Estimation of Area and Production of Root and Tuber Crops in Rwanda

By

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Summary

Before the tragic events of 1994, the Agricultural Statistics Division (DSA) of the Ministry of Agriculture (MINAGRI) maintained a comprehensive database of agricultural statistics. The DSA was responsible for providing information on agricultural policy based on annual surveys of rural households. These surveys were conducted under the auspices of the Enquete National Agricole (ENA).

These surveys, which were interrupted in 1994 were resumed in 1999 by the Food Security Research Project (FSRP) and the Agricultural Statistics Division (DSA) of the MINAGRI. The FSRP/DSA began conducting agricultural surveys in 1999 using a national sample of 1584 households. The FSRP/DSA collects land use (area) and production data on a seasonal basis (twice a year). The FSRP/DSA has 11 enumerators (one per province) as compared to 78 enumerators that the ENA had before 1994. The current sample size is also 26% bigger than the one the ENA used. Since the FSRP did not have as much financial resources as those available to the ENA, it had to find a less costly but also accurate method to conduct the surveys. The most time consuming and therefore expensive activity of data collection is area/field measurement. After considering various area measurement methodologies, the FSRP/DSA selected the P^2/A (Perimeter Squared over Area) Methodology. This methodology minimizes time and costs.

The P^2/A methodology is based on the unique and relatively stable relationship between a given field's perimeter squared (P^2) and its area (A) for a known form of field. Perimeter squared (P^2) and area tend to vary together and in the same direction. In fact, the two are so highly correlated that a field's perimeter could be used as a proxy measure of its area. This methodology further utilizes enumerator pacing around the field to measure the perimeter (once the average length of the enumerator's stride has been calibrated and recorded). This innovative methodology has allowed the FSRP/DSA to conduct surveys on a national sample using a limited number of enumerators and at a reasonable cost. The estimates are also statistically sound.

Crop production is estimated using farmer recall for the season (6 months). Just after harvest, the enumerators visit the households and ask the farmer on the quantity produced during the season.

Such innovative methodologies are necessary in the face of declining resources for statistical surveys. Statisticians therefore have to be innovative in creating methodologies that serve the client's needs without compromising data accuracy.

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1. The Importance of Root and Tuber Crops in Rwanda

a. Background to Rwanda

Rwanda is the most densely populated country in Africa with 300 people per square kilometer (and up to 600 people per square kilometer of arable land). The average farm size in 2001 was 0.7ha (Nyarwaya et al, 2001). Rwanda has a bi-modal rainfall pattern with two main growing seasons, with average annual rainfall of 1280 mm. The altitude ranges from approximately 1,200 meters on the eastern plains and rises steadily to 3,000 meters in the volcanic mountains to the northwest.

b. The Importance of Root and Tuber Crops in Rwanda

The main root and tuber crops in Rwanda are sweet potatoes, cassava, and Irish potatoes. The importance of root and tuber crops in Rwanda is demonstrated by their prominence in terms of production (tonnage) and the area occupied (hectares). In 2001, these three crops accounted for 56% of the total production (tonnage) (see figure 1) of food crops and occupied 34% of the total cultivated land (see figure 2). Sweet potatoes and cassava are generally grown at lower altitudes whereas Irish potatoes are grown in the highlands (Munyemana, 1999). Irish potatoes have been cultivated in Rwanda for nearly a century, and most accounts trace introduction of the crop to the arrival of German missionaries in the late 19th century (Scott, 1988).

Figure 1: Food Crop Production in Rwanda: Percentage by Group of Crops, 2001

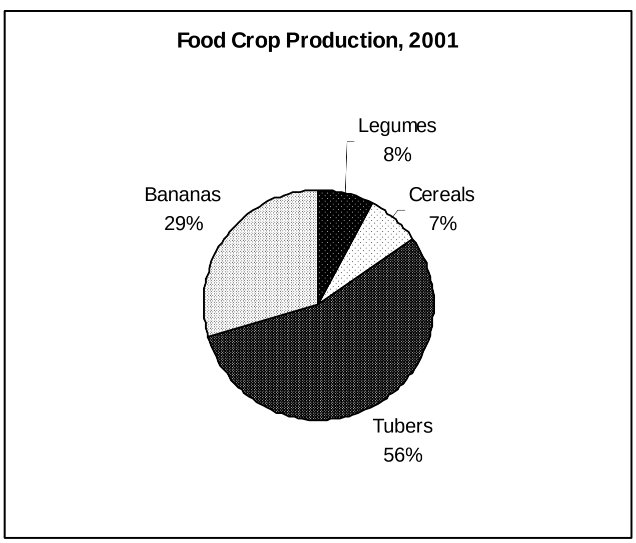
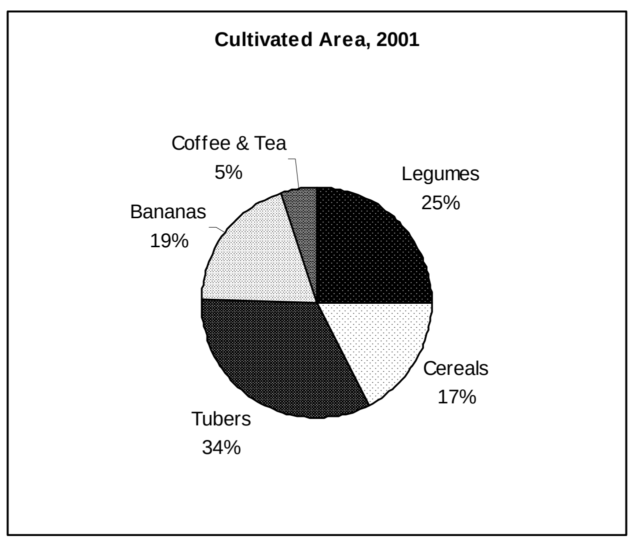


Figure 2: Cultivated Area in Rwanda Percentage by Group of Crops, 2001



2. Agricultural Statistics in Rwanda

a. Background

Rwanda is currently in transition from a period of emergency to one of development following the 1994 war and genocide. Before the tragic events of 1994, the Agricultural Statistics Division (DSA) of the Ministry of Agriculture (MINAGRI) maintained a comprehensive database of agricultural statistics. The DSA was responsible for providing information on agricultural policy based on annual surveys of rural households. These surveys were conducted under the auspices of the Enquete National Agricole (ENA).

This database consisted of two parts: (1) an annual agricultural survey (crop production, land use, cultivated area, livestock, income and expenditure, etc.), and (2) a series of focused surveys/studies on selected topics such as crop sub-sectors (beans, sorghum, sweet potatoes, coffee), agroforestry, non-farm income strategies, farm inputs use, nutrition, etc.

b. Current Status

These surveys, which were interrupted in 1994 were resumed in 1999 by the Food Security Research Project (FSRP) and the Agricultural Statistics Division (DSA) of the MINAGRI. This means that there is a gap in agricultural statistics in Rwanda between 1990 (the last year that an agricultural report was published using an agricultural survey conducted on a nationally representative sample) and 2000 (when agricultural surveys were resumed on a nationally representative sample). The resumption of these activities was aimed at updating the agricultural statistics database and improving the internal capacity of MINAGRI to collect, process, and analyze data on key food security issues and to better inform the policy making process in ways that will contribute to the promotion of food security in Rwanda.

The FSRP/DSA began conducting agricultural surveys in 1999 using a national sample of 1584 households. The FSRP/DSA collects land use and production data on a seasonal basis (twice a year). The enumerators visit the households twice per season. The first visit is for area measurement of the fields and crop density measurement. This is done two to three months after planting so that the enumerator can estimate the densities of the various crops in the fields. The second visit is for measuring production and this is done just after the harvest period. The FSRP/DSA has 11 enumerators (one per province) as compared to 78 enumerators that the ENA had before 1994. The current sample size is also 26% bigger than the one the ENA used. Since the FSRP did not have as much financial resources as those available to the ENA, it had to find a less costly but also accurate method to conduct the surveys. The most time consuming and therefore expensive activity of data collection was the area/field measurement. After considering various area measurement methodologies, the FSRP/DSA selected the P^2/A (Perimeter Squared over Area) Methodology. This methodology minimizes time and costs.

3. Estimation of Area – P^2/A Methodology (Perimeter Squared over Area)

a. Summary of Methodology

The P^2/A methodology is based on the unique relationship and relatively stable relationship between a given field's perimeter squared (P^2) and its area (A). Perimeter squared (P^2) and area tend to vary together and in the same direction. In fact, the two are so highly correlated that it would not be unreasonable to suggest that a field's perimeter could be used as a proxy measure of its area. In Rwanda the simple correlation (r) between perimeter squared and area is 0.95. For purposes of generating aggregate estimates of area in Rwanda, the average ratio between perimeter squared and area could be simply applied to our perimeter squared measurements – which are easily and accurately obtainable.

However, because fields can and do vary a great deal in shape, their P^2/A ratios vary accordingly. A square field, for example, has a P^2/A ratio of 16; whereas a field whose length is say, 3 times its width has a P^2/A ratio of 21 (see table 1). It is therefore argued that the precision of our area estimation can be improved significantly if the actual P^2/A is known for each field. An important objective of the P^2/A method is to permit the enumerator to estimate this ratio expediently and with a minimum degree of error.

Table 1: Ratios for General Form of Plot

General form of Plot	**P^2/A ratio**	**Area of field**
1x1	16	P^2/16
1x1.5	17	P^2/17
1x2	18	P^2/18
1x3	21	P^2/21
1x4	25	P^2/25
1x5	29	P^2/29

b. Practical Application of P^2/A Methodology

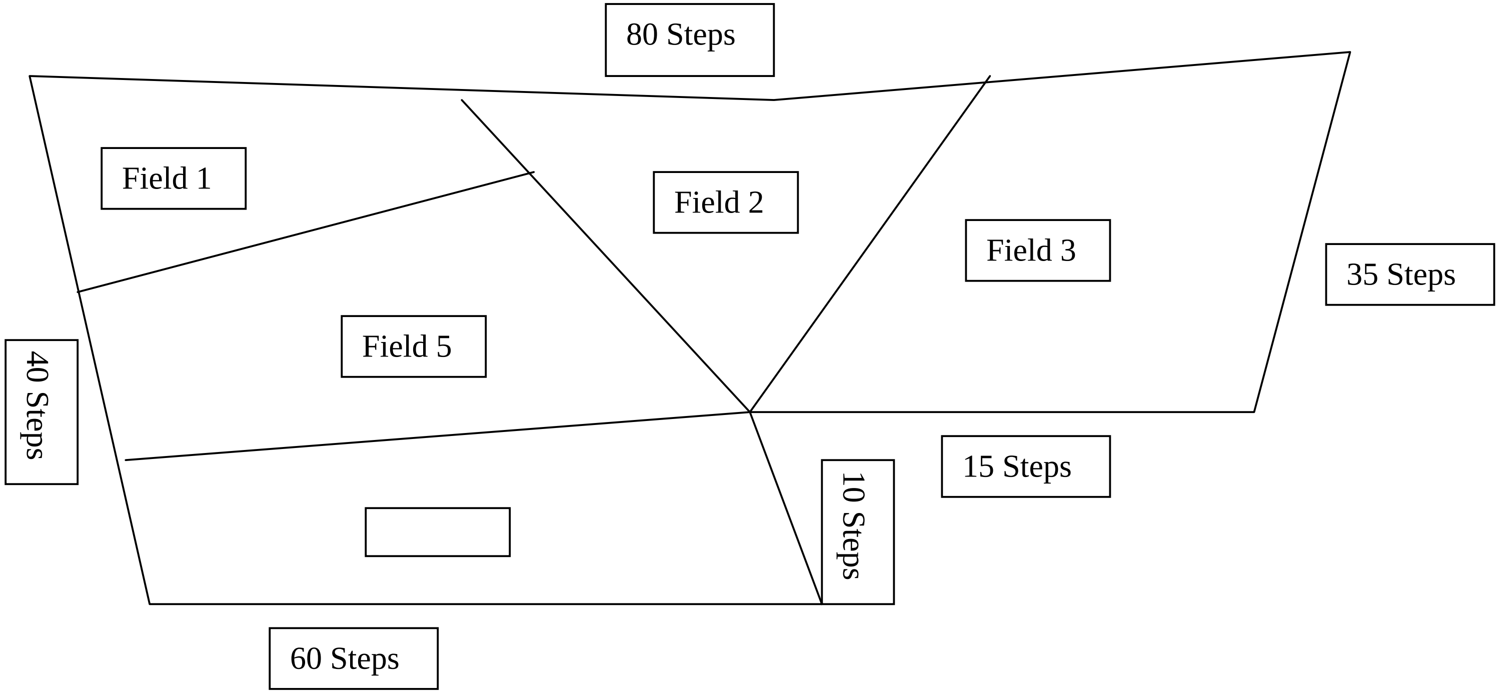
Recording the length of the enumerator's stride: In measuring the perimeter of the field, the FSRP/DSA decided to have the enumerator pace the field and record the number of steps taken around the field. It was therefore necessary calibrate the average length of each enumerator's stride and record it for use in the computation of the perimeter of the field. This is done by having the enumerator pace around several fields of known perimeter (actually measured by a tape measure). These fields are of varying slopes so as to reflect natural fieldwork conditions. After several trials, the average length of the enumerator's stride is obtained.

Sketch of the plot: In measuring the perimeter, the enumerator begins by making a rough sketch of the plot (for purposes of this paper, we will call a piece of land a "plot", and the plot often contains several "fields" (see figure 3 below). The enumerator then identifies the distinct fields within the plot and numbers them. The enumerator then measures the length of each side of the plot by pacing it and writes the number of steps next to the corresponding side of the sketch. After recording the number of steps the enumerator may need to re-adjust the sketch of the plot to reflect the actual number of steps taken. With the sketch and plot before him, the enumerator determines the rough dimensions of the plot indicating whether the plot is rectangular, triangular, or of an irregular form and in this case indicating the ratio of the sides (e.g. length x width = 1:1, 1:2, 1:3, etc.). He then fills in this information in the box below the sketch (see figure 3).

Computation of the plot area: The plot area is calculated using a computer program. The program uses the information entered in the box below the sketch (perimeter, general shape of plot, etc.). The perimeter is calculated using the sum of the enumerator's steps (of known length). Since the general form of the field has also been indicated, once can therefore calculate the area of the plot using the P^2/A methodology.

Computation of the area of the fields and the area of each crop: In Rwanda, each plot typically contains several fields and each field typically contains more than one crop due to mixed/inter-cropping. The enumerator then fills in table 2 accordingly (see table 2). For each field, the enumerator records the principal crop present in that field and the density of that crop in the field (as a percentage of a pure stand of that particular crop). The enumerator then does the same for the second, third, etc. crop present in that field as necessary. The sum of the percentages of these crops in each field do not necessarily have to add up to 100%, it can be less than or more than 100% (in mixed or inter-cropping, it is common to have these percentages add up to over 100%). This process is done for all the fields in the plot. In the last column, the enumerator estimates the percentage of the area taken up by that field in the whole plot. This process is done for all the fields in the plot. The last column should sum up (downwards) to 100%. One can therefore calculate the area of each field within the plot because the area of the whole plot has already been determined. The actual area of each crop is determined by normalizing the percentages (across) of the crop by the area of the field. A computer program is used to calculate the area of the field and each crop.

Figure 3: Plot Sheet



No. of fields in the plot: ____________________

1. If rectangle: Length (steps) = ______________ Width (steps) = ___________________

2. If triangle: Height (steps) = ________________ Base = (steps) ____________________

3. If other shape: Perimeter (steps) = __________ General form = 1x ___________(see codes)

Codes:

1 1.5 2 3 4 5 etc.

Table 2: Characteristics of the Fields in the Plot

Field N° in this plot	**Crops present in the field: This season (2002 B)** *(see crop codes)*										**Chemical fertilizers and pesticides used, season 2001 A**				**Improved seeds** *(see crop codes)*				***Area*** *Estimation of area (%) of total plot area taken up by field* *This column should sum up to 100%*
	1st crop		2nd crop		3rd crop		4th crop		5th crop		NPK Kg	Urea Kg	DAP Kg	Pesticide Kg or liter	Code	Kg	Code	Kg	
	code	density %	code	density %	code	density %	code	density %	code	density %									
1																			%
2																			%
3																			%
4																			%
5																			%
6																			%
7																			%
All other fields																			%
																			100%

Crop Codes

1-Beans	6-Maize	11-Irish Potatoes	21-Bananas (cooking)	40-Fallow	50-Other food crops.
2-Peas	7-Wheat	12-Seet Potatoes	22-Bananas (beer)	41-Pasture	51-Other cash crops
3-Peanuts	8-Millet	13-Colocases	23-Bananas (dessert)	42-Woodlot	
4-Soya	9-Rice	14-Igname	29-Bananas		60 -
5-Sorghum	10-Cassava				
		15-Vegetables	30-Coffee	49-Rugo	99-Do not know

Table 3: Production Sheet (modified)

Production Sheet	Préfecture	Commune	Secteur	Cellule	Ménage	Nom du chef de ménage: Date d'Interview:
	|___|___|	|___|___|	|___|___|	|___|___|	|___|___|	

Crop	**Did you harvest any ...(crop) during this season?** **0 - no 1 - yes**	**How much ... (crop)... did you harvest during .....** *(Write the number of units harvested. Ask more questions to get more accurate estimates if necessary)* *(Season= 6 previous months)* *Don't know=99999* **Unit used**	Number of Units **...this season?**	 **....this month?**	**Unit used during harvest** 1-kg 2-sac 3-bunch of banana 4- other (basket., bucket, etc) *specify* *Code*	 *if code 2 or 5,* *the quantity in kg*
Beans			________green ________ dry			________,______ kg
Peas			________green ________ dry			________,______ kg
Soybeans			________green ________ dry			________,______ kg
Sorghum						________,______ kg
Maize			________green ________ dry			________,______ kg
Wheat						________,______ kg
Rice						________,______ kg
Vegetables						
Sweet Pot.						________,______ kg
Irish potatoes						________,______ kg
Cassava			________green ________ dry	________green ________ dry		________,______ kg
Bananas						________,______ kg
Coffee						________,______ kg
Tea						________,______ kg

4. Estimation of Production

Production is estimated using farmer recall. Just after harvest, the enumerators visit the households to estimate production. The enumerators use the Production sheet above (Table 3) to ask the farmer how much he or she harvested. For crops that are harvested at one specific time (such as beans or maize), this is fairly easy for the farmer to remember. For the crops that are harvested over an extended period of time such as cassava and sweet potatoes, this is a bit more difficult. Even for these crops, they are usually harvested over 2 or 3 months during the season. The enumerators are trained to ask the farmers how much they harvested each week over this 2-3 month period and they then multiply by the number of months to get the season's production.

Another difficult aspect of measuring production is the use of non-standard units that farmers use to measure their production. Surveys and studies have been conducted to determine the weights for many of these non-standard units so conversion factors are known. Where the farmer uses a measure that is not known the enumerator estimates the weight of the measure and records it.

5. Conclusions on the Methodology

a. Area Measurement using P^2/A Methodology

This methodology is ideal when there is a limited number of enumerators with a need to survey a large sample. It allows enumerators to measure area fairly quickly and also cuts down survey costs. In a country such as Rwanda where the average household has 4 plots of irregular shapes, it would take a very long time to measure area using the traditional methods of measuring field angles and perimeter using a tape measure. The P^2/A methodology is flexible and has been found to be fairly accurate. Field trials of this methodology found a 12% gross error in actual area measurement at the plot level. This represents over and under estimation which cancelled out to give a 2% net error. This is considered a significantly unbiased estimate especially at the aggregate provincial or national level. This also allows one to use fewer enumerators thereby reducing training costs and enumerator errors and it is also easier to supervise fewer enumerators. It is also important to re-calibrate the stride of the enumerator during the course of the season as it may change with time. In a country such as Rwanda that is very hilly, the step of the enumerator may also vary depending on the slope of the land. The more sides that a field has increases the incidence of error. Measuring field angles and using a tape measure is obviously a more accurate method but takes a lot of time and therefore increases costs.

b. Production Estimate

This recall method saves a lot of time and keeps the costs down. For crops harvested at one specific time, this method works well. For crops that are harvested over an extended period of time such as the root and tuber crops, this is more difficult to measure. A farmer may not remember the amount harvested four months ago and may give an erroneous answer. The ideal method for measuring crop production for crops that are harvested over an extended period of time, is to do repeat visits to the household by the enumerator every 2 weeks or every one month.

6. Recommendations

Agricultural statistics are critical for any country and especially more so for developing countries where about 90% of the population is dependent on agriculture and a large percentage of the GDP (40% in Rwanda) comes from agriculture. Having good accurate statistics is also very costly. The decision makers who have to allocate budgets for statistical programs may not appreciate the importance of statistics and therefore be reluctant to spend many resources on them. It is therefore important for statisticians to promote the importance of statistics whenever a chance is available.

Knowing that there is often a shortage of resources for statistics, statisticians should also be creative and innovative in designing survey methodologies that address the demands of the clients without compromising the accuracy of the data. One such methodology is the P^2/A methodology for measuring area. Another possible methodology is the use of GPS to measure area. The GPS system may require a substantial initial investment but in the long run it is very accurate and can be used to address a variety of demands, not only agricultural.

In setting up expensive systems such as the GPS system, several ministries/services can consider collaboration in sharing the initial costs. The results from the use of such a system can be applied to a wide of range of services such as mapping roads, health centers, educational centers, etc. in addition to area measurement for agriculture.

Finally, in countries where human resources in statistics are limited, they can consider centralizing their statistical services under one agency/unit. This allows the consolidation of smaller units (in human resources and equipment) to create a critical mass of human resources that can benefit from synergies.

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