

# Increasing Scarcity of Land and Intensification of Farming Systems: the Evidence of Dairy-Banana Integration in Uganda

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## **Abstract**

In this paper, we focus a mixed farming system of intensive-dairy and crop production. The intensive-dairy and crop farming system provides manure, taken from stalls of improved dairy cattle, to crops such as banana. By using panel data of 894 rural households in 2003 and 2005 in Uganda, we find the number of improved cattle per ha increases the organic fertilizer application per ha at least by 170 kilograms in. The organic fertilizer use increases banana yield by about 5 percent, when the organic fertilizer application increases by one ton per ha, although this estimate could be downward biased because of the attenuation bias from the poor quality of organic fertilizer application in quantity and quality. The integration of dairy and banana production is suitable in Uganda where soil degradation is concerned.

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## 1. Introduction

There is a re-emerging effort to realize African Green Revolution. In 2006, for instance, the Rockefeller and Gates foundations created Alliance for a Green Revolution in Africa, which is now headed by former U.N. Secretary General Kofi Annan (<http://www.agra-alliance.org>). Because of heterogeneous environments and the lack of a dominant cereal crop in Sub-Saharan Africa (hereafter Africa), however, there is a lack of an agreement among researchers and policy makers on how to realize the African Green Revolution (Holmen, 2005). Although it might be possible to transfer the high-input Green Revolution technology to limited favor areas in Africa, different types of technology are needed for heterogeneous environments and multiple staple crops in most parts of Africa (ICRISAT, 2001).

When factor prices of some inputs are relatively expensive, a technology that depends less on those inputs has a potential to emerge as an alternative and more appropriate technology (Hayami and Ruttan, 1985). A particular technology that we focus on in this paper is a mixed farming system of intensive-dairy and crop farming system, which is adopted by some farmers in East African highlands (Otsuka and Yamano, 2005). This farming system is based on the use of manure generated from improved dairy cattle, i.e., cross breeds of European and local cattle, which are often raised in stalls. This is an appropriate technology in the East African highlands where irrigated water is not available and chemical fertilizer is expensive. Soil scientists have studied this and other crop-livestock farming systems in the past. For instance, Rufino et al. (2006) summarizes studies on the nitrogen recycling under different crop-livestock farming systems in Africa and argue that the nitrogen efficiency could be improved significantly by improving farm managements at various steps starting from

livestock feeding to crop harvesting. Although there have been some economic studies on crop-livestock farming systems in the past (e.g., McIntire, Bourzat, and Pingali, 1992), none of the previous studies has identified the causal impacts of adopting the intensive dairy-crop farming system on crop production at the micro-level by using panel data.

The purpose of this study, therefore, is to identify the causal impacts of adopting the intensive-dairy and crop farming system on the organic fertilizer use and banana yield in Uganda by using panel data of 894 rural households. Banana is the most important staple crop in Uganda as well as some parts of Central Africa but has been neglected by the international research organizations. Manure is often used to create a seedbed before planting banana and to mulch banana roots after planting. Because manure or compost releases nitrogen over time during a long growing season of banana and keeps moisture, the use of manure on banana provides nutrients to soil that has been concerned for degradation in Uganda (Giller, et al., 2006).

In this paper, we find that improved cattle are adopted more in communities where there is no or small communal grazing land. It seems that Ugandan farmers are sifting from grazing to zero-grazing and from local to improved cattle because of the increasing land scarcity. According to the plot fixed effects model, the number of improved cattle per ha increases the organic fertilizer application per ha at least by 243 kilograms in South-Western region and 87 kilograms in the other regions. The organic fertilizer use increases banana yield by about 20 and 30 percent in South-Western and the other regions, respectively, when the organic fertilizer application increases by one ton per ha. The adoption of improved cattle and integrating the dairy and banana production, therefore, seems to be a promising farming system to intensify the

agricultural production.

The outline of the paper is as follows: the next section describes the dairy-banana farming system. Section 3 introduces the panel data used in this paper. We explain the estimation models and variables in Section 4, which is followed by conclusions in Section 5.

## 2. Intensification of Agriculture in Uganda

The need for agricultural intensification is growing rapidly in Uganda. Uganda has one of the highest population growth rates in the world. The population of Uganda has been increasing at an annual rate of three percent, or higher, since the 1960s. Because of the high population growth and the slow population movement from rural to urban areas, the arable land per person has decreased from 0.6 ha per person in the 1960s to 0.3 ha per person in the 2000s. The current level of arable land per person is comparable to that of South-East Asian countries. The land productivity in Uganda, however, stays well below the land productivity in South-East Asian countries which enjoy high land productivity largely due to the Asian Green Revolution. Thus, Ugandan farmers have a strong need to intensify their agricultural production, but the most of them do not have access to irrigated water nor do they apply chemical fertilizer because of high prices of chemical fertilizer. In many places, chemical fertilizer is simply not available in the markets. Uganda has also received less benefits from international agricultural research than other African countries because its main staple crop is banana, which has been neglected by the international agricultural research organization compared with other major crops such as rice and maize. Instead, the

selection of banana varieties has been carried out by local farmers in the past (Gabre-Madhin and Haggblade, 2004).

Under these conditions, some of successful Ugandan farmers have adopted a farming system that integrates dairy and crop productions. In this farming system, a farmer adopts improved dairy cattle that are cross-breeds of European and African cattle. Typically, the cross-bred dairy cattle are kept in stalls all day or at least at nights. While the cattle are kept in the stalls, they drop manure and urine in the stalls. The manure and urine in the stalls could be easily collected and applied on banana and other crops. Figure 1 depicts the typical farming system. Note that stall-feeding of cattle with cultivated feeds does not enhance the total amount of soil nutrients in the entire farming system (Buresh 1999). In fact, the total amount of nutrients will likely decline because of the export of nutrients from the plant-soil-animal system through harvested products and milk. Such a system, however, enhances the internal cycling of nutrients, and the efficiency depends on farm managements at various steps starting from feeding animals to crop (Rufino et al., 2006). For instance, although manure should be fermented for a few months before being applied as compost on crops, many Ugandan farmers who apply manure on crops apply it without fully fermented. According to our surveys in Uganda, described in the next section, farmers indicate that, more than 80 percent of cases where manure is applied on crops, they apply it without fully developing it into compost. This suggests that there is a large potential for public intervention through extension services and crop breeding which is more responsive to organic fertilizer instead of chemical fertilizer.

Important questions we ask in this paper are: (1) how much does the adoption of this farming system increase the organic fertilizer application on banana plots? (2)

How much does the organic fertilizer application increase the banana yield?<sup>1</sup> An evaluation of a technology adoption, however, is not easy because adopters could have higher yields and income than non-adopters even before adopting the intensive-dairy and crop farming system. Thus, a simple comparison of adopters and non-adopters could be biased. Thus, in the following sections, we employ panel data of 894 households in rural Uganda and try to isolate the impacts of the adoption of improved dairy cattle. But, first, we explain the panel data in the next section.

### 3. Data and sample households

The data used in this article come from 940 and 894 households in rural Uganda surveyed in 2003 and 2005 respectively as part of the Research on Poverty, Environment, and Agricultural Technology (REPEAT) project, which was conducted by Makerere University, Foundation for Advanced Studies on International Development, and National Graduate Institute for Policy Studies (Yamano et al. 2004). The survey was conducted in August-October 2003 and August-October 2005, and the sample for the REPEAT project largely builds upon and complements a completed research project on policies for improved land management in Uganda, conducted by the International Food Policy Institute (IFPRI) and Makerere University between 1999 and 2001 (Pender et al. 2001).

Table 1 shows the distributions of the 894 households, which were interviewed twice in our surveys, by four regions. On average, the proportion of the sample households who own improved cattle increased from 10 percent to 12.6 percent over the

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<sup>1</sup> We have not completed but are planning to conduct a profitability analysis,

survey periods. In South-Western region, the proportion has almost doubled, from 10 percent in 2003 to 19 percent in 2005. South-Western region of Uganda is an important part of the milk shed because of its favorable environment for dairy production and a good access to Kampala, the capital city of Uganda. The recent liberalization of the milk market in Uganda seems to have encouraged milk production in this region. In the other regions, the proportions of households who own improved cattle remain at the same level from 2003 to 2005. In South-Western region, the organic fertilizer application on banana plots has also more than doubled, from 158 kilograms per ha in 2003 to 375 kilograms per ha in 2005, while it remains about the same in the other regions over the same period.

The majority of banana produced in Uganda is so called cooking banana, or plantain, which is mainly used as a staple food crop. There are two more varieties in Uganda: brewing and desert banana. These varieties are high-value but have lower yields than cooking banana. Although there are so called high-yielding banana varieties, farmers are often not sure about their banana varieties. According to our surveys, the respondents replied that about 35 percent of banana plots are planted with high-yielding banana. However, we do not find any difference in yield between local and high-yielding varieties. Thus, in this paper, we do not distinguish high-yielding varieties from local ones. The banana yield is very high in South-Western region. The average banana yield is about 7.0 tons per ha in this region. In the other regions, the banana yield is less than 2 to 3 tons per ha, which is drastically different from it in South- Western region. South-Western regions are located closer to Rwanda and in high lands. The five average annual rainfall is about 995 mm, and the average altitude is 1,638 m. The climate is suitable to banana production.

Along with the 2003 survey, we have conducted soil sampling and measured soil contents. We have collected soil samples from one annual crop plot cultivated by sampled household in the first cropping season of 2003. Where the household produced none of annual crop, an alternative plot was selected for soil sampling. The total number of soil samples is 632 from 632 households. Soil samples collected from the 0-20cm depth were air-dried and ground to pass a 2 mm sieve and analyzed for pH, Organic Matter (OM), texture, extractable P, K, and Ca according to Foster (1971) methodology. Extractable P, K, and Ca were measured in a single ammonium lactate/acetic acid extract buffered at pH 3.8. Soil pH was measured using a soil to water ration of 1:2.5. The results on soil contents are presented in Table 2.

Note that because we collected the soil samples at the 2003 survey, the soil contents may reflect farming practices in the prior cropping seasons that are asked about in the survey. Thus, the soil contents should not be treated as exogenous variables, although much of soil contents do not change significantly in the short-term. Note also that we did not collect soil samples during the 2005 survey because of a budget constraint. Thus, in this paper, we treat the soil contents as exogenous precondition variables to the crop productions asked in the 2005 survey, as we discuss more in detail in the following sections.

In Table 2, we find that the soils in Western and South-Western regions are richer in organic matter (column B) than the other two regions. Regarding to soil structure, we find it is less clay in Western and South-Western regions (column G) also. To examine relationships between the banana yield and soil contents, we have conducted some non-parametric analyses and find a strong correlation between the banana yield and organic matter (Figure 2). Figure 2 shows the results from locally

weighted regression models for 2003 and 2005 surveys separately. Because we collected only one soil sample from one plot, which may not be planted banana, per household in 2003, we match the organic matter with banana yields in 2003 and 2005 at the household level, assuming that the soil contents are similar among plots cultivated by the same household.

To further investigate the relationship between the adoption of improved cattle and organic fertilizer application, we stratify the samples into four groups based on the adoption of the improved cattle over time (Table 3). The first is the group of the households who did not own improved cattle both in 2003 and 2005 (we call this group as No-No). The second is the group of households who owned improved cattle in 2003 but not in 2005 (Yes-No). The third is the group of households who did not own improved cattle in 2003 but own at least one of them in 2005 (No-Yes). The last group is the group of households who owned improved cattle both in 2003 and 2005 (Yes-Yes).

The No-Yes group provides us the before-after comparison of the adoption of improved cattle over time. The organic fertilizer application of the No-Yes group has increased from 125 kilograms per ha to 436 kilograms per ha, an increase of 311 kilograms per ha. Because the No-No group in the same region increases the organic fertilizer application by 237 kilogram per ha, from 259 to 497 kilograms per ha, the difference-in-difference estimator of the adoption of improved cattle is about 73.6 kilograms per ha. A simple t-test finds that the DID estimator is statistically significantly different from zero. Thus, the net impact of adopting the improved cattle on the organic fertilizer is about 74 kilograms per ha on banana plots. Therefore, it seems that the adoption of the improved cattle has a positive impact on the organic

fertilizer application on banana plots.

The descriptive analyses in Table 2 and 3 and Figure 2 seem to suggest that (1) the adoption of improved cattle increases the organic fertilizer application and (2) the organic matter in soil has a positive correlation with the banana yield. But, there remains a possibility that these two positive relationships are only reflecting associations, not causality. For instance, the organic fertilizer application could be driven by other factors such as soil fertility or cultural practices, than the adoption of improved cattle, or the banana yield could be high in South-Western regions, not because of high organic matter contents, but because of other factors in the region. Thus, in the next section, we discuss our estimation approaches and limitations in identifying causal effects of (1) the adoption of improved cattle on the organic fertilizer use and (2) the organic fertilizer application on banana yield, while controlling for the initial organic matter in the soil.

#### 4. Estimation models and Variables

##### 4.1. Estimation models

We start this sub-section with the regression analysis of the determinants of the adoption of improved cattle. Improved cattle are more expensive than local cattle. For instance, an improved cow costs about \$200 per head, while a local cow costs about \$80 per head. An improved heifer is also much more expensive than a local heifer. Thus, wealthier households are more likely to adopt the improved cattle. The need to adopt improved cattle is high in areas where there is little grazing land. Historically,

cattle are grazed on communal grazing lands in Uganda. Although there remain some areas where they still graze their cattle, the communal grazing land is probably diminishing because of declining availability of land. In our 2003 survey, we have asked the availability of communal grazing land per household at the community level. Out of the 94 communities, 50 communities replied that there is no communal land for grazing.<sup>2</sup> Even among the 44 communities where there is some communal land, the median size of the communal land is about 0.2 ha per household. Thus, we expect that the adoption of improved cattle and the size of communal land have a negative relationship. By the same argument, we also expect that the population pressure has a positive relationship with the adoption of improved cattle. To test these hypotheses and estimate determinants of the number of improved cattle owned, we estimate the following models:

$$N_{hct} = X_{hct}\beta_X + e_{hct} \quad (\text{Tobit}) \quad (1)$$

where  $N_{hct}$  is the number improved cattle owned by household  $h$  in community  $c$  at time  $t$ ;  $X_{hct}$  is a set of household and community characteristics; and  $e_{hct}$  is the error term. The household characteristics include variables that represent the household wealth and labor availability, and the community characteristics include the availability of the communal land at the community level. We describe all variables in the next sub-section. For comparisons, we also estimate the same model for local cattle. Because local cattle are mainly grazed, we expect that the availability of grazing land

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<sup>2</sup> We define communal land as any land that local people have open access. Among 94 communities in our samples, there are 82 patches of communal land. Out of them, 62 patches are communal grazing or pasture land, 14 are private land but open to public, and the rests are bushes and natural forests. Among the 62 patches of communal grazing land or pasture land, only 5 patches have any use restrictions, while 6 patches of the 14 privately own land have restrictions.

and the population pressure have the opposite signs on the local cattle than the improved cattle.

Next, we estimate the impacts of the number of improved cattle owned per ha of the total farm size on the organic fertilizer application. We estimate the application of the organic fertilizer use at the plot level. A household may have multiple banana plots, which have different plot characteristics. We expect that a plot which is farther away from the homestead receive less organic fertilizer than ones near the homestead because the organic fertilizer is bulky and heavy. Thus, we control for observed plot characteristics, such as the distance from the homestead to the plot and the size of the plot:

$$Y_{phct} = \beta_N N_{hct} + P_{phct} \beta_P + X_{hct} \beta_X + u_{phc} + e_{phct} \text{ (Tobit)} \quad (2)$$

where  $Y_{phct}$  is the amount of organic fertilizer applied on plot  $p$  of household  $h$  in community  $c$  at time  $t$ ;  $P_{phct}$  is a set of plot characteristics; and  $u_{phc}$  is the unobserved fixed plot effects. The rest of the variables are as defined before.

Our main concern is the correlation between the independent variables and the omitted variables. Especially, the number of the improved cattle and the organic fertilizer application could be both correlated with the unobserved plot characteristics,  $u_{phc}$ . Soil fertility is usually a typical example of the unobserved plot characteristics. If farmers apply more organic fertilizer on plots that are lacking the organic matter, then the estimated impact of the organic fertilizer on the banana yield would be biased downward. Fortunately for this study, we have data from soil samples in 2003. Thus, we include the soil fertility into the model:

$$Y_{phct} = \beta_N N_{hct} + S_{hct} \beta_S + P_{phct} \beta_P + X_{hct} \beta_X + u_{phc} + e_{phct} \text{ (Tobit)} \quad (3)$$

where  $S_{hct}$  is a set of soil nutrient and structure variables of household  $h$  in community  $c$  at time  $t$ . The rest of the variables are as defined before. Because the soil samples are taken during the 2003 survey, the soil nutrient and structure may reflect the organic fertilizer application and production of the 2002 to 2003 cropping seasons. Thus, first, we include the soil nutrient and structure variables for the estimation of the organic fertilizer application in the 2004 to 2005 cropping seasons and, second, in the pooled data.

Even after controlling for the initial soil fertility, there could be other omitted variables that could create biases. Such biases could be eliminated at least partly by using the instrumental variables model, the least square fixed effect models, or a combination of both. The lack of plausible identification variables, however, makes it difficult to use the instrumental variables model. As long as panel data are available, one can apply the fixed effects model. A major problem of applying the least square fixed effects model is that the amount of organic fertilizer application per ha is censored at zero and the least square fixed effects model would be biased by the censoring. Thus, in this paper, we simply compare the OLS estimators from pooled data, including soil fertility variables, with the fixed effects estimators at the plot level to see if the estimated coefficients differ between the two models. If the results are different between the two models, then there are other omitted variables, other than the soil fertility, that create biases.

Finally, we estimate the banana yield model as follows:

$$Z_{phct} = \beta_Y Y_{phct} + S_{hct} \beta_S + P_{phct} \beta_P + X_{hct} \beta_X + e_{phct} \quad (5)$$

where  $Y_{phct}$  is the banana yield, tons per ha; and the rest of the variables are as defined before. In this model, we are also concerned about the potential correlation between the omitted variables and the independent variables, especially the amount of organic fertilizer application. By following the same argument for the previous model on the organic fertilizer application, we estimate the equation (4) with the 2005 data with and without the soil fertility data and estimate it with the plot random and fixed effect models.

At the end, what is the impact of the adoption of the improved cattle on the banana yield? We calculate this impact by using the two estimated coefficients from the equations (3) and (5):

$$\Delta Z_{phct} = \hat{\beta}_Y \Delta Y_{phct} = \hat{\beta}_Y \hat{\beta}_N \Delta N_{hct}. \quad (6)$$

We calculate this total impact after estimating the estimation models.

## 4.2 Variables

Let us start describing the dependent variables. The first dependent variable is the number of improved cattle owned by the household. The number of improved cattle includes all types of cattle, such as calves, heifers, cows, and bulls. We just simply count numbers of cattle and do not distinguish types. Although this may overestimate the presence of calves and heifers because they produce less manure than cows and bulls, we simply count calves and heifers equally as cows and bulls because

we do not know the age or weight of each cattle.<sup>3</sup> In addition, we also use the number of local cattle owned as another dependent variable to compare the results with the ones on improved cattle.

The second dependent variable is the amount of organic fertilizer, tons per ha, applied on the banana plot. This measure the total amount applied over one cropping season. Although we have asked separately for animal manure in dry form, wet form, and compost in the surveys, we simply combine them together. Note, however, that it is quite difficult to know how farmers prepare manure before applying. The quality of manure and compost, therefore, could be widely different from one farmer to another. Such measurement errors in the quality of the manure will generate a bias toward zero, an attenuation bias, when the amount of the manure is used as an independent variable. Thus, if we find a significant coefficient, we should note that it is a conservative estimate and the unbiased estimator could be larger in magnitude.

The third dependent variable is the banana yield, tons per ha. This is also a difficult variable to measure. To estimate the banana production, respondents are asked to answer how many banana-bunches are harvested over a cropping season and the average weight of the harvested bunches. By multiplying the number of bunches with the average weight, we obtain the total quantity of banana harvested over a cropping season, and, by dividing it with the banana plot size in ha, we obtain the banana yield. In this paper, we only focus on cooking banana and exclude brewing and desert banana because cooking banana is the dominant variety, which occupies

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<sup>3</sup> This makes the impact of the number of cattle on the organic fertilizer application underestimated if we consider the number cattle as the number of cows and bulls. In this paper, we should consider the impact of the number of cattle as the impact of any cattle. We may employ a scaling unit to convert the number of any cattle into the number of cows or bulls.

more than 90 percent of banana plots.

The independent variables include three sets of variables: plot, household, and community characteristics. The plot characteristics include the plot size in ha in logs, the walking time from the homestead to the plot, its squared term, and a dummy variable for rented-in plots. The second set of independent variables is the household characteristics, which include the number of men, the number of women, the number of boys, and the number of girls in the household. These variables are expected to measure the labor availability in the household. The household characteristics also include the education level and age of the household head, a dummy variable for female headed households, the owned land size in ha, and the value of assets, which include farm equipments and furniture. The asset variable does not include land because we control for the land size separately.

The community characteristics include some important variables. The size of the communal grazing land per household in the community is asked in our community surveys. Out of the 94 communities, 50 communities have no communal grazing land. Among the 44 communities that have some communal grazing land, the median size of the communal grazing land per household is 0.2 ha per household. Thus, it is clear that, even in the communities with the communal grazing land, the availability of the grazing land is small. A related variable is the population density measured at the district level. This variable measures the availability of labor and the demand for consumption goods, such as milk.

## 5. Results

### *Adoption of Improved and Local Cattle*

The results in Table 4 indicate that the availability of communal grazing land has a strong negative impact on the number of improved cattle, while it does not have any impacts on the number of local cattle. This is consistent with our expectation that improved cattle are more adopted in areas with no or little grazing land. Because improved cattle are more than twice expensive than local cattle, it is expected that the asset value has a larger positive impact on the number of improved cattle owned than the number of local cattle. The results indicate that the asset value has a strong impact on the improved cattle ownership, while it has only a small impact on local cattle ownership.

### *Determinants of Organic Fertilizer Application*

The results from the Tobit models of the 2005 data indicate that the estimate impact of the number of improved cattle per ha on the organic fertilizer application on banana was slightly overestimated, at 185 kgs per ha, when the soil fertility variables are not included (column A). After including the soil fertility variables, the size of the impact becomes 170 kgs per ha. But the size of the bias is not large. To examine if this is still biased cause by other omitted variables, we compare results from the Random and Fixed effects models in columns C and D. The results suggest that the Random effect estimator is under-biased even when soil fertility variables are included. Thus, this result suggests that the estimated coefficient of the number of improved cattle is still possibly under-biased. Thus, we should interpret that the result in column B is a conservative estimator, suggesting the lower bound.

In contrast, we do not find any impacts from the number of local cattle on the organic fertilizer application. Because local cattle are mainly grazed in open fields, it is difficult to collect manure from them. This may be the reason for this finding.

### *Banana Yield Model*

Finally, we present the results on banana yield in Table 6. The results of the Fixed Effects model indicate that the organic fertilizer application has a strong impact on banana yield. According to the results, the banana yield increases by about 5.4 per cent when the organic fertilizer application increases by 1 tons per ha. The results are robust against inclusion of the soil fertility variables. The comparison of the Random and Fixed Effects models indicate that the results in the Random effect model are slightly biased downward.

## 6. Conclusion

In this paper we examine a mixed farming system of intensive-dairy and crop farming system in Uganda by using panel data in 2003 and 2005. This farming system is based on the use of manure generated from improved dairy cattle and is appropriate in the East African highlands where irrigated water is mostly not available and chemical fertilizer is expensive. We find that improved cattle are adopted more in communities where there is no or only limited communal grazing land. It seems that Ugandan farmers are sifting from grazing to zero-grazing and from local to improved cattle because of the increasing land scarcity. The results indicate that the number of

improved cattle per ha increases the organic fertilizer application by 179 kilograms per ha. The results also suggest that this is a conservative estimator and the true impact could be larger. An additional organic fertilizer by 1 ton per ha increases banana yield by about 6 percent. Note that this also is a conservative estimate because the attenuation biases caused by the poor quality data of the organic fertilizer application, both in quantity and quality, would bias the impact of the organic fertilizer application on the banana yield toward zero.

Although the impacts of the number of improved cattle per ha on the banana yield may seem small, there are several reasons to support this farming system. First, the results in this paper are conservative estimates and the real impacts could be much larger. Second, the intensive-dairy and banana farming system increases the organic fertilizer application in a country where most farmers do not apply any fertilizer. Thus, in the long-run, the organic fertilizer use helps farmers to maintain the banana yield. The long-run effects are not measured in this paper but could be more important than the short-run impact. Third, the intensive-dairy and banana farming system help farmers to diversify their income and be less vulnerable against natural and economic shocks. Forth, and finally, the system has a large room for improvements. According to our surveys, more than 80 percent of cases, farmers apply manure without fully developing it into compost. The benefits of the organic fertilizer and how to handle it is still new information to many farmers in Uganda. This suggests that there is a large potential for public intervention through extension services and crop breeding which is more responsive to organic fertilizer instead of chemical fertilizer. Although banana is a major crop in Uganda and other central African countries, the number of studies is relatively small compare with other major crops such as maize. Thus, there is a need

to further investigate how to intensify the banana production. The organic fertilizer application is a main component, and an intensified dairy production seems the best way to increase the organic fertilizer application in Uganda.

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Table 1. Cattle Ownership, Organic Fertilizer Use, and Banana Yield in Uganda

	Number of House- holds	Improved Cattle Ownership		Organic Fertilizer Application on Banana Fields		Cooking Banana Yield		Annual rainfall	altitude
		2003	2005	2003	2005	2003	2005		
		(A)	(B)	(C)	(D)	(E)	(F)		
	#	%	kgs/ha		tons/ha		mm	m	
East	394	7.9	10.2	112	88	2.2	1.8	1,375	1,273
Central	278	12.6	12.9	112	174	2.1	2.6	1,157	1,219
West	38	10.5	5.3	53	78	3.8	3.6	879	1,431
S-West	184	10.3	19.0	159	448	7.0	7.1	995	1,638
Total	894	10.0	12.6	120	202	2.8	2.9	1,208	1,339

Table 2. Soil Fertility Data in 2003

	Number of soil samples	Organic Matter	K	Ca	P	Ph	Clay
	(A)	(B)	(C)	(D)	(E)	(F)	(G)
		%	Cmolc/kg		Mg/kg		%
East	340	4.18	1.06	4.36	63.6	6.40	30.8
Central	160	4.81	0.73	3.49	50.2	6.27	30.8
West	39	7.56	0.96	4.82	248.4	6.02	20.6
S-West	93	6.43	1.02	3.04	45.3	5.83	25.7
Total	632	4.89	0.97	3.98	69.7	6.26	29.4

Table 3. Organic Fertilizer Application on Banana by Improved Cattle Ownership

Ownership of Improved Cattle in 2003 and 2005	Number of Banana Plots		Organic Fertilizer Application per ha		
	2003	2005	2003	2005	Dif.
				kgs/ha	
Neither year	1,369	1,516	88.9	104.3	-15.4
Only in 2003	91	81	193.3	155.3	-38.0*
Only in 2005	149	169	124.6	435.6	+311.0**
Both years	178	183	259.2	496.6	+237.4**
	1,788	1,949	114.2	172.0	+57.8*

Note: \* and \*\* indicate the 5 and 1 percent significance level, respectively.

Table 4. Determinants of Improved and Local Cattle Holdings per Ha at the Household Level (Pooled – Tobit Model)

	Improved Cattle (A)	Local Cattle (B)
<i>Household Characteristics</i>		
HH Head's Education	0.013 (0.26)	-0.169 (3.13)**
HH Head's Age	0.024 (1.63)	0.029 (2.02)*
Number of men	0.464 (3.48)**	0.209 (1.43)
Number of boys	0.054 (0.47)	0.286 (2.36)*
Number of women	-0.089 (0.63)	0.075 (0.48)
Number of girls	0.001 (0.01)	0.107 (0.87)
Female head (=1)	-1.589 (2.29)*	0.150 (0.24)
Land Size	0.099 (1.49)	-0.061 (1.34)
Land Size Squared	-0.001 (1.40)	0.000 (0.77)
<i>ln</i> (Asset Value)	0.817 (4.48)**	1.503 (8.03)**
<i>Community Characteristics</i>		
Grazing Land	-4.504 (4.86)**	-0.401 (0.65)
Grazing Land Squared	0.532 (4.64)**	0.047 (0.58)
Population Density	-0.008 (3.14)**	-0.006 (1.93)
<i>ln</i> (Altitude)	-3.747 (1.85)	1.785 (0.72)
Annual Rainfall 100mm	-3.747 (1.85)	1.785 (0.72)
Year 2005	0.608 (1.73)	0.062 (0.17)
Constant	7.816 (0.53)	-37.179 (2.09)*
Number of households	1708	1708

Table 5. Determinants of Organic Fertilizer Application on Banana Plots  
 Dependent variable: the organic fertilizer application per ha of banana plots

	2005 Data		Panel Data	
	Tobit	Tobit Add soil data	Random Effects	Fixed Effects
	(A)	(B)	(C)	(D)
No. of Improved Cattle per ha	185.098 (3.96)**	170.484 (3.66)**	72.477 (6.41)**	119.114 (5.76)**
No. of Local Cattle per ha	13.646 (0.61)	15.158 (0.68)	3.247 (0.69)	-3.128 (0.45)
<i>Soil Fertility in 2003</i>				
Organic Matter		-154.863 (2.37)*	-13.895 (1.30)	
Ca (Cmolc/kg)		-16.539 (0.27)	-0.249 (0.03)	
P (Mg/kg)		-0.144 (0.17)	-0.042 (0.29)	
K (Cmolc/kg)		83.237 (0.56)	4.759 (0.18)	
Ph		293.330 (1.22)	-3.685 (0.08)	
Clay (%)		11.791 (1.16)	-0.426 (0.23)	
<i>Plot Characteristics</i>				
Ln (Plot size)	-143.425 (1.44)	-138.617 (1.40)	-14.389 (0.91)	
Walking Distance in minutes	-38.726 (3.69)**	-36.633 (3.50)**	-1.817 (1.37)	
Walking Distance squared	0.106 (1.55)	0.095 (1.44)	0.004 (0.53)	
<i>Household Characteristics</i>				
Max. Education of men	-2.092 (0.67)	-1.375 (0.44)	-1.367 (2.22)*	
Max. Education of women	-3.772 (1.60)	-3.339 (1.41)	-0.689 (1.61)	
ln(assets)	399.404 (4.41)**	358.054 (3.98)**	39.800 (2.71)**	-26.887 (1.08)
Average Monthly Rain	2.589 (1.01)	2.099 (0.79)	-0.308 (0.91)	
Rainfall Shock	451.510 (1.12)	379.679 (0.95)	69.726 (1.55)	25.851 (0.50)
Constant	-14,675.094 (2.75)**	-18,527.357 (2.89)**	-1,930.395 (1.68)	406.909 (1.37)
Number of plots	1250	1250	2423	2427

Table 6. Determinants of Banana Yield in *ln* (Banana output in tons per ha per season)

	2005 Data		Panel Data	
	OLS	Add soil data	Plot RE	Plot FE
	(A)	(B)	(C)	(D)
Organic Fertilizer (tons /ha)	0.060 (2.41)*	0.061 (2.51)*	0.047 (2.94)**	0.054 (2.80)**
<i>Soil Fertility in 2003</i>				
Organic Matter		0.095 (3.96)**	0.072 (2.83)**	
Ca (Cmolc/kg)		-0.083 (3.50)**	-0.075 (3.18)**	
P (Mg/kg)		0.001 (2.42)*	0.001 (3.58)**	
K (Cmolc/kg)		0.064 (0.92)	0.042 (0.60)	
Ph		-0.218 (2.07)*	-0.293 (2.69)**	
Clay (%)		-0.004 (0.97)	0.001 (0.29)	
<i>Plot Characteristics</i>				
Plot Size in ha	-0.217 (4.42)**	-0.261 (5.34)**	-0.477 (11.97)**	
Walking Distance in minutes	0.010 (1.75)	0.012 (2.06)*	0.001 (0.17)	
Walking Distance squared	-0.000 (0.78)	-0.000 (1.07)	0.000 (0.58)	
<i>Household Characteristics</i>				
Max. Education of men	0.004 (2.22)*	0.003 (2.02)*	0.006 (3.29)**	
Max. Education of women	-0.002 (1.55)	-0.001 (0.89)	-0.001 (1.00)	
<i>ln</i> (assets)	0.077 (1.72)	0.091 (2.06)*	0.174 (4.70)**	0.236 (3.55)**
Year 2005	0.000 (.)	0.000 (.)	-0.266 (4.65)**	-0.211 (3.65)**
Short Rain Season	0.142 (1.71)	0.150 (1.84)	0.050 (1.24)	0.037 (0.86)
Constant	-0.968 (1.75)	-0.198 (0.22)	-2.540 (5.53)**	-2.159 (2.50)*
Number of households	786	786	1572	1575

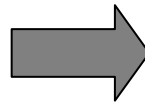
Table 8  
 Impacts of Adopting Improved on Income  
 (Household Fixed Effects Model)

	Total Income	By Income Source		
		Crop Income	Livestock Income	Off-farm Income
	(A)	(B)	(C)	(D)
Adoption of Improved Cattle	120.7 (3.40)	33.3 (1.98)	55.6 (3.83)	31.7 (1.24)
Constant	129.4 (2.62)	170.7 (7.25)	-1.94 (0.10)	-39.2 (1.10)
Community x 2 <sup>nd</sup> Round	Included	Included	Included	Included
Number of households	880	880	880	880

**Low Integration**

Crop

Dairy  
Open grazing  
Local Cattle



**High Integration**

Crop

Feed



Manure

Dairy  
Stall-fed  
Improved Cattle

Figure 1. Shifting to High-Integrated Dairy-Crop Farming System in Uganda

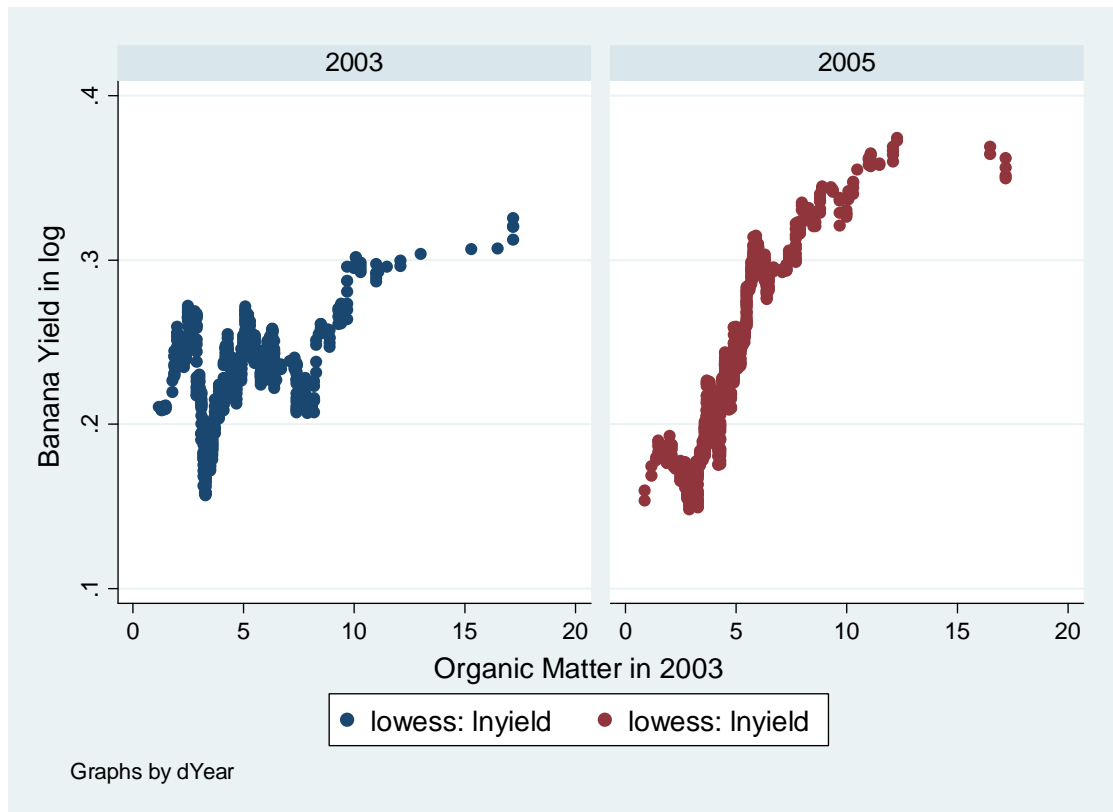


Figure 2. Banan Yield and 2003 Soil Organic Matter