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Production and Marketed Surplus of Crops in Uganda, 1999-2006

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UGANDA STRATEGY SUPPORT PROGRAM (USSP)
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Abstract

Recent trends in Ugandan agriculture indicate output is increasing for most crops but at a declining rate. The pervasive decline in output per unit of input (factor productivity) threatens the economic well-being and food security of producers and consumers of food in Uganda. Many households are both agricultural producers and consumers and have little access to other sources of livelihood (UBOS 2007). For these households, the declining productivity is particularly serious. Evidence is presented in this paper that improved agricultural inputs and extension information contribute to higher yields, but rates of adoption of improved agricultural inputs are low and many farmers have no access to extension services. Despite the low productivity, marketed surplus as a share of total agricultural output has increased for many food crops (PMA 2007).

On the basis of the regression results, we address policy-related “levers of productivity” that influence agricultural output in Uganda. All agricultural inputs besides land (labor, fertilizer, chemicals, improved seeds, and agricultural assets) have a positive and statistically significant impact on output per acre on farms in at least one of the three size categories. Schooling, agricultural know-how, and credit also have positive effects on per-acre output. Land is the exception among inputs: the finding that expanding cultivated acreage is associated with a decline in output per acre is robust across a large number of model specifications with which we experimented during the analysis. Clearly, Uganda's food security problems cannot be solved at the "extensive margin," but must be addressed by greater use of modern inputs and technology.

Land area cultivated in Uganda has increased more rapidly than agricultural output over the period 1999-2006, implying a decrease in land productivity. The technology employed in agriculture remains rudimentary and there is relatively little use of modern inputs. Output per acre could be increased through greater use of fertilizer, agricultural assets, agricultural chemicals, improved seeds, credit, and extension services. Each of these inputs plays an effective role in land productivity in at least one farm size category. Fertilizer stands out for its positive and statistically significant effect on productivity across all farm sizes. An important task of agricultural policy is to remove the impediments that prevent greater use of modern inputs.

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1. Introduction

Recent trends in Ugandan agriculture indicate output is increasing for most crops but at a declining rate. The pervasive decline in output per unit of input (factor productivity) threatens the economic well-being and food security of producers and consumers of food in Uganda. Many households are both agricultural producers and consumers and have little access to other sources of livelihood (UBOS 2007). For these households, the declining productivity is particularly serious. Evidence is presented below that improved agricultural inputs and extension information contribute to higher yields, but rates of adoption of improved agricultural inputs are low and many farmers have no access to extension services. Despite the low productivity, marketed surplus as a share of total agricultural output has increased for many food crops (PMA 2007).

We report on changes in output, acreage, factor productivity, adoption of improved agricultural practices, and marketed surplus of crop agriculture in Uganda over the period 1999-2007. We present summary statistics for the period 1999-2006 and a multivariate analysis of affecting the value of crop output per acre. Both secondary and primary data are used. Secondary data from the Uganda National Household Surveys (UNHS) and the National Service Delivery Surveys were obtained from the Uganda Bureau of Statistics (UBOS 2007). UNHS data used in the paper are from the 1999/2000 and 2005/2006 rounds of the survey. In the 1999/2000 round, over 10,000 households were interviewed in all parts of the country except the Acholi sub-region and Kasese and Bundibugyo districts due to insecurity. In the 2005/2006 round, over 7000 households were interviewed. In addition, the analysis in the paper draws on data from the Food and Agriculture Organization (FAO), Ministry of Agriculture, Animal Industries, and Fisheries (MAAIF) and Ministry of Finance, Planning, and Economic Development (MFPED). Some desired indicators are not available from secondary sources, and for these indicators a household survey was undertaken by the External Monitoring Unit (EMU) at Makerere University. The survey was undertaken from the second half of April 2007 through the end of July 2007, covering 2,000 households throughout the country.

2. Changes in Land Area of Major Crops

Mean household land area by crop is shown in Table 1. Means are calculated only across households that actually produce the crop. The largest mean household acreage increase (of about 3 times) was recorded in Irish potato, followed by beans, maize and sweet potato. For each crop, mean values are calculated across only the households that produce each crop. Reasons for the large area increase in Irish potato production are not clear. Acreage increases in the other crops appear to reflect a long-term transition from food crops to non-traditional cash crops. Supporting this assessment, trade data (not shown here) indicate that, in terms of value, maize exports grew by 16 percent, bean and legume exports by 27 percent, sesame exports by 500 percent and banana exports by 20 percent between 2001 and 2005 (UEPB, 2006). The increase in sweet potato acreage may have occurred because cassava, the closest substitute, was negatively affected by the African cassava mosaic virus, though this epidemic is now largely under control. Coffee has suffered from the coffee wilt disease, and cotton acreage is constrained by a poor marketing network and insecurity in the cotton growing areas of the Acholi sub-region in the North. While total rice output increased over the period 1999/2000 to 2005/06, the increase appears to have occurred because more land was brought under rice cultivation, not because yields have increased. As rice cultivation has expanded, the mean rice acreage per farm household and the mean rice yield (kg/ha) have declined (Table 1), despite the mounting of a campaign to promote its production. Many of the new rice farmers have lower yields than those who grew rice in the past. The low productivity may be explained, in part, by drought and the heavy labor requirements of rice (PMA Bulletin for December, 2007). Rice requires about 40 days of labor just for bird scaring over the growing season. As Universal Primary Education (UPE) was effectively implemented in more areas, the availability of children for bird scaring declined, and the opportunity cost of bird scaring time is quite high for adults.

Table 1—Total output and mean household land area of major crops, 1999 and 2006

Crop	Output			Mean Household Land Allocation		
	1999/2000 (metric tonnes)	2005/2006 (metric tonnes)	Change (%)	Mean hectares, 1999/2000	Mean hectares, 2005/2006	Change (%)
Maize	739,177	2,440,000	230	0.34	0.85	150
Millet	184,197	188,800	3	0.32	0.59	84
Sorghum	113,240	162,400	43	0.31	0.62	100
Rice	41,896	880,000	2000	0.39	0.29	-26
Beans	495,652	665,000	34	0.31	0.78	151
Groundnut	125,617	219,000	74	0.26	0.28	8
Simsim	97,000	166,000	71	0.32	0.36	13
Cotton	21,439	18,870	-12	0.42	0.43	2
Irish potato	208,359	154,600	-26	0.19	0.57	200
Coffee	154,700	120,139	-22	0.40	0.17	-58
Sweet potato	2,620,065	1,696,000	-35	0.20	0.44	120
Cassava	2,245,882	1,656,000	-26	0.30	0.33	10
Matooke	6,129,724	5,360,500	-13	0.36	0.7	94

Source of output data: UNHS 1999/2000 and 2005/2006, Reports on the Agricultural Modules; UCDA 2006. Cotton data obtained from CDO in bales, converted to kg @ 1bale=185kg and divided by 1000 to get equivalent in tons. Source of land allocation data: Uganda Bureau of Statistics (UBOS); UNHS data 1999/2000 and 2005/2006.

Overall, farmers appear to be opening up more land rather than intensifying on existing cultivated land. If land-saving technologies were spreading, one would expect acreage to increase less rapidly than agricultural production (in physical terms). Instead, we observe that overall agricultural production is flat while cultivated acreage has increased.

The observed overall increase in crop acreage appears to arise from little advance in application of land-saving technology (seeds, fertilizer, better agronomic practices) and increasing reliance on area expansion to drive agricultural output. Average farm sizes remain small. Output of simsim (sesame), cassava, sweet potato and maize has increased. Output of rice, bananas, coffee, cotton and beans has declined owing to the effects of plant disease epidemics and pests. For instance, bollworms and weeds are major constraints in cotton production, and can reduce yields by 30-40 percent (PMA, 2009).

3. Changes in Productivity of Major Crops

3.1 Land productivity

Table 2 shows national level changes in land productivity for major crop enterprises between 1999 and 2006. The largest increase in yield occurred in simsim, followed by cassava, sweet potato, and millet. Land productivity declined in all other key crops, with the greatest declines in bananas (matooke), coffee, beans, and maize. At the regional level, noteworthy increases in yield in Irish potato in the East, in cassava, sweet potato, and simsim in the North; and in simsim in the West (Table 3). The widespread yield decline has diverse causes. These include continuing, though declining, insecurity in the Acholi sub-region in the North that rendered a large proportion of the farming community redundant, climatic changes that have led to erratic rainfall patterns, disease and pest epidemics especially in coffee and bananas, low rates of adoption of soil-enhancing technologies (such as manure and fertilizer) and growing soil exhaustion, and low agricultural commodity prices that act as a disincentive for agricultural production and investment.

Table 2—Change in mean household level land productivity (yield) of major crops between 1999 and 2006 (kg/ha)

Crop	Mean yield REPEAT Survey 2002/03 (kg/ha)	Mean yield UNHS 1999/2000 (kg/ha)	Mean yield UNHS 2005/2006 (kg/ha)	Change (%)
Maize	1,609	1,400	541	-61
Millet	n/a	583	719	23
Sorghum	n/a	504	323	-36
Rice	n/a	1,385	734	-47
Beans	641	988	358	-64
Groundnut	1,222	680	636	-6
Simsim	n/a	114	278	144
Cotton	n/a	628	292	-53
Irish potato	n/a	1,457	1,003	-31
Coffee	1,019	1,215	369	-70
Sweet potato	n/a	1,664	2,070	24
Cassava	n/a	401	544	35
Matooke	1,200	8,594	1,872	-78

Table 3—Change in mean household level land productivity (yield) of major crops between 1999 and 2006 across regions of Uganda, 1999 and 2006 (kg/ha)

Crop	Central			Eastern			Northern			Western		
	99/00 (kg/ha)	05/06 (kg/ha)	Chng (%)	99/00 (kg/ha)	05/06 (kg/ha)	Chng (%)	99/00 (kg/ha)	05/06 (kg/ha)	Chng (%)	99/00 (kg/ha)	05/06 (kg/ha)	Chng (%)
Maize	1289	578	-55	1939	519	-73	557	364	-35	1289	651	-50
Millet	930	994	7	497	393	-21	358	478	33	930	1172	26
Sorghum	595	353	-41	458	371	-19	271	206	-24	595	470	-21
Rice	692	694	0	1354	736	-46	2011	618	-69	692	979	42
Beans	1097	357	-67	816	138	-83	577	472	-18	1097	458	-58
Groundnut	877	669	-24	587	536	-9	619	509	-18	877	848	-3
Simsim	54	74	38	117	84	-28	110	319	191	54	123	129
Cotton	1076	231	-78	612	287	-53	632	300	-53	1076	450	-58
Irish potato	1712	1631	-5	1321	6813	416	-	894	-	1712	769	-55
Coffee	1296	327	-75	1094	374	-66	475	535	12	1296	496	-62
Sweet potato	1499	1522	1	1995	1765	-12	1376	5200	278	1571	1936	23
Cassava	428	378	-12	322	573	78	78	599	665	406	696	71
Matooke	2875	2209	-23	16882	699	-96	-	-	-	6642	2348	-65

Source: Uganda Bureau of Statistics (UBOS); UNHS data 1999/2000 and 2005/2006

Among the causes of low land productivity, prices and costs are especially important. International prices of Uganda's two most important agricultural exports, coffee and cotton, have been low and fluctuating since 1990, a trend that continued throughout our study period (World Bank, 2007). For both coffee and cotton, producer prices in Uganda are close to the cost of production, providing relatively little incentive for producers (Matthews, Claquin, and Opolot, 2009). Within Uganda, domestic marketing margins have fallen for many commodities, suggesting that margins are becoming more efficient, yet transport costs remain high, keeping farm gate prices relatively low (World Bank, 2007). Furthermore, farmer utilization of high yielding varieties is hampered by high prices of some inputs, such as fertilizer and seed, and by the absence of assured markets for products.

It is a matter of grave concern that in Uganda over the period 1999-2006 change in total area cultivated was the main driver of agricultural output. In most countries where agricultural productivity has increased, land productivity (yield) is the key driver, and 80 percent of change in agricultural output is attributable to yield variability (World Bank 1996). In general, yield is important because higher level productivity is likely to lead to a larger quantity marketed. The average yields obtained by Ugandan farmers are well below their attainable potential, measured by outputs in research trials, and very large yield gaps remain. Table 4 shows the yield gaps for maize, beans, groundnuts, bananas and coffee for which research station yield data are available. The yield gap estimates indicate there is a great deal of potential to increase productivity. The largest yield gap is in maize, for which research stations yields are at least 10 times average farmer yields. The smallest yield gap is in bananas, although this could change if the bacterial wilt problem were to worsen.

Table 4—Yield gaps of selected crops in Uganda.

Crop	Average farmer yields (kg/ha)	Research station yields (kg/ha)	Yield gap (%)
Maize	551	5,000-8,000	92
Beans	358	2,000-4,000	88
Groundnuts	636	2,700-3,500	79
Bananas	1,872	4,500	58
Coffee	369	3,500	89

Source: UNHS 2005/06 and World Bank (2006).

Yield gap is computed by dividing the difference between research station yield and farmers yield by research station yield, expressed as a percentage. Yield data should be interpreted with caution, owing to possible inaccuracies in the estimation of area allocated to each crop. Cultivated area, especially where there is intercropping, is hard to estimate accurately and, therefore, yield data is subject to measurement error.

Observations reported above on yield are corroborated by an evaluation report of the Program for the Modernisation of Agriculture (PMA Joint Evaluation 2006). This evaluation noted that land productivity has remained more or less constant except for cereals, whose yields increased by 34 percent between 1996 and 1999. The PMA evaluation report attributes stagnation in yield to reliance on manual labor, poor farm management, limited access to inputs and low technology adoption, and low crop diversification. Low market participation is also cited as limiting farmers' ability to exit poverty.

3.2 Labor and capital productivity

No country-wide data on agricultural output per unit of labor and capital for the whole of Uganda were available prior to the 2005/06 Uganda National Household Survey. While labor and capital productivity rates can be calculated from the 2005/06 survey, there are no rates available from earlier years against which to compare them. As time series are not available for labor and capital productivity, we compare cross-sectional yields differences between the majority of farmers and the top decile of farmers. The purpose of this comparison is to understand the extent to which productivity of the majority of farmers differs from the regional benchmark set by the most productive farmers. While a portion of the productivity differences within regions is undoubtedly related to differences in soil quality, soil moisture, altitude, and other exogenous factors, large benchmark-to-average productivity ratios across farms within a given district are likely to arise from differences in rates of usage of modern inputs and differences in farming practices.

Large differs in labor productivity are observed within regions. For maize, the benchmark-to-average ratio of labor productivity ranges from 8.1 in Central region to 17.6 in Western region. For bananas, the labor productivity ratios range 4.1 in the Northern region to 15.4 in the Eastern region. For coffee, the ratios range from 3.1 in the Northern region to 7.0 in the Eastern region. Differences in capital productivity among farms within the same region are also large. For maize, the benchmark-to-average capital productivity ratios range from 10.0 in the Central region to 27.5 in the Western region. For bananas, the ratios range from 8.8 in the Central region to 14.1 in the Northern region. For coffee, the ratios range from 4.1 in the Western region to 12.8 in the Eastern region. From these patterns, it seems reasonable to conclude that labor and capital productivity on the average farm are far below their potential, and that large on-farm improvements in productivity could be made.

Another reason to believe labor and capital productivity rates are low is that average household expenditures on hired labor and capital inputs declined from 1999-2006 (Tables 5 and 6). A decline is registered even when no adjustment is made for inflation, which would tend to drive nominal expenditures upward. If labor and capital productivity were increasing, one would expect expenditures on these inputs to also increase, since a growing return to each unit of input would tend to attract a higher quantity of inputs.[1] Instead, nominal average household expenditures on hired labor declined by 10 percent from 1999-2006 at the national level, while nominal average household capital expenditures declined by 48 percent. Among the regions, labor and capital expenditures declined the most in the Central region, where spending on hired labor declined by 23 percent while spend on capital declined by 55 percent.

Table 5—Change in mean household level expenditure on hired labor at national and regional levels from 1999-2006 (UShs per annum)

Region	Mean expenditure on hired labor 1999/2000 (UShs/annum)	Mean expenditure on hired labor 2005/2006 (UShs/annum)	Change (%)
National	48,402	43,353	-10
Central	64,819	49,927	-23
Eastern	36,549	36,625	0
Northern	29,614	29,785	1
Western	61,001	57,570	-6

[1] This logic holds unless wages for hired labor and the cost of capital increase, inducing substitution to other inputs. However, an increase in rural hired labor wages over the study period is unlikely given the high population growth rate in Uganda (around 3.4 percent per annum). An increase in the cost of capital is also unlikely, since interest rates declined from a high of 36 percent per annum in 2000 to the current 18-20 percent.

Table 6—Change in mean household level capital utilization (nominal) at national and regional levels from 1999-2006 (Ush per annum)

Region	Mean capital expenditure 1999/2000 (Ush/annum)	Mean capital expenditure 2005/2006 (UShs/annum)	Change (%)
National	121,141	62,650	-48
Central	144,083	65,548	-55
Eastern	103,646	55,572	-46
Northern	99,657	51,847	-48
Western	118,887	69,357	-42

4. Variation in Adoption of Improved Crop Varieties

The national rate of adoption of improved varieties has increased in Uganda by approximately three percentage points from 8.1 percent to 10.9 percent over the period 1999-2007, as shown in Table 7.[2] Increases in adoption rates of improved varieties are registered for 10 of 13 key crops. Consistently high adoption rates are noted for maize, beans, groundnuts and cassava. The greatest increase in improved-variety adoption occurred in maize. This can be attributed to a successful program of developing and disseminating improved maize varieties, especially the popular LONGE series. Increase in adoption of improved varieties of maize was also driven by local purchases of maize by the World Food Program (WFP) and by exports to other countries in the region.

Table 7—Change in proportion of households adopting improved varieties at national level for 13 key crops, 2000 and 2007

Crop	Pct. of Adopters 2000	Pct. of Adopters 2007	Change (%)
Maize	17.4	50.1	32.7
Millet	3.5	0.4	-3.1
Sorghum	1.1	2.2	1.1
Rice	3.0	3.2	0.2
Beans	12.1	25.3	13.2
Groundnut	4.1	20.4	16.3
Simsim	1.2	0.7	-0.5
Cotton	40.9	1.8	-39.1
Irish potato	1.7	4.3	2.6
Coffee	4.8	1.8	-3.0
Sweet potato	1.1	2.9	1.8
Cassava	9.4	22.2	12.8
Matooke	5.2	6.9	1.7
Mean(all crops)	8.1	10.9	2.8

Source: Uganda Bureau of Statistics (UBOS); UNHS data 1999/2000 and EMU Field Survey 2007.

[2] Increased adoption of new technology and declining productivity may, at first, appear contradictory. However, as Feder, Just, and Zilberman (1985) point out, farmers often adopt new technologies on only a portion of their land. If the bulk of land is devoted to conventional technology, and productivity on that land is declining, overall productivity could decline. Furthermore, farmers often adopt only a part of the whole technology package, in which case, productivity of land devoted to the new technology may be lower than that of the conventional technology. For example, in a technology package consisting of improved seeds and fertilizer, if improved seeds are used without fertilizer, yield may be lower than that of unimproved seed since improved seed.

The EMU survey, which was undertaken to fill gaps in data not available through other sources, was designed in collaboration with the Uganda Bureau of Statistics (UBOS), which also designed the UNHS survey. For both the UNHS and EMU surveys, the same sampling methodology was used and the samples for both surveys were drawn from the same enumeration areas. The households are not identical in the two surveys, since the UBOS privacy policy prohibits the agency from releasing names of households in the UNHS survey. However, given the similarity of the sampling methodologies and of the enumeration areas, the two data sets are relatively similar.

A decline in adoption of improved varieties occurred in cotton, coffee, millet, and simsim. Promotion of improved varieties has been emphasized by the extension system, and it is not clear why adoption rates remain low for some crops. One possibility could be scarcity and high cost of improved seed. The change in the national rate of improved-variety adoption is higher for maize than for any other crop. Adoption of improved maize varieties increased significantly in all four regions (Table 8). In contrast, the national rate of adoption of improved cotton dropped, declining more than for any other crop. The large drop in adoption of improved cotton might arise from insufficient adaptive research to address disease and pest problems and from insecurity which plagued the traditional cotton growing areas of the Acholi sub-region in the North during much of the study period. The adoption rate for coffee has declined across the country except for a small increase in the West. Mean adoption rates averaged across the 13 crops were higher in 2007 than in 2000 in three of the four regions but declined slightly in the East.

Table 8—Change in the proportion of adopters of improved varieties for 13 key crops across regions of Uganda, 2000-2005

Crop / Region	Central			Eastern			Northern			Western		
	1999/00 (%)	2007 (%)	Change	1999/00 (%)	2007 (%)	Change	1999/00 (%)	2007 (%)	Change	1999/00 (%)	2007 (%)	Change
Maize	19.0	55.3	36.3	26.2	59.4	33.2	6.5	33.6	27.1	5.3	35.6	30.3
Millet	0.4	0.0	-0.4	5.8	0.4	-5.4	1.0	1.6	0.6	0.8	0.0	-0.8
Sorghum	1.0	0.0	-1.0	2.2	1.2	-1.0	0.4	10.4	10.0	0.3	0.0	-0.3
Rice	1.2	2.8	1.6	3.9	2.4	-1.5	0.0	2.4	2.4	0.0	6.7	6.7
Beans	14.3	43.9	29.6	22.3	9.6	-12.7	6.0	20.8	14.8	2.6	25.0	22.4
Groundnut	5.7	0.8	-4.9	6.4	37.5	31.1	2.3	41.6	39.3	1.3	0.0	-1.3
Simsim	2.1	0.0	-2.1	3.9	0.4	-3.5	0.0	3.2	3.2	0.0	0.0	0.0
Cotton	7.2	0.0	-7.2	43.6	2.8	-40.8	44.8	4.8	-40.0	0.0	0.0	0.0
Irish potato	3.3	0.4	-2.9	7.0	1.2	-5.8	0.0	0.0	0.0	0.3	26.0	25.7
Coffee	5.6	3.7	-1.9	5.3	0.8	-4.5	28.2	0.0	-28.2	0.2	1.9	1.7
Sweet potato	1.6	6.5	4.9	1.2	2.0	0.8	0.1	0.0	-0.1	0.1	0.0	-0.1
Cassava	7.9	30.9	23.0	20.4	13.1	-7.3	3.9	37.6	33.7	1.8	4.8	3.0
Matoke	5.4	16.7	11.3	8.8	0.0	-8.8	2.4	0.0	-2.4	0.9	8.7	7.8
Mean (all)	5.8	17.9	12.2	12.1	10.9	-1.2	7.4	17.3	10.0	1.1	15.5	14.5

Source: Uganda Bureau of Statistics (UBOS); UNHS data 1999/2000 and EMU field survey 2007.

5. Changes in Adoption of Soil Improvement Techniques

For countries whose economies rely heavily on the stock of natural resources, advances in agricultural productivity depend to a large extent on how well the environment and natural resources are managed and used. Recent developments in Uganda have put much stress on its environment and natural resource base. Estimates of the cost of natural resource degradation in Uganda place it as high as 17 percent of gross national income (GNI) per year, of which 6 percent consists of forest degradation and 11 percent soil degradation (NEMA, 2005). Thus, encouraging and incentivizing rural households to adopt improved soil fertility and environmental conservation management practices is an urgent matter.

The percentage of rural households using improved soil fertility management and environmental conservation practices is derived by dividing the number of households in rural areas using these practices by the total number of households in these areas. The analysis is conducted at two levels. The first level examines measures used by farmers to prevent soil erosion, one of the major soil degradation problems. The second level of analysis examines measures used to improve soil fertility.

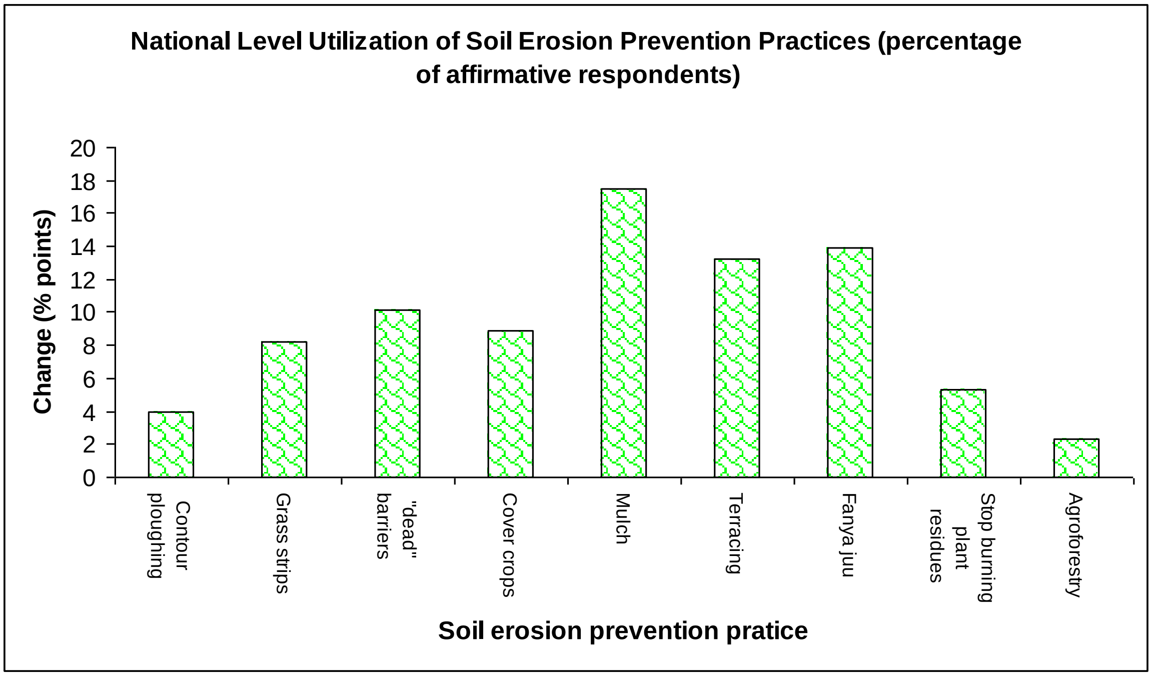
The present analysis is based on External Monitoring Unit (EMU) surveys, conducted by one of the authors (Bashaasha) in 2000 and 2007. The EMU questionnaires asked respondents whether they observed soil erosion on their fields and whether measures have been taken to prevent soil erosion. The majority (80%) of respondents report having observed incidences of soil erosion on their fields. A slightly smaller proportion of respondents (61 percent) report having taken one or more measures to reduce soil erosion. A number of soil erosion prevention practices were used. As shown in Table 9 and Figure 1, there have been improvements in the use of all soil erosion prevention practices across the board.

Table 9—National level utilization of soil erosion prevention practices (percentage of respondents reporting)

Practice	2000 (%)	2007 (%)	Change
Contour plowing	16.0	20.0	4.0
Grass strips	21.0	29.2	8.2
“Dead” barriers of plant material or stones	7.0	17.1	10.1
Cover crops	5.3	14.2	8.9
Mulch	17.3	34.8	17.5
Terracing	15.8	29.0	13.2
Fanya juu	36.1	50.0	13.9
Stop burning plant residues	3.3	8.6	5.3
Agroforestry	13.3	15.6	2.3

Source: EMU 2000 and 2007 field surveys.

Figure 1—Changes in aggregate utilization of soil erosion prevention practices (percentage of respondents reporting).



Source: EMU Field Surveys, 2000 and 2007.

At the national level, the soil erosion prevention practice that has increased most is mulching, followed by terracing and *fanya juu* (digging a trench along the contour of a slope and throwing the soil uphill to form an embankment) at about the same level. Agroforestry and the use of contour plowing are the soil erosion prevention practices that have changed least. Agroforestry recorded the lowest level of growth among the measured practices though, in principle, its agronomic benefits can be immense.

There are no significant regional differences with regard to undertaking at least one type of preventive measure to control soil erosion. The proportion responding in the affirmative was 65 percent in Central region, 67 percent in the East, 51 percent in the North and 61 percent in the West. However, there are regional variations in the particular soil erosion preventive measures adopted, as indicated in Table 10**.** Agroforestry increased in the Central region whereas the practice of *fanya juu* declined. In the East, both contour farming and use of grass strips dropped over the period of analysis. In the West, *fanya juu* and the use of mulching grew most rapidly, while the practice of agroforestry declined among households. No comparative information exists for the North as the EMU survey in year 2000 did not cover that region.

Table 10—Utilization of soil erosion prevention practices at regional level (percentage of respondents reporting)

Practice / Region	Central			Eastern			Northern			Western		
	2000 (%)	2007 (%)	Change	2000 (%)	2007 (%)	Change	2000 (%)	2007 (%)	Change	2000 (%)	2007 (%)	Change
Contour plowing	8.0	11.6	3.6	20.8	10.9	-9.9	n/a	40.4	n/a	23.1	25.3	2.2
Grass strips	7.1	20.9	13.8	60.5	47.4	-13.1	n/a	18.8	n/a	9.3	25.3	16
"Dead" barriers of plant material or stones	5.1	7.6	2.5	10.9	16.4	5.5	n/a	16.4	n/a	8.7	28.8	20.1
Cover crops	4.6	16.1	11.5	9.2	14.9	5.7	n/a	8.0	n/a	3.4	15.5	12.1
Mulch	36.1	51.4	15.3	7.5	13.2	5.7	n/a	18.3	n/a	11.7	50.9	39.2
Terracing	17.7	27.1	9.4	10.7	25.3	14.6	n/a	20.7	n/a	21.5	40.8	19.3
Fanya juu	69.6	54.5	-15.1	32.7	47.7	15	n/a	42.3	n/a	5.8	52.5	46.7
Stop burning plant residues	6.3	0.1	-6.2	3.1	3.7	0.6	n/a	2.8	n/a	1.0	26.9	25.9
Agroforestry	9.4	31.9	22.5	2.9	10.3	7.4	n/a	15.5	n/a	16.8	3.2	-13.6

Source: EMU field surveys 2000 and 2007.

Respondents not undertaking any soil erosion prevention or mitigation measures cited a number of reasons. More than half (55 percent) of all respondents who reported observing soil erosion did not think it was a very serious problem. Another 32 percent respondents reported lack of personal knowledge on what to do about the soil erosion problem. Minor reasons, cited by less than 10 percent of respondents, included lack of time, money and labor to undertake soil erosion preventive measures.

Respondents in the EMU Survey were also asked to report whether they were consciously doing anything aimed at improving soil fertility. A significant proportion (64 percent) indicated doing so. At the regional level, 77.4 percent of respondents in the West, 75 percent in Central, 61 percent in the East, and 38 percent in the North were using at least one measure to improve the fertility of the soil. Soil fertility improvement practices are indicated in Table 11 along with relative utilization levels at the national level.

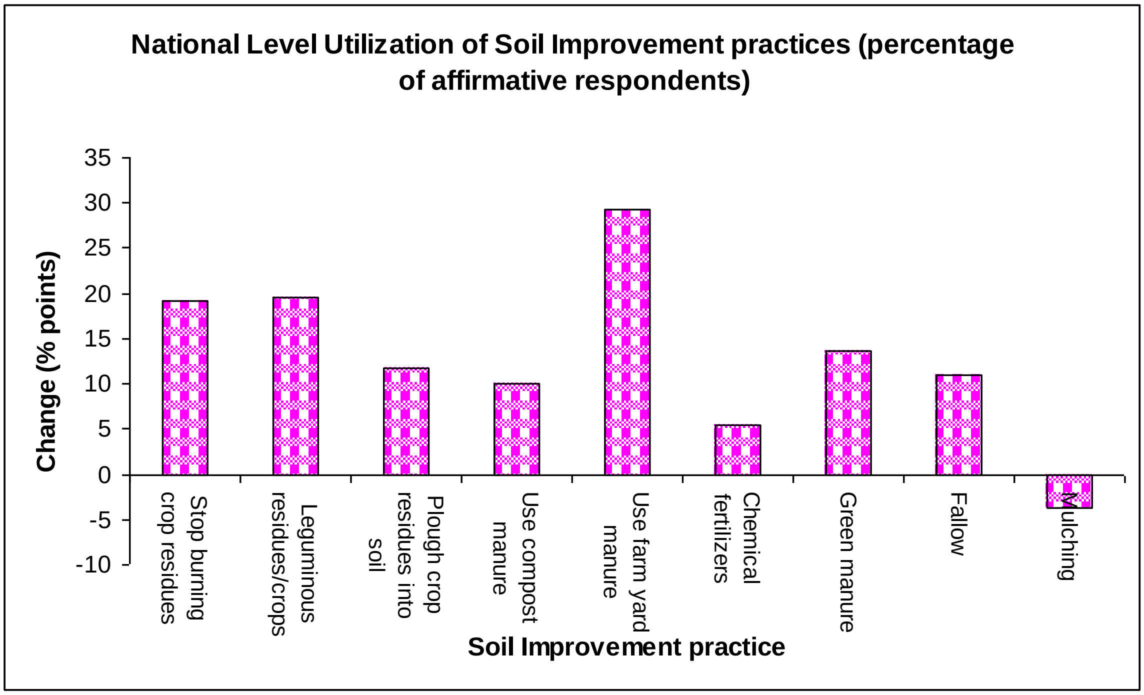
Table 11—National level utilization of soil improvement practices (percentage of affirmative respondents)

Practice	2000 (%)	2007 (%)	Change
Refraining from burning crop residues	10.6	29.8	19.2
Leguminous crops	15.7	35.3	19.6
Plough crop residues into the soil	16.4	28.1	11.7
Use compost manure	30.5	40.5	10.0
Use farm yard manure	30.1	59.4	29.3
Chemical fertilizers	4.4	9.8	5.4
Green manure	3.5	17.1	13.6
Fallow	21.6	32.6	11.0

Source: EMU field surveys 2000 and 2007.

The most widely used soil improvement practices in 2007 were use of farm yard manure, use of compost manure, planting of leguminous crops, fallowing, and refraining from burning crop residues. Adoption of these practices increased a great deal between 2000 and 2007. As can be seen in Table 11 and Figure 2, the largest change in soil improvement measures has been registered in the usage of farmyard manure, followed by utilization of legumes and refraining from burning crop residues. Other soil improvement measures are use of green manure, use of chemical fertilizers, and mulching, though utilization of these measures remains low. Whereas mulching was found to be popular as a method of controlling soil erosion, its use as a soil improvement practice is low among households. Utilization of chemical fertilizers has improved slightly from by 4.4 percent in 2000 to 9.8 percent in 2007.

Figure 2—Changes in aggregate utilization of soil fertility improvement practices (percentage of respondents reporting).



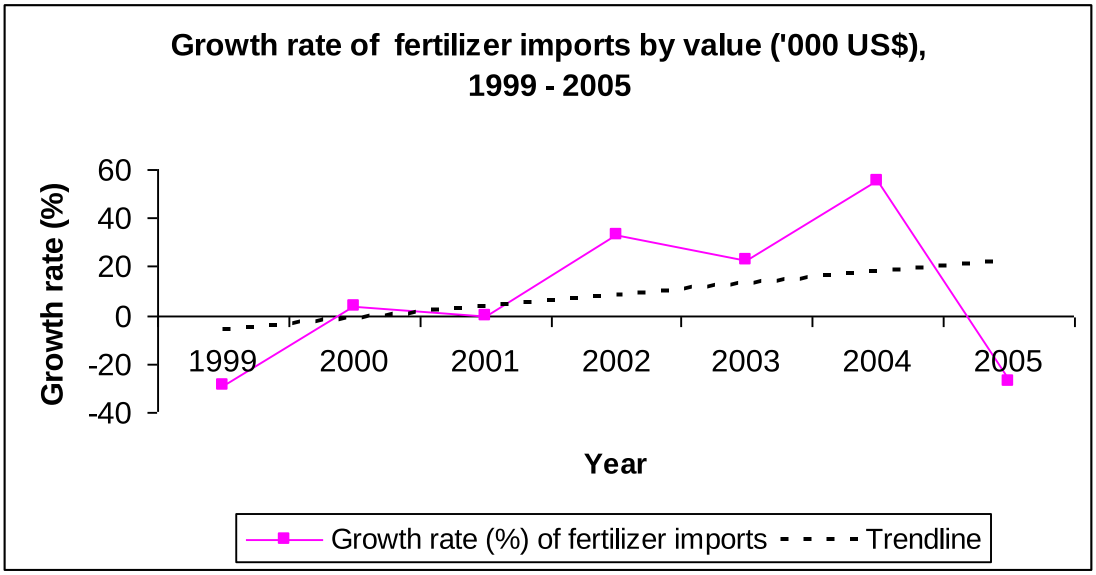
Source: EMU Field Surveys, 2000 and 2007.

The utilization of manure has increased rapidly in Uganda, whereas the application of inorganic fertilizers has increased little. Manure is important in smallholder agricultural production systems in Uganda. The World Bank (2006) notes that natural fertilizer (manure) use is associated with approximately 40 percent higher production on average, all else held constant. The same study found no statistical evidence to support the hypothesis that chemical fertilizer contributes output in Uganda. However in Section 9 we present statistical evidence that fertilizer use is an important determinant of output per acre in. For sub-Saharan Africa, in general, Reardon (1998) argues that combined use of inorganic and organic fertilizer is essential for boosting agricultural productivity.

Current policy interest related to fertilizer use in Uganda is centered on cost. Whereas, cost considerations offer an entry point to promote fertilizer use, promotional programs highlighting the benefits of fertilizer use and dispelling some of the negative perceptions may be equally important. Organic manure may be appropriate in the short run, as it has immense benefits on the structure of the soil, but it is necessary to complement it with inorganic fertilizers to increase agricultural productivity.

The proportion of households using inorganic fertilizers increased slightly over the period 2000 to 2007 (Figure 3). Also, it appears that actual users of fertilizer are intensifying their use. This is indicated by the positive rate of growth of fertilizer imports, assuming there is little or no re-exporting, from 1999 through 2005. The overall growth rate of fertilizer imports for the period 1999-2005 is 8.4 percent.

Figure 3—Growth rate of inorganic fertilizer imports by value ($US thousands) for the period 1999-2005.



Source: UBOS, 2007.

Whereas fertilizer imports into the country have grown by over 8 percent, the average amount of fertilizer use at the household level has declined (UBOS, 2007). It seems likely that much of the growth of fertilizer imports can be attributed to relatively large farmers or commercial plantations cultivating tobacco, sugarcane, or tea.

6. Institutional and Agronomic Factors Related to Change in the Crop Sector

Weather is a key factor in Uganda's agricultural productivity, reported earlier as low and declining. A report by the Famine Early Warning System (FEWS NET, 2004) noted that, in 2004, production of major staple and cash crops, including banana (matooke), beans, maize, millet and sorghum, was expected to be up to 40 percent lower than normal because of the poor rainy season. The most affected regions were Central, East, and West, where many crops had developed poorly. Banana production was projected to decline by about 30 percent. The effect of crop diseases is also highlighted by the World Bank's Country Economic Memorandum (2006), which notes that Coffee Wilt Disease (CWD) and Banana Bacterial Wilt (BBW) wreaked significant economic damage in Uganda.

Cassava production has benefited from availability of mosaic-resistant varieties, which have been disseminated widely. Sweet potato, maize and groundnut have not suffered major disease outbreaks; furthermore, these crops have benefitted from uninterrupted research and extension support. In contrast, production of coffee and bananas has been hampered by epidemics. Rice production in the Central region has benefited from promotion led by the office of the Vice President. In simsim production, it is not clear what is driving dramatic increases in output, but it probably has to do with improved security in the traditional simsim growing areas of the Lango sub-region in the North[3].

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[3] Apac and Lira, two districts in the Lango sub-region, together produced 56.7 percent of total simsim in the country in 2005/06, according to our calculation using the 2005/06 UNHS data.

The National Agricultural Research Organization (NARO) has released and disseminated a number of improved crop varieties. As of 2004, the Ugandan Agricultural Research System, of which NARO is the apex organization, had released 23 varieties of maize, 16 varieties of beans (*Phaseoulus vulgaris*), nine varieties of soybean, eight varieties of rice, three varieties of wheat, four varieties of sorghum, seven varieties of finger millet, two varieties of pearl millet, 11 varieties of groundnut, four varieties of sesame, two varieties of sunflower, two varieties of pigeon pea, four varieties of cowpea, 15 varieties of cassava, 14 varieties of sweet potato, nine varieties of Irish potato, and five varieties of bananas (PMA 2006).

Commercial production of improved varieties, such as the epuripur variety of sorghum for the brewery industry, sunflower and sesame for the vegetable oil industry, clonal coffee, cotton, rice, maize, and Irish potato, has created a boom in commercial agriculture. As a result of privatization and reforms in the seed industry, the number of seed suppliers has increased from one to thirteen companies. Seed production increased from 2,935 metric tons in 2003 to 8,539 metric tons in 2007 (PMA 2007).

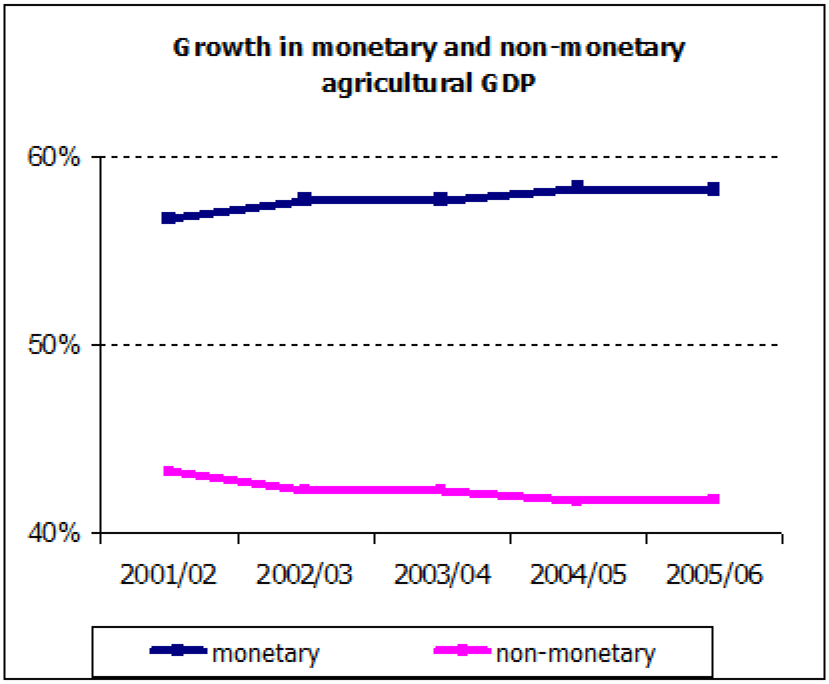
Through concerted research efforts and aggressive dissemination of scientific knowledge, crop diseases such as a banana wilt, coffee wilt, cassava mosaic, and maize streak virus, which had threatened the production of major crops, have been largely brought under control, thus preventing more decline in the production of these crops and incomes of the more than 50 percent of rural households that depend on them. Through the efforts of the Danish International Development Agency (Danida), NGOs, and District Farmer Associations, over 40,000 households in northern Uganda and West Nile have acquired improved seeds, inputs, and farm implements. With the support of Danida's Agriculture Sector Programme Support, 45 District Farmer Associations have developed income-generating enterprises for its 170,000 members. A study in 2007 revealed that 43 percent of members of those associations were using modern agricultural technology, and that their income had increased by 44 percent between 2004 and 2007. Between 2001 and 2006, the PMA Non-Sectoral Conditional Grant, channeled through 41 districts, enabled some farmers to establish fruit/tree nurseries and seed multiplication plots (PMA 2006).

7. Changes in Agricultural Commercialization

A number of dimensions can be examined to assess the extent to which agriculture is shifting from subsistence to a commercial orientation. They include (i) an increase in the monetization of agriculture, with a larger share of production now being marketed than before, (ii) increased use of purchased agricultural inputs, (iii) a shift to the production of higher-valued crops, and (iv) diversification of agricultural commodity exports.

Monetary agricultural gross domestic product indicates the total value of agricultural production that is sold. Non-monetary agricultural GDP represents the value of agricultural production used for subsistence. As indicated in Figure 4, agriculture in Uganda is becoming increasingly monetized. Compared to non-monetary agricultural GDP, growth in monetary GDP indicates an upward trend in the recent past.

Figure 4—Growth in monetary and non-monetary agricultural GDP



Source: Background to the Budget for 2006/07.

Marketed agricultural output as a percentage of total agricultural production increased from 56 percent in 2002/03 to 58 percent in 2005/06 (World Bank, 2006). This means that the proportion of farmers depending entirely on subsistence (non-monetary) output is declining and an increasing number of farmers are selling part of their output.

The marketed share of output of individual commodities is computed as a ratio of the real value of sales to the value of total production of the commodity in a given year, expressed as a percentage. The value of each commodity's production is computed by deducting quantities used as seed and feed from the total value of production. The marketed portion of each commodity's output is the value of the quantity sold. The Poverty Eradication Action Plan (PEAP) identifies the baseline for marketed surplus as 20 percent of agricultural production in 2002/03 with a target of 70 percent by 2013/14.

As a measure of market participation, we calculate the proportion of farmers who sold produce during the period 2005/06. Table 12 presents this information at both national and regional levels for 13 key crops. Coffee, with 97 percent of growers selling their output, is the most monetized commodity, followed by maize and cotton. For the rest of the commodities, less than half of the farmers growing them sell a portion of what they produce.

Table 12—Proportion (%) of farmers who sold produce, 2005/06

Crop	National	Central	Eastern	Northern	Western
Coffee	96.6	96.9	99.8	92.0	90.3
Maize	59.1	66.3	54.4	27.0	72.1
Cotton	54.0	n/a	95.0	n/a	93.3
Rice	40.5	5.3	71.0	45.5	55.6
Beans	39.8	49.4	26.6	36.4	38.6
Groundnut	38.9	25.8	22.7	45.5	55.6
Matooke	32.3	36.3	18.2	89.5	36.6
Sorghum	30.2	19.0	14.7	41.0	35.4
Millet	24.0	31.9	11.6	28.5	25.3
Cassava	21.6	28.6	15.2	30.7	17.3
Irish potato	17.9	1.9	40.0	40.0	23.1
Sweet potato	16.6	24.3	5.9	26.7	14.9
Simsim	11.0	n/a	28.6	10.2	100.0

Source: Uganda Bureau of Statistics (UBOS); UNHS data 1999/2000 and 2005/2006.

Changes in marketed share are shown in Figure 5 and Table 13 for 13 key crops between the period 1999/00 and 2005/06. At the national level, dramatic increases in marketed proportions are noticeable for maize, simsim, millet, groundnuts, and rice. The high marketed proportions for coffee and cotton remained unchanged, as expected, since these are traditional cash crops with little or no subsistence utilization. Marketed surpluses for matooke and cassava declined, probably owing to crop epidemics that have affected the two crops.

Figure 5—Change in national level mean marketed share of major crops in Uganda (1999/00-2005/06).

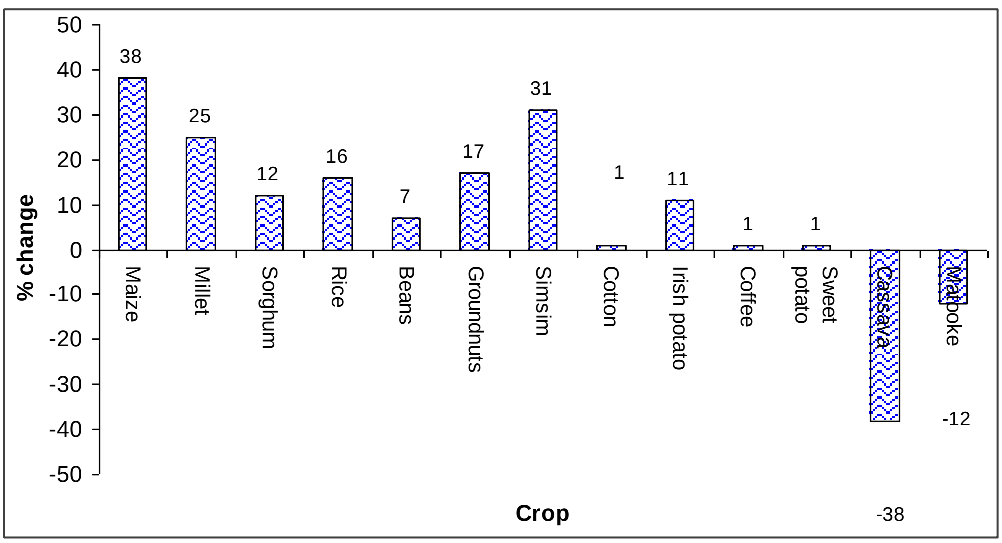


Table 13—Mean national level marketed share of major crops, 1999/00 and 2005/06

Crop	Mean marketed share 1999/2000, %	Mean marketed share 2005/2006, %	Change
Maize	14	52	38
Simsim	10	41	31
Millet	4	29	25
Groundnut	10	27	17
Rice	55	71	16
Sorghum	6	18	12
Irish potato	2	13	11
Beans	9	16	7
Coffee	98	99	1
Cotton	98	99	1
Sweet potato	25	26	1
Matooke	44	32	-12
Cassava	61	23	-38

Source: Uganda Bureau of Statistics (UBOS); UNHS data 19999/00 and 2005/2006. Reports of agricultural module and researcher computations.

The World Bank reports the marketed proportion of total agricultural output to be 58 percent and the marketed proportion of total food crop production to be 46 percent. Given that the PMA baseline was estimated as 20 percent in 2002/03, the overall proportion of 46 percent represents an increase of 26 percentage points and makes the 2013/14 target of 70 percent appear attainable.

8. Institutional Factors Affecting Marketed Surplus

There are several initiatives that have contributed to improved agricultural marketing. The National Agricultural Advisory Services (NAADS) has linked some of its farmer groups to big buyers and processors: Tilda for rice, Nile Breweries for epuripur sorghum, and Mukwano for sunflower. The Kaweri outgrower scheme has been active in coffee and vegetable oil development in Kalangala, Lira and Bundibugyo. The Warehouse Receipt System (WRS) principles, designed to improve efficiency of agricultural contracts, are taking root. In 2005, WRS was piloted in cotton in the Kasese area and in coffee in the East and West. Farmers involved in WRS got a premium price of UShs 200/kg over and above daily market prices in the case of cotton, UShs 30-300/kg for coffee in East, and UShs 70-400 in the West. There has been a tremendous growth in farmers' organizations offering their members services in group marketing, advice and market information. There are currently 41 district farmers associations under the Uganda National Farmers Federation (UNFFE). NUCAFE has over 100 coffee associations, and before the Agricultural Productivity Enhancement Program (APEP) project closed in 2008, it supported over 250 commodity-based producer associations.

Marketing cooperatives are recovering after many years of neglect. There are an estimated 2,000 to 2,500 marketing cooperative societies in the country (Uganda Cooperative Alliance, 2009.). Area marketing cooperatives have also been established in several districts.

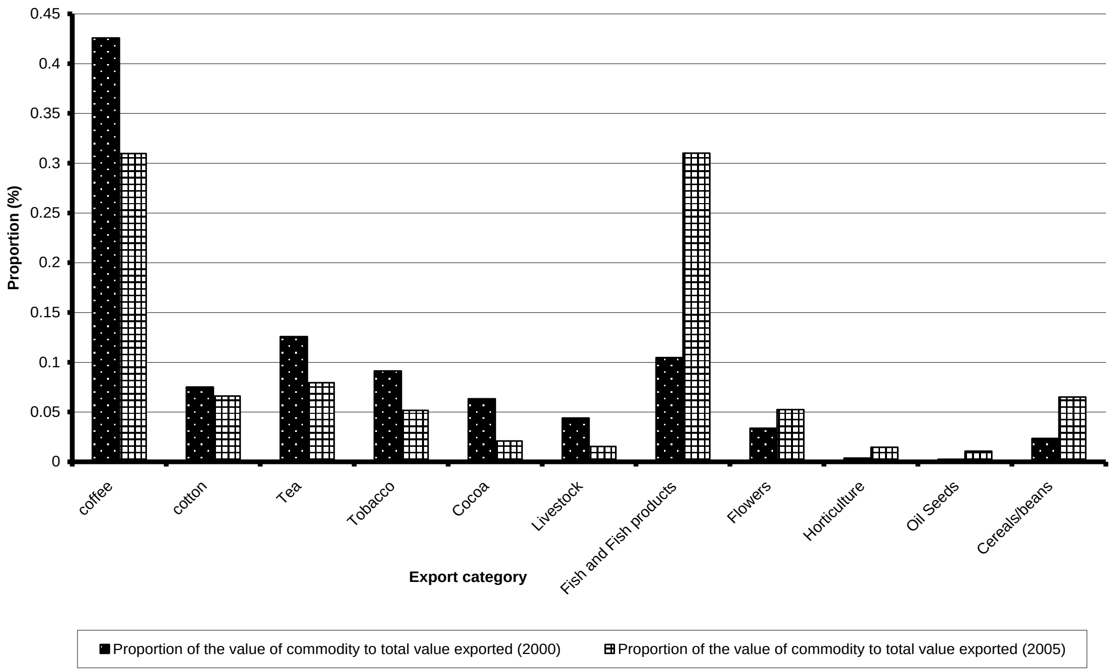
Agricultural market information is broadcasted to farmers on local FM radio stations and can be retrieved by text (SMS) messages on mobile phones. Some improvements have been made in the rural road network, increasing farmer access to markets in those areas. Regional markets for Ugandan products have expanded, especially in Southern Sudan and the eastern part of the

Democratic Republic of Congo. Uganda has also negotiated bilateral trade agreements with several countries, which has increased market access for Uganda's exports.

An evaluation of the NAADS program found that NAADS farmers have higher agricultural incomes than non-NAADS farmers (Benin et al., 2007). Agricultural incomes of NAADS farmers have increased since 2000, while incomes of non-NAADS farmers have declined since 2000. A similar trend is noted for crop and livestock productivity.

The structure of exports continued to shift over the period 2000-2005, as shown in Figure 6. Shares of traditional export crops, such as coffee, cotton, tea, tobacco and cocoa, have declined while shares of new export commodities have grown. This shift signals increasing diversification of agricultural commodity exports. Another dimension of export transformation is that some food crops previously grown solely for subsistence are increasing becoming commercialized as farmers sell a portion of their harvest. A number of previously minor commodities, such as fish and fish products, flowers, horticulture, oil seeds, cereals, and beans, now play an important role in the portfolio of Ugandan exports.

Figure 6—Changes in composition of major agricultural exports, 2000-2005.



The increased tendency towards diversification of exports of agricultural commodities indicates growing commercialization of agriculture in Uganda. However, given the recent decline in the real agricultural growth rate points, major challenges will have to be addressed if the volume, not just the share, of marketed surplus is to expand at a rate that exceeds or at least equals the population growth rate. These challenges, discussed earlier in this paper, include pests and diseases, decline in soil fertility, dependence on rainfall for production, and volatility of commodity prices.

9. Multivariate Analysis of Factors Affecting Crop Output per Acre

9.1 Model

An agricultural yield function was estimated to test hypotheses about sources of cross-sectional per-acre output differences among farms in Uganda (see Appendix). The analysis focuses on the role of variable farm inputs (labor, fertilizer, improved seed, agricultural chemicals), fixed farm inputs (agricultural assets, land), program inputs (agricultural extension, credit), household characteristics, and region. The explanatory variables included in the model are consistent with the neoclassical theory of the firm and with previous production function studies of African agriculture (Fan and Zhang 2008; Deininger and Castagnini 2006; Evenson and Mwabu 2001; Appleton and Balihuta 1996; Bigsten and Kayizzi-Mugerwa 1995; Thirtle et al. 1993). Our analysis avoids a well-known but seldom-corrected bias in cross-sectional studies (Mundlak 1961) arising from producer heterogeneity in management ability. This is accomplished by including an agricultural knowledge index in the model.[4,5]

The dependent variable is per-acre value of output of all crops aggregated using village prices.[6] Inputs are also expressed on a per-acre basis (Barrett et al. 2004). The model is estimated first for all farms combined and then for each of three farm size categories. We hypothesize that crop production technology varies by farm size. Support for this hypothesis was found using a Wald test on models estimated on subsamples of the data. Structural shifts in technology were identified at approximately two acres and 13 acres per farm. Thus, the sample was segmented into three farm size categories: small (less than two acres), medium (2-13 acres), and large (more than 13 acres).

A robust (Huber-White) estimator is used to estimate a double-log, extended Cobb-Douglas version of the yield function. The estimator corrects for potential heteroskedasticity and cluster-correlated errors.[7] The coefficients on the log-transformed inputs are output elasticities. The coefficients of the demographic, plot, and community variables are treated as part of the log-intercept term of the model and, therefore, not logged; in this form, the coefficients on these variables are semi-elasticities.[8,9]

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[4] The index is based on an agricultural knowledge quiz consisting of seven questions about crop agriculture. The index is the number of questions answered correctly by the survey respondent.

[5] Other control variables in the model include schooling (and its square), experience (and its square), gender, land quality (soil quality and slope), crop mix, and region.

[6] Similar to our specification, researchers estimating production functions for African agriculture often define output as the aggregate value of all crops ((Fan and Zhang 2008; Deininger and Castagnini 2006; Evenson and Mwabu 2001; Appleton and Balihuta 1996; Bigsten and Kayizzi-Mugerwa 1995; Pender et al. 2004; Deininger, Klaus and John Okidi 1999)). To facilitate summing output across crops of different types, researchers often convert physical quantity of output to value of output (price times quantity). Either national or village prices could be used in calculating value of output. Deininger and Castagnini (2006), in an agricultural production function study of Uganda, aggregated output using village prices. They repeated their analysis using national prices but report that the pattern of results did not differ.

[7] Because of potential correlation across households within enumeration areas (villages), we cluster-corrected the errors of the model.

[8] The demographic, plot, and community characteristics cannot readily be altered run by the farmer. These variables are not log-transformed because they are part of ln(A), the intercept shifter in the Cobb-Douglas production function, $\ln(y) = \ln(A) + \beta_x \ln(x) + \varepsilon$, where y is output per acre, and x is variable input per acre. A complete version of the model is shown in the appendix.

[9] Semi-elasticities can be converted to elasticities using the formula $\exp(\beta) - 1$.

9.2 Data

The Uganda National Household Survey (UNHS), the most frequently-updated source of detailed household information in Uganda, was the source of the data for the analysis. A total of 5200 farms representing all regions of the country are represented in the 2005/06 UNHS dataset.[10] Mean values of variables used in the analysis are shown in Table 14. Household characteristics are presented for the full sample and for small, mid-size, and large farms. The average household in the sample has six members, of which 2.5 are adults. Average farm size is 4.9 acres, ranging from an average of 1.0 acre for small farms to an average of 43.0 acres for large farms.

Table 14—Means of Farm Household Attributes in Uganda by Farm Size, 2005/061

Category	Full sample	Small Farms	Mid-size farms	Large farms
Dependent variable : Value of agricultural output (UShs)[2]	246,600	126,000	315,000	662,400
Demographic characteristics				
Household size	6.0	5.1	6.5	8.4
Number of adults	2.5	2.2	2.7	3.7
Number of children under 15	3.0	2.6	3.4	3.9
Percent of female headed households	25.9%	33.1%	20.3%	14.3%
Age of household head	44.0	42.3	45.1	48.6
Agricultural inputs				
Acres of land cultivated by household	4.9	1.0	4.8	43.0
Days of labor by household members	90.8	55.7	117.1	151.5
Days of labor by hired workers	14.0	5.3	18.0	55.2
Value of agricultural assets (UShs)[2]	18,000	9,000	18,000	95,400
Value of fertilizer applied (UShs)[2]	1044	342	1404	4140
Value of agricultural chemicals (UShs)[2]	1314	468	1800	4338
Percent land mulched	13.9%	13.3%	14.0%	17.1%
Percent land under improved seed	6.7%	6.1%	7.0%	9.6%
Farm and farmer characteristics				
Percent land good soil	42.1%	35.7%	46.0%	61.6%
Percent land steep	3.1%	3.4%	2.8%	2.4%
Percent of land devoted to cassava	12.8%	11.9%	13.5%	14.3%
Percent of land devoted to beans	8.1%	10.0%	6.8%	3.6%
Percent of land devoted to maize	17.2%	17.4%	17.1%	15.7%
Percent of land devoted to coffee	5.6%	4.5%	6.5%	5.5%
Percent of land devoted to banana	22.8%	25.1%	20.9%	19.7%
Distance from parcel to homestead (km)	1.5	1.2	1.6	2.7
Score on farmer knowledge quiz (out of 7)	3.4	3.3	3.5	3.8
Number of extension visits in past 12 months	0.22	0.11	0.24	0.92
Number of observations	5200	2373	2575	252

Source: UNHS 2005/06; means computed by authors.
[1]Farms categories: small (less than 2 acres), mid-size (2-13 acres), large (more than 13 acres).
[2]The average Ugandan shillings/US dollar exchange was approximately 1800.

[10] The 5200 farm households are a subset of the 9700 households in the 2005/06 UNHS dataset. Ten households were randomly selected from each of 750 enumeration areas (mostly villages).

9.3 Results

The estimated regression parameters of the agricultural yield model are shown in Table 15. All inputs except land have positive signs and most are statistically significant (α = 1%), indicating they increase per-acre output. The relationship between labor and output per acre is positive and statistically significant for all three farm-size categories (α = 1%).[11] This result holds for both household and hired labor. For household labor, output from an additional unit of labor is highest on medium-sized farms, next highest on small farms, and lowest on large farms. In contrast, hired labor has the greatest per-acre effect on output on large farms and the least effect on small farms.

Table 15—Estimated regression parameters for agricultural yield model – dependent variable: value of output per acre

Indicator	Full	Small	Medium	Large
Household labor per acre (log)	0.327***	0.309***	0.334***	0.266***
Hired labor per acre (log)	0.030***	0.027***	0.031***	0.048***
Fertilizer value per acre (log)	0.030***	0.042***	0.024***	0.038**
Chemical value per acre (log)	0.011***	0.006	0.013***	0.005
Land in improved seeds per acre (log)	0.014***	0.009	0.019**	0.018
Land size in acres (log)	-0.331***	-0.346***	-0.340***	-0.513***
Asset value per acre m(log)	0.012*	0.007	0.014	0.092**
Schooling of household head	0.117***	0.121***	0.105***	0.199**
Agricultural knowledge score of head	0.062***	0.045**	0.066***	0.113*
Number of extension visits	0.02	0.017	0.012	0.027
NAADS training	0.032	0.163*	-0.063	0.145
Off-farm income/100,000	0.000*	0.000	0.000	0.000
Credit available /100,000	0.004***	0.001	0.004**	0.005**
Percent of land good soil	0.118***	0.167***	0.073	0.006
Percent of land steep	0.227*	0.181	0.296**	-0.105
Percent of land mulched	0.215***	0.254***	0.191**	0.242
Age of household head	0.001	0.001	0.000	-0.003
Sex of household head (1 if female)	-0.051	-0.06	-0.047	0.167
Percent of land cassava	0.228***	0.371***	0.100	0.167
Percent of land beans	0.182**	0.218**	0.169*	-0.238
Percent of land maize	0.112*	0.105	0.095	0.284
Percent of land coffee	0.223**	0.357***	0.097	0.364
Percent of land banana	0.375***	0.451***	0.333***	0.221
Eastern	-0.068	-0.089	-0.047	-0.250
Northern	-0.653***	-0.780***	-0.538***	-0.752***
Western	0.211***	0.179**	0.233***	0.209
Constant	10.479***	10.542***	10.557***	10.487***
R-squared	0.471	0.381	0.385	0.63
N	5196	2373	2571	252

Fertilizer, which makes a positive and statistically significant contribution to productivity for all farm sizes, has its greatest marginal output effect on small farms (α = 1%).[12] Agricultural

[11] Appleton and Balihuta (1996) also found a positive and statistically significant relationship between land size and value of total agricultural output in Uganda. However, their dependent variable is output rather than output per acre and their data are from 1992-93.

[12] Fan and Zhang (2008) also find a positive relationship between the value of agricultural output and fertilizer in Uganda, though in their production function, their dependent variable is output per worker rather than output per acre.

chemicals and improved seeds are both positive and significant on medium-sized farms but not significant on small and large farms.[13] The use of improved seeds also has a positive and statistically significant effect on output per acre.[14]

Next, we examine the role of land and several kinds of capital: physical capital (agricultural assets), human capital (schooling and agricultural knowledge), financial capital (availability of credit and off-farm income), and natural capital (quality of slope and slope of land). The coefficient of cultivated land is negative and significant across all three farm sizes, indicating that as farm size increases within each category, output per acre declines ($\alpha = 1\%$). The drop in the conditional return to land is greatest on large farms. Many authors posit a negative relationship between land size and the value of output per acre because of rising managerial inefficiency and labor costs as size increases (Binswanger and Rosenzweig 1986). In the case of Uganda, our study is not the first to find a negative relationship between land size and output per acre (Deininger and Castagnini 2006; Appleton and Balihuta 1996).[15]

Physical capital (agricultural assets) has no effect on per-acre output on small and medium-sized farms, while on large farms, it has a positive and significant effect ($\alpha = 5\%$). In contrast, using Uganda data for 1992-93, Appleton and Balihuta (1996) found a positive relationship between agricultural assets and agricultural output though the marginal output contribution of assets declined as the volume of assets increased.

Schooling of the household head has a positive and statistically significant and on per-acre output on all three farm sizes ($\alpha = 1\%$). The greatest marginal effect of schooling occurs in the large farm category. Agricultural knowledge, measured using the score on a crop production quiz, is positive and statistically significant for all farm size categories. Similarly to schooling, the greatest impact of agricultural knowledge occurs on large farms. Appleton and Balihuta (1996) also found a positive and statistically significant relationship between schooling and value of total agricultural output in Uganda.[16]

The output effect of agricultural extension, measured by the number of visits per farm per year by an agricultural extension agent, is not statistically significant for any of the farm size categories. This finding is consistent with 15 out of 26 estimates of the effects of extension on agricultural output in developing countries reviewed by Birkhaeuser, Evenson, and Gershon Feder (1991).[17] On the other hand, participation by a member of the household in a NAADS

Pender et al. (2004), in a model of the value of aggregate agricultural output, found no evidence of a statistical relationship between fertilizer use and output.

[13] Deininger and Castagnini (2006) also found a positive relationship between agricultural chemical use and the value of aggregate output per acre in Uganda.

[14] We are aware of no previous studies that have examined the effect of improved seeds on agricultural output in Uganda. This variable is measured as the percent of cultivated acreage planted in improved seeds.

[15] Appleton and Balihuta (1996) estimated an aggregate agricultural production function for Uganda in which the defendant variable was output, rather than output per acre. Their model included variables for both land size and land size squared. The negative and statistically significant coefficient on land size squared is consistent with our finding of a negative relationship between land size and output per acre.

[16] The dependent variable in Appleton and Balihuta (1996) is value of total output, rather than output per acre, and their model was estimated using data from a different period (1992-93).

[17] Appleton and Balihuta (1996) found a positive and statistically significant relationship between extension and agricultural output in Uganda. However, their dependent variable was value of total agricultural output, rather than output per acre, and the extension variable measured availability in the village. To our knowledge, our estimates are

training in the village has a positive and statistically significant effect on small farms but not on medium-sized and large farms.

Availability of credit, measured as the respondent's estimate of the total value of loans that could be obtained if desired, has a positive and statistically significant effect on per-acre output of medium-sized but not on small farms and large farms.[18] Off-farm income, which in principle can be a source of financial capital to farmers is not significant for farms of any size, although it is positive and significant in the four-sample regression (α = 10 %).

Soil quality, measured by the percent of the farm that has good soil, has a positive and statistically significant effect on productivity for small and medium-sized farms but not for large farms. The percent of the farm that has sloped land is statistically significant but the sign is positive, the opposite of what was expected. Mulching, used to retain soil moisture and increase soil quality, has a positive and statistically significant effect on small and medium-sized farms but not on large farms.

Several other variables were included as controls. Age and gender are not statistically significant for any of the farm size categories. Crop mix variables are included in the regression to control for the effect of crops of differing yields and prices on total value of output. Dummy variables are included to control for systematic regional differences in output per acre.[19]

9.4 Discussion of results

On the basis of the regression results, we address policy-related "levers of productivity" that influence agricultural output in Uganda. All agricultural inputs besides land (labor, fertilizer, chemicals, improved seeds, and agricultural assets) have a positive and statistically significant impact on output per acre on farms in at least one of the three size categories. Schooling, agricultural know-how, and credit also have positive effects on per-acre output. Land is the exception among inputs: the finding that expanding cultivated acreage is associated with a decline in output per acre is robust across a large number of model specifications with which we experimented during the analysis. Clearly, Uganda's food security problems cannot be solved at the "extensive margin," but must be addressed by greater use of modern inputs and technology.

Increasing agricultural output per acre requires a broad spectrum of investments targeted at farms of all sizes. However, at the margin, if fertilizer is available in limited supply, our results suggest that output is expanded most when fertilizer goes to small farms. Agricultural chemicals and improved seeds are most effective on medium-sized farms. Schooling and agricultural know-how have their greatest impact on large farms.

Evidence of the effects of agricultural extension (NAADS) and credit availability on per-acre output is weak. It should be noted, however, that definitive conclusions cannot be drawn about

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the first to examine the relationship between actual number of extension visits per farm and output per acre in Uganda.

[18] Deininger and Castagnini (2006), using a different credit variable, find village-level credit availability has no effect on agricultural output per acre. Our analysis appears to be the first study of Ugandan agriculture that specifies the credit variable at the household level. In a model of output, rather than output per acre, household-level credit availability could be endogenous if large farms have greater access to credit than small farms. In our model, however, this problem is avoided since our dependent variable is output per acre. On a per-acre basis, output is not expected to be a driver of credit availability since output per acre declines as farm size increases.

[19] The Central Region is the default region.

the effects of extension. The traditional agriculture extension system and NAADS were both in transition during the study period (2005-06), and therefore definitive conclusions on the effects of on-farm extension visits and village NAADS training cannot be drawn. The finding that rural credit has a relatively small impact on agriculture is not surprising given the limited reach of finance into the agricultural economy of Uganda (Jones 2006).

10. Conclusion

Land area cultivated in Uganda has increased more rapidly than agricultural output over the period 1999-2006, implying a decrease in land productivity. The technology employed in agriculture remains rudimentary and there is relatively little use of modern inputs. Output per acre could be increased through greater use of fertilizer, agricultural assets, agricultural chemicals, improved seeds, credit, and extension services. Each of these inputs plays an effective role in land productivity in at least one farm size category. Fertilizer stands out for its positive and statistically significant effect on productivity across all farm sizes. An important task of agricultural policy is to remove the impediments that prevent greater use of modern inputs.

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Appendix 1–Agricultural Yield Function

We begin with a Cobb-Douglas production function, defined in equation (1) in terms of total output per farm. The intercept term is then defined in equation (2) to account for demographics, plot characteristics, participation in extension activities, and region. Equation (2) is then substituted into equation (1), and output and variable inputs are divided by area cultivated. This gives us equation (3), the yield function, the equation estimated in the paper.

Equation 1—Production function for ith farm:

$$\ln(Y_i) = \ln(A_i) + \beta_1\ln(D_i) + \beta_2\ln(DSQ_i) + \beta_3\ln(T_i) + \beta_4\ln(LH_i) + \beta_5\ln(LF_i) + \beta_6\ln(F_i) + \beta_7\ln(C_i) + \beta_8\ln(S_i) + \varepsilon_i \quad (1)$$

Y = total value of output

A = intercept shifter representing technology, demographics, plot characteristics, participation in extension, and region

D = area cultivated

DSQ = square of area cultivated

T = agricultural asset value

LH = days of household labor

LF = days of hired labor

F = value of fertilizer

C = value of agricultural chemicals

S = percentage of land under improved seeds

Equation 2—Intercept shifter defined:

$$\ln(A_i) = \gamma_0 + \gamma_1 EXT + \gamma_2 NAT_i + \gamma_3 R_i + \gamma_4 I_i + \gamma_5 AGE_i + \gamma_6 AGESQ_i + \gamma_7 SC_i + \gamma_8 SCSQ_i + \gamma_9 G_i + \gamma_{10} Q_i + \gamma_{11} PLG_i + \gamma_{12} PLS_i + \gamma_{13} PLM_i + \gamma_{14} PLC_i + \gamma_{15} PLB_i + \gamma_{16} PLMA_i + \gamma_{17} PLBE_i + \gamma_{18} PLCO_i + \gamma_{19} E_i + \gamma_{20} N_i + \gamma_{21} W_i + \mu_i \quad (2)$$

γ_0 = intercept shifter representing technology

EXT = number of extension visits

NAT = participation in NAADS training

R = availability of credit

I = off-farm income

AGE = age of head of household

AGESQ = square of age of head of household

SC = head's years of schooling

SCSQ = square of head's years of schooling

G = head's gender

Q = head's agricultural quiz score

PLG = percentage of land with good soil

PLS = percentage of land steep

PLM = percentage of land under mulch

PLC = percentage of land cassava

PLB = percentage of land beans

PLMA = percentage of land maize

PLBE = percentage of land bananas

PLCO = percentage of land coffee

E = Eastern region

N = Northern region

W = Western region

Equation 3—Yield function (re-arranged to farmer-controlled inputs first):

$$\ln(Y_i/D_i) = \gamma_o' + \beta_1\ln(D_i) + \beta_2\ln(T_i/D_i) + \beta_3\ln(LH_i/D_i) + \beta_4\ln(LF_i/D_i) + \beta_5\ln(F_i/D_i) + \beta_6\ln(C_i/D_i) + \beta_7\ln(S_i/D_i) + \gamma_1 EXT + \gamma_2 NAT_i + \gamma_3 R_i + \gamma_4 I_i + \gamma_5 AGE_i + \gamma_6 AGESQ_i + \gamma_7 SC_i + \gamma_8 SCSQ_i + \gamma_9 G_i + \gamma_{10} Q_i + \gamma_{11} PLG_i + \gamma_{12} PLS_i + \gamma_{13} PLM_i + \gamma_{14} PLC_i + \gamma_{15} PLB_i + \gamma_{16} PLMA_i + \gamma_{17} PLBE_i + \gamma_{18} PLCO_i + \gamma_{19} E_i + \gamma_{20} N_i + \gamma_{21} W_i + \varepsilon_i \quad (3)$$

In the final estimated version of the model, variables representing the square of age and schooling were dropped since they were statistically insignificant.