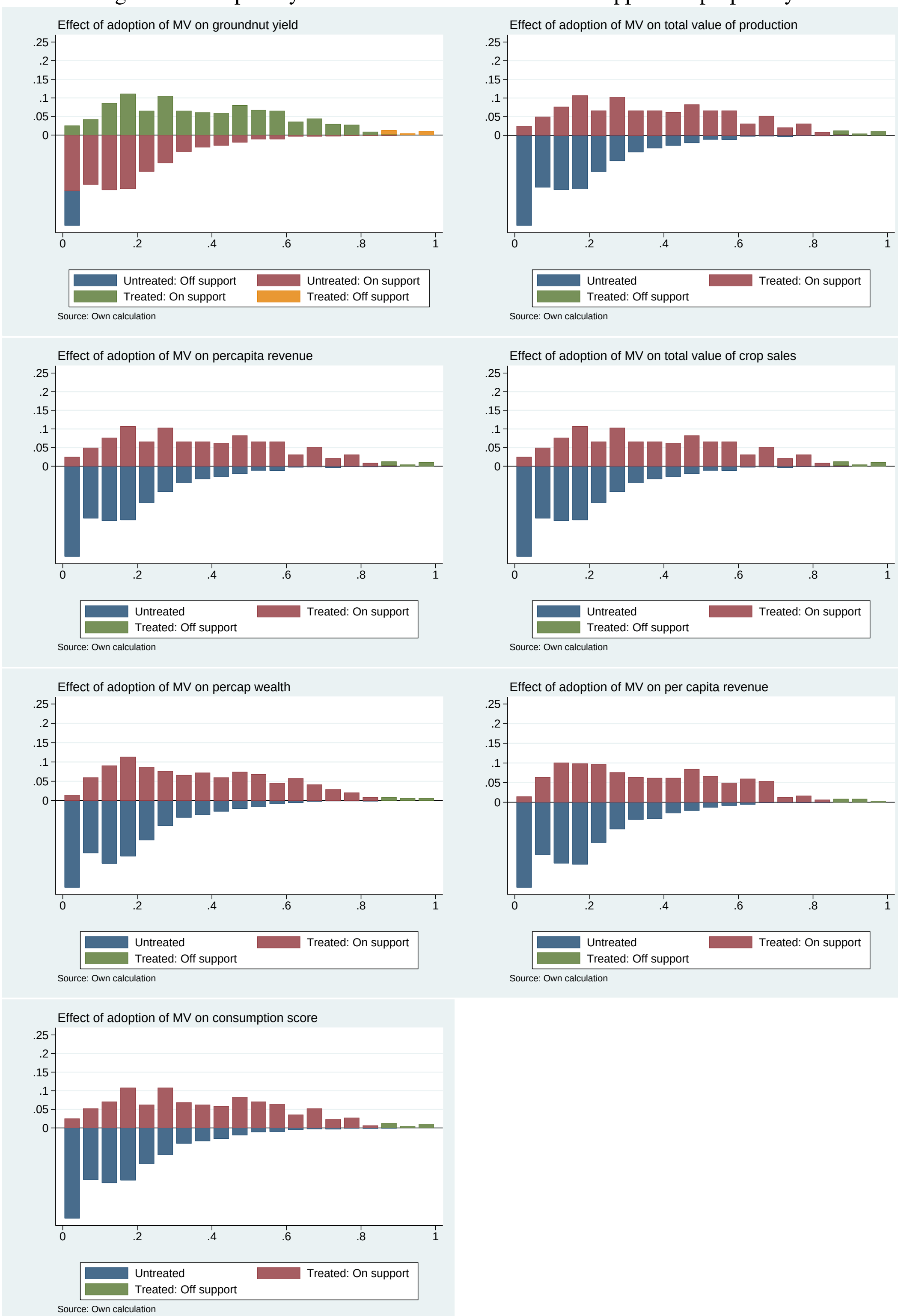
	Household level impacts			
Variable	Estimation methods	Estimated Impacts	Est. Standard Error	T-stat / Z-stat Significance ( )
Crop yield (kg/ha)	NN matching	196.255	47.386	4.14***
	Kernel matching	155.053	35.975	4.31***
	Bias-adj NN matching*	201.56	33.682	5.98***
Log (total value of production)	NN matching	0.760	0.087	0.87
	Kernel matching	0.037	0.066	0.55
	Bias-adj NN matching	0.029	0.054	0.594
Log(per capita total revenues)	NN matching	-0.004	0.071	-0.05
	Kernel matching	-0.039	0.055	-0.71
	Bias-adj NN matching	0.097	0.063	0.125
Log(per capita value of groundnut sale)	NN matching	0.223	0.135	1.65
	Kernel matching	0.275	0.123	2.24
	Bias-adj NN matching	0.336	0.117	0.004?
Log(per capita total wealth)	NN matching	-0.065	0.093	-0.70
	Kernel matching	0.024	0.074	0.33
	Bias-adj NN matching	-0.006	0.067	0.932?
log (per capita expenditures)	NN matching	-0.125	0.076	-1.63
	Kernel matching	-0.129	0.058	-2.23
	Bias-adj NN matching	0.042	0.048	0.372
Score of consumption	NN matching	3.629	1.956	1.86**
	Kernel matching	2.251	1.411	1.59
	Bias-adj NN matching	5.771	1.369	4.21 (0.000)
*** significant at 1%, ** significant at 5% and * significant at 10%				

magnitudes of the statistically significant impacts on groundnut yield and score of consumption are quite substantial signaling significant impacts on reducing food insecurity. However, there is no impacts on poverty. This may be explained by the fact that though groundnut varieties increase yield, households are cutting back on other investments which may be labor demanding and therefore impacting on the overall revenues and profits.

Comparisons of the unmatched and matched samples using PSM indicate that in all cases, the adopters and non-adopters sample households are more similar in the matched sample than in the non-matched sample in terms of observed characteristics, and the differences in the matched sample are almost always statistically insignificant (unlike the unmatched samples which are in many cases statistically different). This indicates that propensity score matching substantially improves the comparability of the samples. Nevertheless, there are still some significant differences remaining in the matched samples, which could lead to biases in the PSM results. The bias-corrected NN estimator addresses this concern. However, as discussed in the methodology section, the distance metric used for this estimator is more arbitrary than the PSM metric. Hence, we report the results of both estimators.

In almost all cases, the estimated impacts are quite similar using the two matching methods. Adoption of pearl millet varieties is found to significantly increase the mean value of yield and

Figure 0.2: Propensity score distribution and common support for propensity score estimation



scores of consumption. Table 11 presents the distribution of the propensity scores and the region of common support. It shows the bias in the distribution of propensity scores between the group of adopters and non-adopters and clearly reveals the significance of proper matching as well as the imposition of common support condition to avoid bad matches.

Stochastic dominance methods

Adoption of modern groundnut varieties may also affect other moments of the distribution of livelihood outcomes eg. Yield besides the mean; e.g., they may also affect the variance of yields. To visually investigate such impacts, we have plotted graphs of the cumulative density function (cdf) of livelihood outcomes for matched households adopters and non-adopters (Figure 0.2). These figures demonstrate that adoption of modern groundnut varieties has a strongly significant positive impact on mean yield, shift the entire distribution of yield to the right, which implies a lower risk of low yield (for any yield threshold) for adopters and non-adopters of modern groundnut varieties.

It can be seen that adoption of modern groundnut varieties has insignificant impacts on total value of production, per capita expenditures, per capita wealth. There is little systematic differences in the shape or location of the distribution functions. Hence adoption of modern varieties has little apparent impacts on production risk as well as on mean production.

Econometric results

The estimated impacts of modern pearl millet and sorghum varieties on household livelihood outcomes are summarized in Table 12 and detailed in Annexes 4 through 11. Three regression models are reported for each livelihood outcome: i) an unrestricted ordinary least squares (OLS) model, in which all variables used to predict adoption of varieties are included in the model, ii) a restricted version of the OLS model in which many household level factors found to be jointly statistically insignificant in the unrestricted OLS model are dropped from the model; iii) an instrumental variables (IV) version of the restricted model to address potential endogeneity of adoption. The variables dropped in the restricted OLS model and the IV model include household demographic composition, education of the household head, and the value of household assets owned etc. depending on the outcome. Although some of these variables could in principle affect the outcome variable by other means than affecting adoption, the statistical results indicate that such impacts are statistically insignificant. Hence, these variables are used as instrumental variables in the Restricted IV regression

The estimated impacts of modern groundnut varieties on household livelihood outcomes are summarized in Table 12 and detailed in Annexes 1 through 13 can be provided on demand. Three regression models are reported for each livelihood outcome: i) an unrestricted ordinary

Figure 0.3: CDF of adopters and matched adopters of groundnut varieties

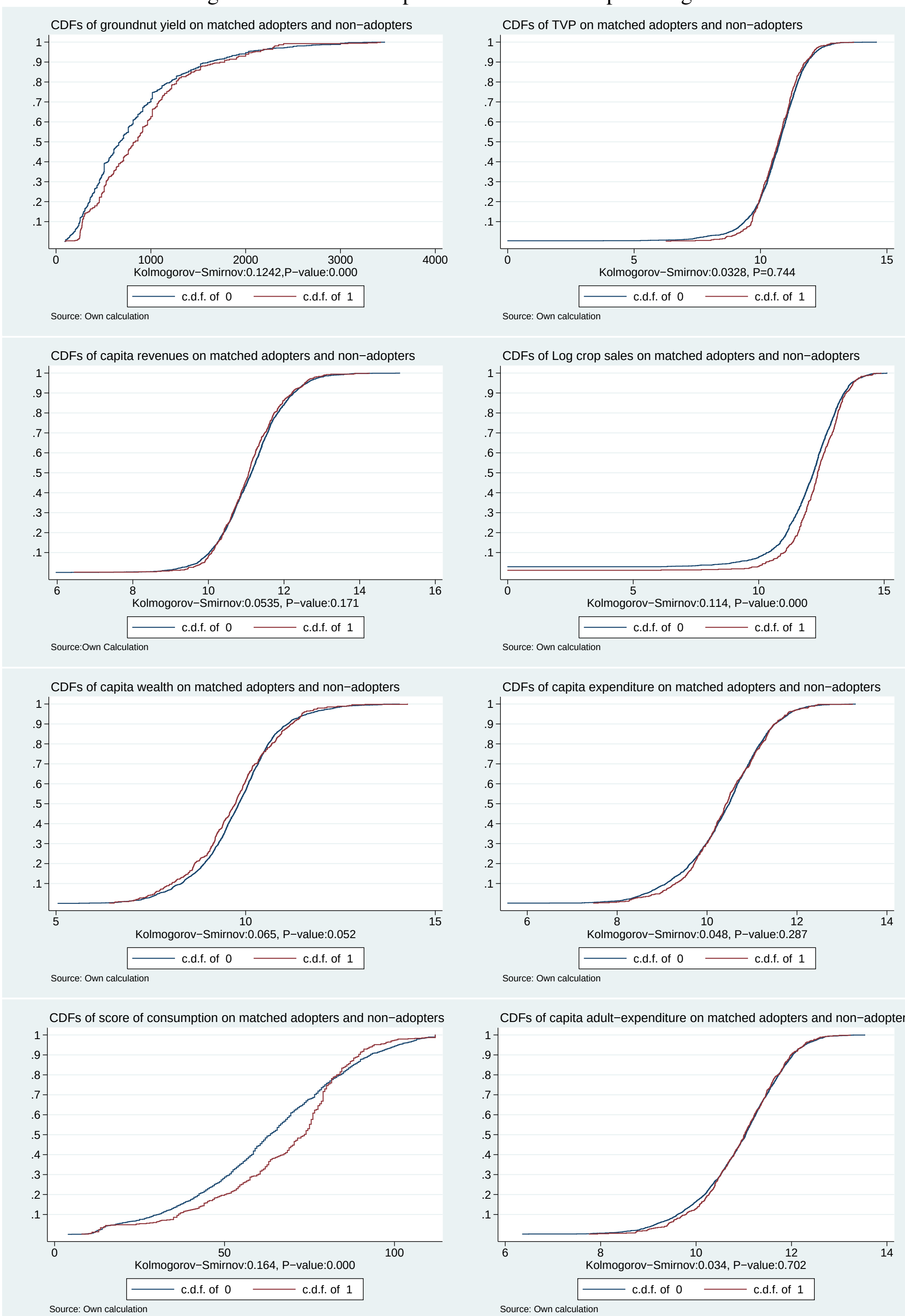


Table 12: Impacts of adoption of modern groundnut varieties estimated by econometric methods

Variable		Household level impacts		
	Estimation methods	Estimated impacts	Estimated Std Error	p > |t|
Crop yield (kg/ha)	Simple regression	171.097	31.217	0.000
	IV regression	155.829	30.284	0.000
Log(total value of production perf capita)	Simple regression	0.001	0.063	0.104
	IV regression	0.245	0.321	0.445
Log(per capita total revenues)	Simple regression	-0.008	0.042	0.847
	IV regression	0.049	0.042	1.19
Log(per capita value of groundnut sale)	Simple regression	0.195	0.111	0.080
	IV regression	0.323	0.107	0.003
Log(per capita total wealth)	Simple regression	3.161	1.185	0.008
	IV regression	3.161	1.175	0.007
Score of consumption	Simple regression	3.160	1.184	0.008
	IV regression	3.161	1.176	0.007
Log (per capita expenditures)	Simple regression	-0.128	0.047	-2.72
	IV regression	0.203	0.175	0.245

least squares (OLS) model, in which all variables used to predict adoption of varieties are included in the model, ii) a restricted version of the OLS model in which many household level factors found to be jointly statistically insignificant in the unrestricted OLS model are dropped from the model; iii) an instrumental variable (IV) version of the restricted model to address potential endogeneity of adoption. We here report an unrestricted OLS and the IV regresssion. The variables dropped in the restricted OLS model and the IV model include household demographic composition, education of the household head, and the value of household assets owned etc. depending on the outcome. Although some of these variables could in principle affect the outcome variable by other means than affecting adoption, the statistical results indicate that such impacts are statistically insignificant. Hence, these variables are used as instrumental variables in the Restricted IV regression.

The first three regressions enable assessment of the impacts of adoption of varieties on livelihood outcomes. Comparing across these three regressions also allows assessment of the robustness of the conclusions to specification issues and potential endogeneity of adoption. The reduced form estimation enables assessment of the total impacts of adoption on the livelihood outcomes, as explained in the methodology section. The Hansen J test of the over-identifying restrictions in the IV model indicates that the instrumental variables used in the model are valid, since the test statistic is statistically insignificant (Davidson and MacKinnon, 2004). The Anderson statistic shows that the IV model is weakly identified, leading to concerns about bias in the IV model (Bound et al., 1995).

The exogeneity test supports the OLS model as the preferred model, since exogeneity of adoption is not rejected (implying that OLS is consistent) and since OLS is more efficient (and likely less biased with weak instruments) than the IV model. The restricted OLS model is preferred over the unrestricted model, since the variables dropped are statistically insignificant and only reduce the efficiency of the model. Other factors found to have significant impacts on groundnut yield include the value of livestock owned in the household (positive (+) impact in the unrestricted OLS and restricted models), the area of land owned by the household (- in all regressions), plot size (-), soil fertility of the plot (+ for very good compared to poor), soil texture of the plot (+ for sandy/clay). We will not comment in detail on these findings for all livelihood outcomes. However, we note that some of these findings are consistent with many other studies of determinants of crop production in sub-Saharan Africa and other developing regions. For example, the inverse relationship between farm size and productivity has been found in many studies (e.g.,Sen, 1975, Berry and Cline, 1979, Barrett, 1996, Lamb, 2003, Pender et al., 2004Sen, 1975, Berry and Cline, 1979, Barrett, 1996, Lamb, 2003, Pender et al., 2004), as has the positive impact of livestock on productivity.

The estimated determinants of household total value of production per capita are reported in Annex 2. In this table, we report results of three regressions: i) unrestricted OLS (including program participation and all explanatory variables used in Table 4.8); ii) restricted OLS, dropping the variables reflecting the social status of the household head (which are jointly insignificant in the unrestricted model); and iii) IV estimation, adoption as endogenous. The social status variables are used as instrumental variables. We also use the household endowments in 1999/01 of land, land quality, other assets, education, as instrumental variables (the levels of these variables in 2009/10) are used as explanatory variables in the regression). As shown by the statistical tests reported in Annex 2, the instrumental variables used are valid (insignificant Sargan test) and exogeneity of the program participation variables is supported (insignificant C exogeneity test). However, weak identification is again a problem in this IV model (insignificant Anderson statistic). The restricted OLS model is therefore the preferred model.

Impacts on the poorer versus wealthier households

To investigate whether the impacts of adoption of modern groundnut varieties vary by the wealth status of households, we estimated the productivity, total value of production, per capita expenditure and score of consumption separately for the first quarter, second, third and fourth quarter of the sample based on wealth. The results showed that the first 2 quarters have not benefited. However, the last 2 quarters have benefitted by significantly increasing wealth. These findings imply that wealthier households are the one benefitting from the adoption of improved groundnut varieties probably because they own more land and have the capital to invest more in groundnut production thereby deriving more profits (Table 13). Based on total value of production per capita, it is noted that producers in the second wealth class have increased the total value of production. However, results indicate that producers in the 1st and third wealth class hae reduced their expenditures. There seems to be no clear pattern on impacts on poverty indicators.

Table 13: PSM matching results (NN) of adoption of groundnut varieties based on wealth

Groundnut producers	Coefficient	Standard deviation	T-Stat
Average groundnut yield			
Less than US$533.40 (1st quarter)	140.88	93.83	1.50
Between US$ 533.40 and US$1,170.78 (2nd quarter)	70.86	103.33	0.69
Between US$1,170.78 and 2,180.76 (3rd quarter)	250.48	94.36	2.65***
More than US$2,180.76 (4th quarter)	200.71	101.19	1.98**
Log of total value of production per capita			
Less than US$533.40 (1st quarter)	-0.16	0.12	-1.34
Between US$ 533.40 and US$1,170.78 (2nd quarter)	0.35	0.19	1.85**
Between US$1,170.78 and 2,180.76 (3rd quarter)	-0.05	0.14	-0.35
More than US$2,180.76 (4th quarter)	-0.02	0.15	-0.11
Log of per capita expenditures			
Less than US$533.40 (1st quarter)	-0.27	0.16	-1.70**
Between US$ 533.40 and US$1,170.78 (2nd quarter)	-0.21	0.13	-1.56
Between US$1,170.78 and 2,180.76 (3rd quarter)	-0.26	0.15	-1.77**
More than US$2,180.76 (4th quarter)	-0.21	0.18	-1.15
Score of consumption			
Less than US$533.40 (1st quarter)	4.88	4.24	1.15
Between US$ 533.40 and US$1,170.78 (2nd quarter)	-1.79	3.69	-0.49
Between US$1,170.78 and 2,180.76 (3rd quarter)	-2.56	4.51	-0.57
More than US$2,180.76 (4th quarter)	1.70	3.44	0.49

Impacts of modern groundnut varieties by agro-ecological zone

To investigate whether the impacts of adoption of modern groundnut varieties vary by agro-ecological zone, we estimated the productivity, total value of production, per capita expenditure and score of consumption (food security) regressions separately for the agro-ecological zone of less than 700 mm, between 700 and 900 mm rainfall, between 900 and 1100 mm and more than 1200 mm. The results showed that there significant differences between adopters and matched non-adopters based on groundnut yield in the first and third zone AEZ than the second and fourth. However, there are no significant differences between adopters and matched non-adopters based on total value of production except for households located the third AEZ. There are also no significant differences based on per capita expenditures and score of consumption between adopters and matched non-adopters.

Desirable traits preferred by producers and perception on changes in livelihood outcomes

Table 14: PSM matching results (NN) of adoption of groundnut varieties based on agro-ecological zone

Groundnut producers	Coefficient	Standard deviation	T-Stat
Average groundnut yield			
AEZ [500-700 mm[	838.97	283.72	2.96***
AEZ[700-900 mm[	75.83	60.89	1.25
AEZ [900-1100 mm[	377.95	89.70	4.21***
AEZ [1200 mm and above[	-101.02	184.04	-0.55
Log of total value of production			
AEZ [500-700 mm[	-0.28	0.31	-0.92
AEZ[700-900 mm[	-0.13	0.09	-1.49
AEZ [900-1100 mm[	0.66	0.18	3.68***
AEZ [1200 mm and above[	-0.16	0.25	-0.66
Log of per capita expenditures			
AEZ [500-700 mm[	-0.51	0.52	-0.98
AEZ[700-900 mm[	-0.02	0.12	-0.16
AEZ [900-1100 mm[	-0.07	0.14	-0.48
AEZ [1200 mm and above[	-1.11	0.26	-4.29***
Score of consumption			
AEZ [500-700 mm[	-3,06	6.65	-0.46
AEZ[700-900 mm[	-0.98	2.94	-0.33
AEZ [900-1100 mm[	4.97	3.68	1.35
AEZ [1200 mm and above[	9.00	6.59	1.37

Traits preferred by farmers on varieties

Probit regressions were used to assess the characteristics sought by farmers on the most popular groundnut varieties in Nigeria. The 3 most popular varieties, all improved varieties and local varieties were investigated. Results indicate farmers preferred the groundnut variety SAMNUT 21 because of its plant vigor, color of the leaves and diseases resistance. And they dislike this variety due to its poor pod filling and grain color. With regard to SAMNUT 22, farmers preferred its early maturing trait (+), growth habit (+), plant maturity (+) and haulm yield (+). Farmers expressed their preferences for vigor (+), resistance to drought (+), growth habit (+), plant maturity (+), haulm yield (+) and pod yield (+) but dislike the pod filling and its low haulm yield (-) for SAMNUT 23 (Table 15). Over all, all the 3 recent varieties (SAMNUT 21, SAMNUT 22, SAMNUT 23) are preferred for the vigor (+), resistance/tolerance to diseases and pests (+), growth habit (+), plant maturity (+) and higher number of pods (+) and dislike for haulm yield (-). As for the local varieties, producers like its pod size, pod filling, grain color, pod yield and haulm yield but dislike its poor vigor, the color of the leaves, low resistance to diseases and pests, late maturity and lower number of pods. In effect, improved varieties have the characteristics preferred by groundnut producers except for haulm yield. This characteristic is important especially for farmers who are both crop and livestock producers.

Table 15: Probit results of the characteristics of groundnut varieties

	Name of variety									
Variety trait	SAMNUT 21		SAMNUT 22		SAMNUT 23		Recent Varieties		Local varieties	
	Coef.	Std Err	Coef.	Std Err	Coef	Std Err	Coef	Std Err	Coef	Std Err
Vigor (-1=Bad,0=Aver.,1=Good)	0.338[b]	0.132	0.358[a]	0.132	0.211[c]	0.122	0.401[a]	0.074	-0.243[a]	0.057
Color leaves (-1=Disliked,0=Indif.,1=Liked)	0.332[c]	0.170	0.196	0.148	-0.101	0.129	0.094	0.082	0.165[a]	0.061
Resistance diseases (-1=Poor,0=Aver.,1=High)	0.469[a]	0.124	-0.131	0.109	-0.038	0.102	0.165[b]	0.065	-0.114[b]	0.053
Resistance to drought (-1=Poor,0=Aver.,1=High)	-0.020	0.112	-0.133	0.111	0.296[a]	0.105	0.028	0.064	-0.018	0.052
Growth habit (-1=Disliked,0=Indif.,1=Liked)	0.159	0.121	0.215[c]	0.126	0.414[a]	0.138	0.138[c]	0.070	-0.076	0.053
Plant maturity (-1=Late,0=Med.,1=Early)	0.125	0.090	0.204[b]	0.095	0.469[a]	0.098	0.286[a]	0.056	-0.577[a]	0.045
Number of pods (-1=Low,0=Aver.,1=High)	0.162	0.113	-0.061	0.109	0.380[a]	0.103	0.242[a]	0.065	-0.102[c]	0.054
Pode size (-1=Small,0=Aver.,1=Big)	0.170	0.115	-0.134	0.111	0.020	0.098	-0.069	0.064	0.161[a]	0.053
Pod filling (-1=Poor,0=Aver.,1=Good)	-0.273[b]	0.115	-0.067	0.111	-0.228[b]	0.101	-0.057	0.065	0.168[a]	0.054
Pod reticulation (0=Disliked,1=Liked)	0.288	0.245	0.143	0.253	0.227	0.264	0.189	0.148	0.034	0.109
Pod construction (0=Disliked,1=Liked)	-0.236	0.182	0.269	0.253	0.081	0.226	-0.045	0.126	0.037	0.101
Grain color (-1=Disliked,0=Indif.,1=Liked)	-0.460[a]	0.107	-0.024	0.107	0.150	0.109	-0.083	0.065	0.138[a]	0.053
Seed size (-1=Small,0=Med.,1=Large)	-0.077	0.114	0.127	0.107	0.030	0.101	0.058	0.065	0.305[a]	0.053
Pod yield (-1=Low,0=Aver.,1=High)	-0.164	0.112	0.112	0.110	0.430[a]	0.112	-0.023	0.066	0.112[b]	0.056
Haulm quality (-1=Poor,0=Aver.,1=Good)	-0.061	0.114	0.012	0.118	0.256[b]	0.115	0.077	0.069	0.021	0.057
Haulm yield (-1=Low,0=Aver.,1=High)	-0.014	0.113	0.289[b]	0.119	-0.434[a]	0.103	-0.114[c]	0.067	0.178[a]	0.056
Borno	3.877	162.15	-	-	3.658	108.51	3.964	127.88	-1.365[a]	0.195
Gombe	-	-	-	-	-	-	-	-	-0.146	0.264
Jigawa	4.533	162.15	-	-	3.79	108.51	4.72	172.88	-1.302[a]	0.145
Kaduna	-	-	-	-	4.03	108.51	5.05	172.88	-0.861[a]	0.182
Kano	4.209	162.15	3.945	117.40	4.49	108.51	5.09	172.88	-0.549[a]	0.139
Katsina	3.108	162.15	4.269	117.40	4.63	108.51	5.09	172.88	-0.461[a]	0.143
Niger	-	-	-	-	-	-	4.26	172.88	0.025	0.158
Yobe	-	-	-	-	-	-	-	-	-1.196a	0.208
Zamfara	4.116	162.15	-	-	-	-	4.21	172.88	0.216	0.207
Constant	-6.445	162.15	-6.779	117.40	-7.44	108.51	-6.69	172.88	0.822[a]	0.162

[a]significant at 1%, [b]significant at 5%, [c]significant at 10%

Changes in household livelihood outcomes perceived by groundnut producers

Table 16 below summarizes producer perception of changes in the livelihood outcomes since they adopted improved varieties. Overall, 85% of the households claimed to have improved the overall welfare as a result of the adoption of modern varieties. About 87% of groundnut producers reported to have increased their assets, 83% reported to increase increase their farm equipment, 79% reported to have increased their social status. However, lesser farmers claimed to have improved their food security (55%) and health (51%).

V. Conclusions and implications

This study examined the adoption of modern groundnut varieties on household livelihood effects and outcomes mainly productivity, total value of household production per capita, per capita household wealth, per capita household sale, score of consumption and household per capita expenditures. The treatment effect estimation framework was used to estimate the adoption of modern groundnut varieties and their determinants. Matching methods such as the propensity score matching were used to assess the impact of modern varieties because of the non-experimental nature of the data. All matching methods show a positive impact of adoption on groundut yield, and score of consumption a proxy for food security. However, there was no impact of adoption of modern groundnut varieties on per capita household wealth, and per capita expenditure. The adoption of modern varieties has contributed much on food security and less on poverty. This is also supported by econometric methods showing similar results.

There are potential for increasing uptake of groundnut varieties in Nigeria by developing and implementing a successful dissemination project with a strong seed multiplication and delivery component. Government should invest in the promotion of modern varieties through increased awareness and development of community seed production as well as encouraging private seed companies.

There is still a need for fine tuning the current impact assessment research by improving the identification of varieties. The use of finger printing methods or assessment of types by breeders may be necessary to ascertain the type of varieties and its adoption.

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Table 16: Producer perception of welfare changes since the adoption of modern varieties

Livelihood outcome	Producer's perception (%)		
	Deteriorated	Constant	Improved
Assets	1.48	11.21	87.32
Education	0	21.21	78.79
Farm equipment	1.29	15.68	83.03
Food security	2.67	42.53	54.80
Health	5.07	43.73	51.20
Social status	1.42	19.86	78.71
Overall welfare	1.32	13.37	85.32

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Annex 1. List of groundnut varieties released by IAR, ICRISAT and University of Georgia, USA

Name of variety	Old Name	Developed by	Year of release	Parents	Rosette
SAMNUT 1	MK 374	IAR	1960	Local virgina bunch	1
SAMNUT 2	SAMARU 38	IAR	1960		1
SAMNUT 3	M-25.68	IAR	1970		2
SAMNUT 4	69-101	?	1970		2
SAMNUT 5	M 599.74	IAR	1970		1
SAMNUT 6	M 95-71	IAR	1970		1
SAMNUT 7	M 104.74	IAR	1980		1
SAMNUT 8	M 103.74	IAR	1980		1
SAMNUT 9	59-127	Introduction	1980		1
SAMNUT 10	RMP 12	Introduction	19800		2
SAMNUT 11	RMP 91	Introduction	1988		2
SAMNUT 12	M 318.74	IAR	1980		1
SAMNUT 13	Spanish 205	Introduction	1980		1
SAMNUT 14	55-436	Introduction	1988		1
SAMNUT 15	F 452.2	Introduction	1970		1
SAMNUT 16	M 554.76	IAR	1988		2
SAMNUT 17	48-115 B	Introduction	1988		1
SAMNUT 18	RRB	IAR	1988		1
SAMNUT 19					
SAMNUT 20					
SAMNUT 21	UGA 2	IAR	2001		
SAMNUT 22	M 572.80 I		2001		
SAMNUT 23		ICRISAT/IAR	2001		1
SAMNUT 24	ICIAR 19BT	ICRISAT/IAR	2011		1
Rosette [1=susceptible, 2=tolerant, 3=resistant]					

Annex 2. Weight coefficient on major food items

Food group	*Type of food*	*Weights*
Cereals and tubers	Sorghum, millet, , maize	2
Legumes	Cowpea, beans	3
Vegetables and green legumes	Legumes, leaves	1
Fruits	Fruits	1
Animal protein	Fish, fresh and dry meat, eggs, etc..	4
Milk and milk products	Milk, yogurt, cream	4
Sugar	Sugar, honey	0.5
Oil and fats	Groundnut, soybean	0.5

Consumption score (poor food consumption (<=28), borderline consumption average (28-42), Acceptance - Good (>42))

Annex 3. Survival strategies used by household to shortage of food or food insecurity.

Strategy	Frequency
Eat less preferred foods	1 (Never) 2 (Rarely) 3 (Sometimes) 4 (Often)
Contract loan to buy food	1 (Never) 2 (Rarely) 3 (Sometimes) 4 (Often)
Constrains to eat all the days the same thing	1 (Never) 2 (Rarely) 3 (Sometimes) 4 (Often)
Reduce the number of meals per day	1 (Never) 2 (Rarely) 3 (Sometimes) 4 (Often)
Reduce the quantity of the daily ration	1 (Never) 2 (Rarely) 3 (Sometimes) 4 (Often)
Spend a day without eating	1 (Never) 2 (Rarely) 3 (Sometimes) 4 (Often)
Go to bed without eating because had nothing to eat	1 (Never) 2 (Rarely) 3 (Sometimes) 4 (Often)
Did you worry that your household would not have enough food?	1 (Never) 2 (Rarely) 3 (Sometimes) 4 (Often)
Was there ever no food at all in your household because there were no resources to get more?	1 (Never) 2 (Rarely) 3 (Sometimes) 4 (Often)
1 [Never ie. 0 times], 2 [Rarely 1-2 times], 3 [Sometimes 3 to 10 times] and 4 [Often more than 10 times]m	