# Understanding Rwandan Agricultural Households' Strategies to Deal with Prime Age Illness and Death: A Propensity Score Matching Approach[1]

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***Abstract***

*The increasing prevalence of HIV/AIDS in Rwanda – along with the devastating effects of the genocide of 1994 – means that many rural households face extreme stress. Since 90 percent of the population is engaged in agriculture, the consequences should be reflected in agricultural production. This research evaluates differences between households directly affected by HIV/AIDS and other illnesses resulting in premature adult death and households not affected by these events. In particular, strategies to deal with morbidity and mortality and differences in crop production outcomes are examined. Annual agricultural production data from 1999-2001, on a nationally representative sample of rural Rwandan households, are combined with recall information on reported strategies and household demographics – including morbidity and mortality. The main methodological approach uses propensity score matching to asses how affected households differ from comparable, but unaffected, households. Some of the expected shifts to roots and tubers and out of cash crops occur with affected households. With high population density and very small average agricultural holdings, Rwandan households appear to use labor replacement strategies rather than labor-saving technologies to deal with labor shortages. There is a worrisome tendency to shift away from crops that provide erosion control, so soil fertility issues will be increasingly relevant in this hilly country. Since the affected households ex post tend to be in the lower income groups, agricultural policy that can generate rural income growth with diversification of income sources will assist those households, while helping the general population of rural poor.*

## 1. Objectives

The increasing prevalence of HIV/AIDS in Rwanda, along with the likelihood of continued effects of the genocide of 1994, suggests that many rural households may be facing extreme stress and their agricultural production may be changing. Policy makers and development practitioners seek to understand how Rwandan households are affected and how they are reacting to the stress such that development policies can best support improvements in rural livelihoods under this changing environment. If production systems are shifting to less nutritious crop mixtures or ones that increases the potential for soil erosion on the hillsides, measures may be needed to counterbalance the negative effects.

This research seeks to evaluate the agricultural strategies used by households in dealing with morbidity and mortality, and to determine differences in crop production between households that have experienced a recent adult illness or death due to illness compared to those without adult morbidity or mortality. With 90 percent of the population living in rural and semi-rural settings and engaged in agriculture, the consequences of illness and death may be reflected in agricultural production, particularly due to declining labor supply, as suggested by Gillespie (1989).

Several characteristics of rural Rwanda might tend to dampen the potential negative effect on agricultural production of labor lost through adult morbidity and mortality. Given high land scarcity in rural areas, high population densities, population growth, and relatively few off farm income

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[1] Draft paper prepared for the IFPRI/Renewal Conference on HIV/AIDS and Food and Nutrition Security, held in Durban South Africa, 13-17 April, 2005. Comments welcome. This research has been funded through USAID/Rwanda Mission and USAID/ Bureau for Africa and the Bureau Economic Growth, Agriculture and Trade.

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opportunities, farmers may not be faced with the kind of labor difficulties predicted, even in the face of HIV/AIDS. In addition, Gillespie did not allow for potential household responses to loss of adult labor, such as obtaining additional labor through social networks, attracting new household members, and hiring labor, as found in other studies (Yamano and Jayne 2003; Mather et al., 2004).
One of the key analytical challenges to understanding possible changes and differences is that of determining what households affected by death and illness would have been doing if they had not had such traumatic events, to thereby understand the impact of the events. The paper provides insight on both the research question and the use of a specific research methodology, propensity score matching (PSM), applied in the context of adult mortality and morbidity.

The research provides several contributions to the research. It takes earlier theoretical literature about potential effects and empirically tests some of the effects. It uses a nationally representative cross-sectional survey that also has a limited panel set to quantitatively assess impacts. This combination is a relatively low cost method where annual agricultural surveys are already being conducted. The propensity score matching has been used frequently in the program evaluation literature, when experimental design was not possible, but there have been few applications in a development context. This combination of data allows application of PSM to difference in difference estimations, in an effort to control for the unobserved differences between households.

This research is also one of the few that looks separately at the effects of HIV/AIDS during the period of adult illness and after an adult death has occurred. As will be noted, relatively small death effects found in this work may be a reflection that pre-death measurements occurred during the illness period, when the household was already adjusting to HIV/AIDS. If the "pre-death" measurement of outcome is taken after adult illness has ensued, the HH may have already adjusted household assets, crop production, etc, in which case the 'death effect' would underestimate the extent to which the household was initially affected and had to change, since adjustments during illness may be later compensated through demographic or other changes in the households. The periods just before and after death may be when some households are feeling and trying to deal with the worst of the shocks, and may undertake strategies that lead into a poverty trap. This research demonstrates that measuring the average effects of adult illness and death separately provides a test of how illness and death affects compare, and provides insight on the possible need for interventions during illness to mitigate the most severe effects which cause permanent livelihood declines.

## 2. Background

In the early years of the HIV/AIDS epidemic, researchers relied on economic logic to understand the potential impacts of the disease on household structure, production, and livelihoods. In the agricultural sector, major labor scarcities were predicted, both due to the lack of labor contribution by those with AIDS but also due to the need to care for the ill and the pressure to sell production assets to cover medical and burial costs. The loss of skills of the person with AIDS and loss of time for skill transfer to children were all predicted to contribute to severe labor shortages and knowledge loss which would result in cropping shifts and declines in agricultural production. (Topouzis and du Guerny, 1999).

Over time, the empirical base to evaluate the morbidity and mortality impacts and the strategies used to minimize them in improving. The early studies were generally of specific locations with high prevalence (eg. Ainsworth et al., 1995), but broad studies over entire countries have also been conducted (Shisana and Simbayi, 2002). Qualitative studies that focused on stated adjustment strategies of households are now being complemented by more quantitative studies which seek to measure impact. Longitudinal studies compare households in two or more periods of time (Yamano and Jayne, 2004; Beegle 2003). One of the patterns emerging from the literature is the heterogeneity of household response strategies and the impacts of adult mortality, such that the impacts of adult mortality appear to be conditioned by household characteristics such as the gender and role of the deceased, pre-death asset levels, and post-death household composition, and community characteristics such as population density, and cropping systems (Mather et al. 2004b).

Research in Kenya indicates that the demographics of the household and the gender and role in the household of the person who is ill or had died strongly conditions the outcome (Yamano and Jayne 2004). Tanzanian research demonstrates that households change their labor allocations to adapt to illness and death in different ways and the overall effect on agricultural production will vary (Beegle 2003).[3] In Mozambique, households in the south are larger and less dedicated to agriculture, such that agricultural impacts are thought to be low, whereas in the north with more nuclear households and a focus on agriculture, the overall agricultural impacts may be significant, if the epidemic continues to rise (Mather, et al. 2004)

### 3. Understanding Adjustment Strategies of Households

Assessing how households deal with the stress related to HIV/AIDS in rural areas has required new research tools and a multi-disciplinary approach. For example, due to the costs and technical demands of assessing HIV status of populations, earlier research in Rwanda and elsewhere has used adults between the ages of 15 and 60 as "prime-age" (PA) adults for they are in sexually active years as well as in their most productive working years. It is this age group that tends to suffer from pre-mature death that is most likely to be associated to HIV/AIDS, particularly if murder and accidents can be removed as a cause of death.

Donovan et al. (2003) presented the preliminary results from the household survey of 1500 rural Rwandan households that will be analyzed here. During that survey, respondents were asked about what strategies they pursued to respond to the stress of a current PA adult with chronic illness or the death of a PA adult within the previous three years. They were also asked about the major impacts the stress had on their agricultural activities. In cases of both illness and death, and regardless of the gender of the person involved, the majority of households cited a loss of farm labor. Among the agricultural strategies, it was logical to find that the strategies cited involved trying to replace lost labor, bringing in new family members or hiring in labor. The declared strategies varied depending on the gender and role of the person who was ill or died. However, there were very few households indicating a shift in cropping mix, although this is often cited in HIV/AIDS literature as a likely strategy (Topouzis and du Guerny 1999).[4]

Simple comparisons of crop production and area in different crops between affected and unaffected households suggested that there had been shifts in production, or that there are characteristics of households with PA illness or death that make them more likely to cultivate more sweet potatoes or less coffee, for instance. There may be an under-reporting of cropping shifts in the strategy responses, but the stated strategies indicate attempts to maintain agricultural labor supplies. The ex post comparisons of households also showed that the households affected by illness or death did tend to be ex post in the lower two expenditure quartiles (Donovan et al. 2003). One of the concerns raised by the previous work (Donovan et al. 2003) is that some of the shifts may entail more erosive cropping or cropping patterns that suggest substantially lower income generation by affected households. For intervention programs, it will be important to assess this more thoroughly.

### 4. Methodology

There is a large body of literature which seeks to understand how programs or events affect people or households. Rosenbaum and Rubin (1983) proposed an evaluation technique called propensity score matching. The method has seen a recent surge in use and we employ this method here. Propensity score matching (PSM) provides an alternative to experimental methods to evaluate program or event

[3] Beegle's (2003) research in Kenya is one of the few studies that looks at households with a view to separating effects evidenced recently after a death as compared to longer (more than 6 months) after a death. It also looks at labor allocation, a key aspect, infrequently addressed in the research.
[4] For further evaluation of strategies and ex post household characteristics, see Donovan et al., 2003.

effects.[5] To get the true effect of illness or death, we need two things: the outcome of a household with an illness or death (hereafter, an "affected" household) and the outcome of that same household under the same conditions, but without illness or death. Since the latter is unobservable, we need to construct a proxy counterfactual for the missing data. Information on each affected household is matched to a sample of "similar" unaffected households for the same two periods. To determine which households to match, the PSM method evaluates the predicted probability of experiencing an illness or death on the basis of household and local area characteristics. PSM matches each affected household with "similar" unaffected households and uses the outcome of the unaffected households as a proxy for the outcome of the affected household if it had not had an illness or death.

The identification of "similar" is a key feature. There are two aspects to the similarity. First, there may be something about the affected households and why they have a member infected with the HIV virus which makes them different from the general set of households. For example, if a household with a head who has higher than average education is more likely to have a member with HIV, we would want to consider the education of the head (prior to the trauma) in matching the households. Secondly, if education of the head tends to be a factor determining the outcome, in this case crop production, clearly we would want to compare the outcomes of households with similarly educated heads. Thus, matching entails identifying a set of characteristics that are associated with an increased propensity to have a member with HIV and are likely influence the outcome, crop production. The better the set of characteristics in accounting for outcome differences in the absence of treatment, the better chance of eliminating confounding factors that affect the outcome (Becker and Ichino, 2002).

Unlike regression approaches using instrumental variables (IV), PSM looks for pre-event (or time invariant) characteristics that are correlated with both the outcome and the event. With HIV/AIDS, it is often difficult to find an appropriate instrument that is unrelated to the outcome of interest. Another benefit of PSM over the IV approaches is that no functional form must be assumed for the relationship between the outcome and the characteristics.[6] However, it is assumed that those characteristics can be mapped into a *single* number, the propensity score. Rosenbaum and Rubin (1983) show that if the expected outcome in the counterfactual state for an affected household is equal to the expected outcome for an unaffected household, conditional on a set of characteristics, then the expected counterfactual outcome for the affected household is equal to expected outcome for the unaffected household, conditional on that *single* number, the estimated propensity score.

We estimate the effect of the illness or death on household outcomes for the cases of affected households, not for all households in the general population. This is known in the literature as the average treatment effect on the treated (ATT). That is, we will attempt to estimate the counterfactual of what crop production for affected households would have been if no prime-age adult became ill or died in these households. The estimation of death effects and illness effects will be done separately so hereafter the estimation strategy will be discussed in terms of the "affected households." Death and illness refer only to those of prime-age adults. Also, the outcome variables to be evaluated are the crop production in 2001/2002 (ex post) and the change in crop production from 1999/2000 to 2001/2002 for specific crops.

We use a probit model to estimate the propensity score for each household. The dependent variable is an indicator of prime-age death or illness in a household, with separate probit regressions for each type of stress. Recognizing that our estimate of the propensity score is imperfect, and that idiosyncratic factors will affect the individual unaffected household outcomes, we estimate the counterfactual outcomes by averaging outcomes across households who come within a set distance of the predicted propensity score for an ill household. This averaging over many similar unaffected

[5] Bryson, Dorsett and Purdon (2002) provides an excellent review of the use of propensity scores, while Wooldridge (2002) gives the econometric details of the method, as well as additional insights on its use and limitations. Jalan and Ravallion (2003) apply the method in a developing country context.

[6] DiPrete and Gangl (2004) provide a valuable comparison between PSM and instrumental variable (IV) estimations, and ways to evaluate each. They are seen as complementary analyses, not necessarily substitutes.

households should provide a better estimate of the counterfactual by averaging out unobservable factors affecting both the probability of death and production outcomes (assuming the unobservable factors are not systematically related to the probability of death or illness). This method of estimating the counterfactual is known as radius matching. An additional effort to control for household unobservables is made by calculating the difference in differences in crop production and then estimating the effects on those differences, as suggested in the work of Smith and Todd (2003) and Wooldridge (2002).[7]

## 5. Data

The Department of Agricultural Statistics (DSA) at the Rwandan Ministry of Agriculture, beginning in 1999/2000 and through 2001/2002, visited a set of 1584 Rwandan agricultural households during each of the two main agricultural seasons to detail their crop production and land use during the season. In early 2001, a demographic survey was conducted with these households, including information on age, sex, education, and work activities. In early 2002, the households were again asked about their members, including new members, members who were no longer with the households, and currently ill members. There was no medical testing conducted to determine HIV status. Instead, the chronic illness or death due to illness by adults in their prime ages (15-60 years of age) was used to proxy for probably HIV/AIDS presence among ill members (Donovan, et al. 2003).

For this analysis, households with a current adult prime age who was chronically ill (at the time of the FSRP interview in 2002) or those who experienced a prime age adult death in the previous three years will be compared to households without prime age adult illness or death ("unaffected households"). Three years of production data are available for the households to capture the main period of effects of illness and at least part of the period of effects of a death. The 1999/2000 crop year had periods of drought and so was not a very good crop year for most households in Rwanda. We expect that production for most crops by households in 2001/2002 would have increased due to better rainfall, even if land area dedicated to the crop remained constant. It is how affected households compare to unaffected that will have interest.

For a variety of reasons, some households were no longer in the sample in 2002, so only 1520 households were included. To understand the reasons for attrition of households, neighbors and relatives were asked to indicate why a household could no longer be interviewed. In most cases, the informants indicated that people had left to find new land or look for work, but there were a few households who had left due to a death.[8] Additionally, households with incomplete information had to be dropped from the sample. Thus, there remain 1168 households in the analysis, of which 65 experienced a PA death. When estimating the PSM for illness, households with a death are dropped from the control, and vice versa to avoid confounding cases.

## 6. Propensity Score Estimation Results

The results of the propensity score matching are presented in Table 1 for both the case of households with a PA illness and those with a PA death, and are based on STATA (2004) programming by Becker and Ichino (2002). Characteristics in each of the probit regressions between death and illness vary. A key reason for exclusion of some variables was the belief that they might not have been measured prior to the death. Since deaths go back three years and illness goes back only twelve months (with most cases less than that), there are aspects recorded in 2000 that should not be considered "pre-event." Balancing property requirements, based on statistical tests of differences in means between matched and control households, ensure that when groups are matched based on the propensity score, the average characteristics within a group are not significantly different.

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[7] Annex 1 presents some special data considerations for propensity score matching, as used with these data..
[8] See Donovan,et al. 2003 for further information on sampling and sample attrition.

**Table 1: Probit estimates of Propensity Scores: Propensity to have a PA illness in household or a PA death in Household**

| Characteristics | Prime Age Illness in Household | | | | Prime Age Death in Household | | | |
|---|---|---|---|---|---|---|---|---|
| | Coef-ficient | Stand. Error | z | P>\|z\| | Coef-ficient | Stand. Error | z | P>\|z\| |
| Central agricultural zone | 0.484 | 0.193 | 2.51 | 0.01 | -0.298 | 0.142 | -2.10 | 0.04 |
| Eastern agricultural zone | 0.904 | 0.221 | 4.10 | 0.00 | -0.317 | 0.176 | -1.80 | 0.07 |
| Cellule population (log) | -0.169 | 0.148 | -1.15 | 0.25 | 0.144 | 0.129 | 1.11 | 0.27 |
| Cellule with departures greater than arrivals (1=yes) | 0.016 | 0.155 | 0.11 | 0.92 | -0.044 | 0.136 | -0.32 | 0.75 |
| Regular market in cellule (1=yes) | 0.424 | 0.178 | 2.39 | 0.02 | 0.203 | 0.158 | 1.29 | 0.20 |
| Newly forested areas in last 12 months (1=yes) | 0.203 | 0.141 | 1.43 | 0.15 | -0.220 | 0.131 | -1.67 | 0.10 |
| Access to primary market good more than 4 kms | 0.561 | 0.227 | 2.47 | 0.01 | 0.148 | 0.200 | 0.74 | 0.46 |
| Health center (1=yes) | -0.030 | 0.170 | -0.18 | 0.86 | 0.222 | 0.134 | 1.66 | 0.10 |
| Churches (number) | -0.208 | 0.122 | -1.70 | 0.09 | -0.140 | 0.091 | -1.54 | 0.12 |
| Access to rural credit in cellule (1=yes) | -0.172 | 0.170 | -1.01 | 0.31 | 0.065 | 0.141 | 0.46 | 0.64 |
| Access to farmer association in cellule (1=yes) | 0.196 | 0.215 | 0.91 | 0.36 | 0.049 | 0.181 | 0.27 | 0.79 |
| Use of fertilizers and pesticides in cellule (1=yes) | 0.502 | 0.167 | 3.01 | 0.00 | -0.149 | 0.137 | -1.09 | 0.28 |
| Sex of household imputed head in 1999 (1=male; 2=female) | 0.284 | 0.167 | 1.70 | 0.09 | 0.200 | 0.137 | 1.46 | 0.14 |
| Age of head in 1999 | -0.003 | 0.005 | -0.65 | 0.52 | -0.001 | 0.004 | -0.15 | 0.88 |
| Head completed primary school in 1999 (1=yes) | 0.021 | 0.171 | 0.12 | 0.90 | -0.144 | 0.164 | -0.88 | 0.38 |
| Head is either married or separated (1999) | 0.454 | 0.156 | 2.91 | 0.00 | -0.400 | 0.148 | -2.69 | 0.01 |
| Household uses manure/pesticides | -0.102 | 0.182 | -0.56 | 0.58 | | na | | |
| Number of rooms in house > 4 (1=yes) | 0.104 | 0.188 | 0.55 | 0.58 | 0.216 | 0.153 | 1.41 | 0.16 |
| Total income in 2000 (log) | -0.105 | 0.058 | -1.79 | 0.07 | | na | | |
| Residence in cellule for more than 8 years (1=yes) | -0.395 | 0.157 | -2.52 | 0.01 | 0.147 | 0.132 | 1.12 | 0.26 |
| Household member has received remittances (1=yes) | -0.056 | 0.137 | -0.41 | 0.68 | | na | | |
| Household has paid for transport (1=yes) | 0.567 | 0.186 | 3.05 | 0.00 | | na | | |
| Constant | -0.632 | 1.252 | -0.50 | 0.61 | -2.466 | 0.931 | -2.65 | 0.01 |
| Number of Observations | | | | 1129 | | | | 1168 |
| Log likelihood | | | | -210.98 | | | | -265.135 |
| LR chi2(22) | | | | 75.33 | | | | 42.59 |
| Prob >chi2 | | | | 0 | | | | 0.0009 |
| Pseudo R2 | | | | 0.1515 | | | | 0.0743 |

As can be seen in Table 1, almost the full set of available households was matched with death households. In the case of illness, the CSR is narrower and 30 percent of the unaffected households are excluding from the control group.[9] The characteristics used in the probits are expected to be useful in predicting probability of having a member with AIDS (i.e. being an affected household). As noted earlier, unlike instrumental variables in estimations, those characteristics can also be associated with crop production outcomes. For example, having a regular market in the community may be related with higher contacts outside the home and also might be associated with higher incentives for agricultural production for surplus sales. Those households who have lived in the area since before the genocide in 1994 may have greater stability in both land and household members. One of the puzzling results is that households in Central and Eastern zones tend to have higher illness prevalence but lower death prevalence than those households in Western zones.

## 7. Estimated Effects of Illness for Households Experiencing Illness

The PSM of affected households with unaffected control households within the common support region identified significant differences for the total crop production in 2001/2002 of selected main crops and for the change in crop production of those crops from 1999/2000 to 2001/2002. The ex post total production helps us to understand if the households are significantly different after the effects of illness or death of felt. We look at production changes over time to allow for the possibility that ill households had different starting points of production. As suggested earlier, if ill and non-ill households differed in their initial production levels (on average), we would mistakenly attribute this difference to having an ill prime-age adult if we only looked at the ex post results.

### a. Ex Post Level of Crop Production

Table 2 shows that for beans, peas, maize, cassava, irish potatoes, cooking bananas, fruit bananas and coffee, there were no significant estimated effects of illness on production in 2001/2002. However, beer bananas (a cash crop) showed a significant lower total production amount for households with illness compared to households without illness. Beer bananas require processing generally completed by women, so as the labor demands on women to care for the ill and the labor declines due to illness among women, this would be expected.

Sweet potato and fruit banana production for households experiencing illness was significantly higher than production for households without illness. Sweet potatoes play a key role in consumption in Rwanda (Tardiff-Douglin 1991), and they have a labor advantage in production. The labor demands for sweet potatoes are not necessarily lower than for other crops, but the timing of labor is more flexible, as harvesting can take place over time and planting can be timed outside the main planting period for other crops. That flexibility makes it an important food security crop, and households with an illness are cropping up an average of 547 kilograms more than comparable households.

### b. Changes in Crop Production

The changes in crop production from one period to the next reflect a difference-in-differences approach, for the changes are contrasted between the affected and unaffected households (Table 3). As expected with the improved climatic condition in 2001/2002, the control households increased their production of all the major commodities. The effect of illness on beer bananas and sweet potatoes production remains strong. Households with an illness experienced higher growth in sweet potato production and much lower growth/recuperation in production of beer bananas. In general, illness households increased sweet potato production by more that 500 kilograms over the increase experienced by similar unaffected households. Beer bananas increased only 43% of the increase experienced by the control households. Since beer bananas have been a major source of income for women (Kangasniemi, 2001), this result implies a relative decline in women's income earning

[9] Annex 2, Table A presents the information on values of the characteristics for the affected and control households, based on those within the CSR.

**Table 2: Matching estimates of the Effects on Production in 2002 for selected crops: Average Treatment Effect(ATT) on Households with a Prime Age Adult Illness (in kilograms)**

| Crop | Beans | Peas | Maize | Cassava | Irish Potato | Sweet Potato | Cooking Banana | Beer Banana | Fruit Banana | Coffee |
|---|---|---|---|---|---|---|---|---|---|---|
| ATT | 30.25 | -0.05 | -16.80 | -2.61 | 26.73 | 531.18 | -118.42 | -64.64 | 71.59 | -0.32 |
| t-statistic | 0.83 | -0.02 | -0.69 | -0.02 | 0.11 | 2.54*** | -1.43 | -1.78* | 1.63 | -0.05 |
| Households with illness | 64 | 64 | 64 | 64 | 64 | 64 | 64 | 64 | 64 | 64 |
| Control households | 753 | 753 | 753 | 753 | 753 | 753 | 753 | 753 | 753 | 753 |
| Avg.Control production | 161.26 | 8.19 | 81.50 | 507.39 | 251.81 | 905.53 | 520.50 | 281.57 | 118.01 | 17.88 |

Source: DSA data, 2002. Estimates based on propensity score specification found in Table 1.

Controls refers to the number of households without prime age illness who form the basis for the counterfactuals. Radius of 0.01 was used for matching. Significance of t: *, **, *** indicate 0.10., 0.05, and 0.01 confidence levels, respectively.

**Table 3: Matching estimates of the Effects on Change in Production from 1999 - 2002 for selected crops: Average Treatment Effect (ATT) on Households with a Prime Age Adult Illness (in kilograms)**

| Crop | Beans | Peas | Maize | Cassava | Irish Potato | Sweet Potato | Cooking Banana | Beer Banana | Fruit Banana | Coffee |
|---|---|---|---|---|---|---|---|---|---|---|
| ATT | 20.99 | 0.74 | -21.19 | 101.12 | -72.23 | 467.88 | -102.65 | -205.40 | -35.81 | -9.31 |
| t-statistic | 0.60 | 0.24 | -0.79 | 0.73 | -0.96 | 2.45*** | -1.57 | -1.82* | -0.87 | -1.79* |
| Households with illness | 64 | 64 | 64 | 64 | 64 | 64 | 64 | 64 | 64 | 64 |
| Control households | 753 | 753 | 753 | 753 | 753 | 753 | 753 | 753 | 753 | 753 |
| Avg. Control Production Change | 41.93 | 2.33 | 43.38 | 10.20 | 84.46 | 243.14 | 307.00 | 361.17 | 58.85 | 9.25 |

Source: DSA data, 2002. Estimates based on propensity score specification found in Table 1.

Controls refers to the number of households without prime age illness who form the basis for the counterfactuals. Radius of 0.01 was used for matching. Significance of t: *, **, *** indicate 0.10., 0.05, and 0.01 confidence levels, respectively.

potential in the affected households compared to the control households. Additionally, coffee production declined significantly among households with illness over the period.

## 8. Estimated Effects of Death on Crop Production for Households Experiencing Death

Households experiencing a death show significant differences in crop production as compared to matched non-affected households without a death or illness. This tends to follow the descriptive analysis found in Donovan et.al. (2003), in which households with a death appear to be quite similar to those without a death.

### a. Ex Post Level of Crop Production

Table 4 shows the results for evaluating the differences in production levels in 2001/2002. All crops show lower production amounts for households with a death, but with variability between households, significant differences are found only for beans, beer bananas and fruit bananas. The decline in bean production might be important for beans are a key food security crop for Rwandan households, and the average household production per control household for 2002 was 150 kilograms of beans (Table 4), so this reflects an 18% reduction in production. The banana shifts indicate declining income potential, but the lower production is relatively small for beer bananas (4%), while there is a strong 38% decline in fruit bananas, compared to control households. Again, if production shifts occur in years of illness, prior to death, our analysis does not capture that effect.

### b. Crop Production Changes

Table 5 presents the results of analysis on the changes in production quantities from 1999/2000 to 2001/ 2002. As expected due to the improved climatic conditions between the two years, the control households increased their production of both bananas, along with sweet potatoes and the other crops. The affected households showed significant differences only in beer and fruit bananas. Those bananas do not show the production growth found in other households, and may reflect For erosion, this is not a good sign and there is no indication that less erosive crops supplanted the bananas, while income potential clearly declines with less of these types of bananas produced. Contrary to conventional expectation that affected households shift into labor-flexible or labor-saving crops such as cassava and sweet potato, we do not find an increase in cassava and sweet potato production among affected households.

## 9. Implications and Conclusions

This paper presents an application of PSM to the measurement of the impacts of adult illness and death on crop production in Rwanda. We use a combination of cross-sectional and panel data to construct the counterfactual required to estimate these impacts. This application demonstrates that, given appropriate variables and sample size, PSM enables analysts to estimate the impacts of adult illness and death using cross-sectional data with recall complemented with a small amount of panel information. While panel data are preferred for the econometric estimation of impacts, governments and development practitioners cannot always wait for the ideal data to inform local policy decisions.

Given small subsample size of illness and death, we did not differentiate impact conditional on gender or household position of the deceased, as has been done elsewhere (Yamano and Jayne, 2004). Yet this research highlights an important differentiation which has not received much attention to date in the quantitative impact literature – the distinction between production impacts during the illness period as compared with those in the post-death period.

These results suggest that accurate measurement of the impact of adult death depends upon when measurements are taken. While there have been a few studies that look at different periods after death, the analysis of impacts for the illness period has rarely been evaluated. If major shifts occur during the period of illness which are difficult to reverse, such as removal of tree crops, intervention strategies may need to be designed with this specifically in mind. Other research is needed to see if changes during illness also involve asset sales which could lead to permanent changes. Another

**Table 4: Matching estimates of the Effects on Production 2002 for selected crops: Average Treatment Effect (ATT) on Households with a Death (in kilograms)**

| Crop | Beans | Peas | Maize | Cassava | Irish Potato | Sweet Potato | Cooking Banana | Beer Banana | Fruit Banana | Coffee |
|---|---|---|---|---|---|---|---|---|---|---|
| ATT | -27.62 | -2.60 | -10.79 | -108.46 | -45.71 | -75.83 | -112.53 | -88.06 | -40.204 | -5.42 |
| t-statistic | -1.87* | -1.29 | -0.67 | -1.43 | -0.34 | -0.55 | -0.89 | -3.10*** | -2.648*** | -0.83 |
| Households with a death | 77 | 77 | 77 | 77 | 77 | 77 | 77 | 77 | 77 | 77 |
| Control households | 1046 | 1046 | 1046 | 1046 | 1046 | 1046 | 1046 | 1046 | 1046 | 1046 |
| Avg. Control Production | 150.38 | 9.50 | 86.13 | 506.40 | 262.06 | 830.42 | 443.86 | 282.07 | 106.75 | 19.44 |

Source: DSA data, 2002. Estimates based on propensity score specification found in Table 1.

Controls refers to the number of households without prime age death who form the basis for the counterfactuals. Radius of 0.01 was used for matching. Significance of t: *, **, *** indicate 0.10., 0.05, and 0.01 confidence levels, respectively.

**Table 5: Matching estimates of the Effects on Change in Production from 1999 - 2002 for selected crops: Average Treatment Effect (ATT) on Households with a Death (in kilograms)**

| Crop | Beans | Peas | Maize | Cassava | Irish Potato | Sweet Potato | Cooking Banana | Beer Banana | Fruit Banana | Coffee |
|---|---|---|---|---|---|---|---|---|---|---|
| ATT | -6.89 | -1.72 | -0.83 | 8.81 | 48.25 | -209.96 | -78.58 | -198.91 | -41.17 | -4.97 |
| t-statistic | -0.51 | -0.94 | -0.04 | 0.10 | 0.38 | -1.26 | -0.75 | -3.01*** | -2.49*** | -0.94 |
| Households with a death | 77 | 77 | 77 | 77 | 77 | 77 | 77 | 77 | 77 | 77 |
| Control households | 1046 | 1046 | 1046 | 1046 | 1046 | 1046 | 1046 | 1046 | 1046 | 1046 |
| Avg. Control production change | 40.65 | 3.76 | 36.82 | 38.73 | 73.21 | 172.70 | 267.50 | 361.74 | 55.69 | 7.79 |

Source: DSA data, 2002. Estimates based on propensity score specification found in Table 1.

Controls refers to the number of households without prime age death who form the basis for the counterfactuals. Radius of 0.01 was used for matching. Significance of t: *, **, *** indicate 0.10., 0.05, and 0.01 confidence levels, respectively.

aspect which would then be needed is to disaggregate the analysis by type of households (e.g., female-headed versus male headed) and by the gender or role of the person with HIV/AIDS. This was not possible in this research due to small sample numbers.

Regarding the measured impacts, over the illness period, we find relative increases in sweet potato production for ill households and shifts out of beer bananas and coffee. The latter imply lower cash income, while the sweet potato spreads labor demand and provides subsistence production. If banana and coffee tress are replaced with annual crops, that will increase soil erosion problems over time. Investments in sweet potato productivity, however, would have positive results for the affected households.

Death appears to induce shifts out of beer and fruit bananas only, indicating the possible longer term shift out of tree crops when households are under stress, and the consequent reduction in cash income and in erosion protection. We did not find significant effects on other crops. This suggests that labor shortages among affected households looking over time are not as great as suggested by some of the theoretical literature, as households adjust their labor demands and supplies. With a larger subsample, effects conditional on gender and/or household position might be found, for other research indicates that some households are less likely to bring in replacement labor or recuperate from crises. The high population density and land scarcity in Rwanda may be one of the factors conditioning how households respond, limiting their flexibility in agriculture.

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**Annex 1: Special issues in Data for Propensity Score Matching**

This data set lends itself to using the PSM and difference-in-differences estimation for several reasons. First, the households were derived from a random sample with clustering and so both affected and unaffected come from the same population. Second, because the households were all asked the same questions during the same period, we do not experience some of the difficulties found in the traditional matching literature where different sampling and surveys are used for households who participated in training and those who did not (eg., Smith and Todd, 2000). Finally, while the panel on production is brief, it still provides a basis for controlling for household-level time invariant characteristics. The dataset also includes a fairly rich set of variables on which to match households, including community level variables, important to achieve unbiased results (Diaz and Handa 2004).

There are some challenges in using these data. A key difficulty is that the number of cases of affected households is relatively small (65 cases of illness and 78 cases of death). Bryson, Dorsett and Purdon (2002) looked at various studies with small treatment samples, suggesting that the method is still valuable when sample numbers are low, although the matching is more difficult. In this case, the radius matching used radii between 0.005 and 0.01, a fairly broad band. In addition, matching with replacement enabled unaffected households to be matched with more than one affected household if its propensity score was within the bounds.

Estimating the ATT rather than the average treatment effect (ATE) for all households was selected to respond to another potentially difficult issue. PSM is based on the mean stable unit treatment value assumption, in which "the impact of the program on one person does not depend on whom else, or how many others are in the programme" (Bryson, Dorsett and Purdon, 2002, page 11). In the case of HIV/AIDS in highly affected communities, this would not be true and looking at the general effects with ATE is clearly not justified.

Another issue is that of the common support region (CSR). Basically, the analysis matches affected households to unaffected households within the ranges of overlap between the propensity scores of the treated and untreated households. Unaffected households with values of the matching characteristics that are much higher or lower than that observed within the affected households are excluded from the analysis. The same is true for affected households. In small datasets, this can mean a fairly restricted number of matches. It also means that interpretation of the results is confined to households within the CSR. If income is one of the characteristics and all the affected households have total incomes below 500,000 Rwandan francs, then the CSR will not extend to higher income households, if their probability of being affected lies outside the range (Bryson, Dorsett and Purdon, 2002).

PSM relies on having pre-event or time invariant characteristics on which to match the households. In the case of illness in these data, 82% of the cases of illness were ill for less than 25 weeks of the previous year (as measured in 2002), such that the production data from 1999/2000 would be prior to the onset of severe illness. In the case of a death from illness, using the 1999/2000 production and other data is more tenuous, for the onset of illness would be prior to 2000 and effects of the illness may already be reflected in those early estimates. This is a common problem for HIV/AIDS researchers, for the time span involved can be long and the effects are felt throughout illness and after death. Given these caveats, the results of the PSM for households with illness and death are reported below.

**Annex 2:**

**Table A. Mean Characteristics by Household Type for Households in the Common Support Region for Characteristics included in the Propensity Score**

| | Households with Death | Control Households | Households with Illness | Control Households |
|---|---|---|---|---|
| **Community level variables** | | | | |
| Central agricultural zone | 0.32 | 0.39 | 0.38 | 0.44 |
| Eastern agricultural zone | 0.17 | 0.23 | 0.46 | 0.32 |
| Cellule departures greater than arrivals (1=yes) | 0.37 | 0.40 | 0.51 | 0.44 |
| Regular market in cellule (1=yes) | 0.21 | 0.18 | 0.25 | 0.21 |
| Newly forested areas in last 12 months (1=yes) | 0.31 | 0.38 | 0.49 | 0.39 |
| Health center (1=yes) | 0.46 | 0.34 | 0.35 | 0.29 |
| Access to rural credit in cellule (1=yes) | 0.26 | 0.28 | 0.25 | 0.26 |
| Access to farmer association in cellule (1=yes) | 0.87 | 0.84 | 0.88 | 0.85 |
| Use of fertilizers/pesticides in cellule (1=yes) | 0.40 | 0.45 | 0.52 | 0.52 |
| Cellule population (log) | 6.81 | 6.75 | 6.74 | 6.71 |
| Churches in cellule (number) | 0.51 | 0.54 | 0.37 | 0.40 |
| **Characteristics of Head prior to event*** | | | | |
| Proportion Female | 0.50 | 0.31 | 0.29 | 0.31 |
| Completed primary school (1=yes) | 0.17 | 0.22 | 0.25 | 0.24 |
| Head is either married or separated (1999) | 0.23 | 0.42 | 0.60 | 0.47 |
| Age of pre-treatment head in 1999 | 43 | 42 | 41 | 43 |
| **Household level variables prior to event** | | | | |
| Household uses manure/pesticides | na | na | 0.18 | 0.18 |
| Household has received remittances | na | na | 0.60 | 0.57 |
| Household has paid for transport (1=yes) | na | na | 0.22 | 0.10 |
| Distance to primary market (km) | 1.83 | 1.71 | 2.40 | 1.77 |
| Number of rooms in house | 3.60 | 3.58 | 3.77 | 3.54 |
| Total income in 2000 | na | na | 141058 | 159603 |
| Length of residence in cellule | 10.44 | 9.40 | 7.83 | 8.27 |
| N | 78 | 1051 | 65 | 761 |

*Some data imputed. Control households represent only those households from the non-illness, non-death households in the full sample which were matched using Propensity Score Matching, radius of 0.01. "na" indicated variables not included in death estimates.