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Targeting Agricultural R&D for Poverty Reduction: General Principles and an Illustration for Sub-Saharan Africa

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1. Introduction

Poverty has clear geographical dimensions. Large differences between the standard of living of the populations in different geographical areas and "pockets of poverty" are common in all countries, developed and developing. The reasons for these differences in the standard of living and the incidence of poverty are the differences in the agro-climatic conditions, the geographic conditions -- particularly the distance to the main urban centers and the main transport routes, the endowments of natural resources -- including water, and the terrain. In addition, government policies that reflect a host of economic, political, or demographic considerations all too often have a regional bias that augments rather than mitigates the differences. As a result, to take just few examples, mean per capita consumption of the rural population in the Indian state of West Bengal is only half the consumption level in Punjab, and the Headcount measure of poverty in West Bengal is nearly four times higher than its level in Punjab (Datt Ravallion, 1993); the incidence of poverty in the "inland" provinces in eastern China is much higher than in the coastal provinces; in Bangladesh, the headcount measure of poverty in rural areas varies between less than 10 percent in some districts and more than 60 percent in others (Ravallion and Wodon, 1997); in Nigeria, more than two-thirds of the rural poor households concentrate in less than 20 percent of the villages; in Burkina Faso, the incidence of poverty in around one-fifth of the villages is less than 25 percent, whereas in more than half of the other villages the incidence of poverty is well over 60% (Bigman *et. al.* 1999); in Ecuador, the incidence of poverty varies between less than 10 percent in some districts to nearly 60 percent in others (Hentschel *et. al.* 1999). Indeed, in many developing countries the differences in the standard of living between regions are often larger than the differences within region.

Poverty has geographical dimensions also at more local levels. Districts and even villages within the same agro-climatic regions can differ considerably in their standard of living, due to differences in their proximity to the urban centers or to the main transport roads, the quality of the access roads, the availability of public services, and/or the distance to the source of drinking water. Households in villages that are close to the city have much greater trading opportunities and can be engaged more in non-farm activities; farmers in more remote villages, or in villages that do not have access to the transport roads during the rainy season, must grow principally for self consumption. Differences in access to public services, including agricultural extension services and in the quality of the road infrastructure are often the main reasons for the large differences between villages within the same region and they reflect mostly the bias in government policies.

Agricultural research, development, and extension services also have clear geographical dimensions: The larger the country and the more varied its agro-climatic conditions, the larger the differences between the crops grown in different regions and between their farming systems. As a result, commodity-based research programs affect mostly those regions in which these commodities are the main crops, and thematic research programs affect mostly the regions that have the specific (soil, climatic, etc.) conditions which are the subject of the research. Even a relatively small country like Kenya exhibits considerable geographic diversity in agricultural production due to significant differences in climate and soil texture and composition between regions. In the densely populated medium-rainfall zone, the main crops are coffee and horticulture products, whereasin the arid and semi-arid lands, where the population density is much lower, farming is more subsistence oriented, with the main crops being maize, beans and cassava. Farmers in the semi-arid and arid zone will therefore benefit only marginally and indirectly from a research program on cash crops like horticulture products, sugarcane, or coffee, but they are the main beneficiaries of a research program on cassava.

Agricultural R&D also has significant geographical dimensions at more local levels: In some regions, neighboring areas differ in their crop selection because of location-specific soil problems, such as acidity, alkalinity, salinity etc. In other regions, particularly in SSA countries, the distance to the urban center and the access to an all-weather road are factors that have a strong impact on the farming system and on the selection of crops. As noted earlier, farmers that reside further away from the urban center or from the main transport road must grow crops mostly for self-consumption, whereas farmers in the same agro-climatic region but closer to the urban centers can specialize in high-value crops. In Kenya, maize is grown in all geographical areas; in some areas, however, it is grown primarily by small scale producers for home consumption while in other areas production is predominantly in large-scale mixed farms that produce maize, wheat, and barley (Kilambaya, Nondwa and Omamo, 1998). These different systems require, however, different production technologies, different genetic material, and a different organization of extension services. R&D projects that improve production technologies used by large-scale farming will benefit the small-scale producers only marginally.

The large differences in the standard of living and the prevalence of poverty between different geographical areas on the one hand, and differences in the cropping patterns and farming systems between many of these areas on the other hand suggest that agricultural R&D programs, combined with well designed extension services can be an important policy instrument to reduce poverty. By targeting agricultural R&D on commodities that are common in the farming systems of the poor, and targeting the extension services on areas where the poor concentrate, these measures can bring about and increase in output and/or reduction in production costs of the poor thereby raising their incomes and reducing the incidence and depth of poverty.

This paper presents a methodology for assessing the impact of agricultural research, development, and extension on poverty and incorporating this assessment in the process of setting priorities for agricultural R&D projects and programs. Section 2 introduces the general principles of the methodology. Section 3 develops an analytical model that demonstrates the effect of the different factors that determine the criteria for setting priorities among agricultural R&D projects based on their impact on poverty. Section 4 illustrates the use of survey data in Burkina Faso for mapping the incidence of poverty across villages in the country's rural areas. Section 5 offers some concluding remarks.

2. The Methodology

The method developed in this paper for assessing the impact of an agricultural R&D program on poverty has three stages: First, estimating the geographical distribution of the gains from the research program. Second, evaluating the impact of the program on the incomes of the rural population in these geographical areas. Third, calculating the effects of these income changes on the spread and depth of poverty in each of the areas and in the country as a whole. In the next section, we present an analytical model that evaluates the contribution of the various variables that jointly determine the impact of agricultural research programs on poverty. The current section outlines the basic principles of this evaluation.

The general method of estimating the costs and benefits of projects has been developed in ISNAR and IFPRI (see Alston *et al*. 1995). This method consists of the following steps:

1. Estimate the potential for the generation and adoption of the innovation developed in the research project.
2. Estimate the economic costs and benefits of this innovation. These costs and benefits are estimated for each year over the entire period during which the innovation is expected to be operative.
3. Calculate the net present value of the innovation as the discounted value of the stream of costs and benefits during this time period.

The first step of estimating the research *potential* has, in fact, two components: One is estimating the probability that the research will be successful in that it will generate the 'technological innovation' that will yield the desired *outcome*, namely the increase in yields or the reduction in costs. The second component is estimating the probability of adoption, i.e., the 'adoption profile' (Bradford and Kamau, 1998). This probability depends on the expected increase in the yield, the expected additional costs of adopting the new technology — which depend, in turn, on the additional inputs that are required for implementing the new technology — and the prevalence of the farming systems for which this technology is most suitable. The probability of adoption may also depend on local spatial variables, primarily the distance to the urban center and/or to the main transport routes. These spatial variables are significant for several reasons: First, the costs of adopting the new technology include the costs of transporting the necessary inputs and/or outputs; second, the frequency of the visits of extension workers tends to decline with the increase in the distance from the urban centers; third, the distance from the village to the urban center reduces the capacity of the local farmers to adopt production technologies for tradable crops; fourth, the distance to the urban centers also reduces the farmers' capacity to obtain the credit which may be necessary to buy the new inputs. The geographical distribution of the gains from the *outcome* of the research program thus depends not only on the agro-climatic conditions in the country's regions — which determine the crops that farmers can grow —, but also on these local spatial conditions.[1]

The impact of the local spatial conditions on the one hand and differences in the socioeconomic characteristics between villages, including differences in the size of the plots under cultivation, on the other hand are the reasons for the multiplicity of farming systems within the same agro-climatic region. In Kenya, the Kenyan Agricultural Research Institute (KARI) estimates that there are 33 major farming systems in the country's 5 agro-climatic regions. In the coastal area, KARI identified 9 farming systems, ranging from farms that concentrate on high value crops such as coconut, mango, and citrus, to subsistence-oriented farms in which maize, beans, and cassava are predominant. Table 1 provides the details of these farming systems in order to highlight the large differences between them. In the more arid zones, the farming systems are fewer in numbers and less varied, but there are significant differences between farming systems dominated by maize and beans and farming systems in which livestock is dominating (Kilambaya et al. 140-41). [2] In some regions, farming systems in smaller the geographical areas tend to be quite similar, because they are all affected by the same agro-climatic local geographic conditions. In these regions, the smaller the geographical area for which the outcome of the research is estimated, the smaller the difference between households within these areas, and the larger the differences *between* areas. In other regions, particularly in the LAC countries, differences in the size of the plots owned by the farmers and the forms of ownership — ranging from the giant plantations of the rich farmers to the poor sharecroppers — determine the differences in their crop selection.

The second part of estimating the impact of agricultural R&D programs on the incomes of the poor requires a detailed mapping of poverty in the country. The method of estimating the spatial distribution of poverty in a country will be discussed and illustrated in section 4. Once this mapping has been accomplished, the final step is to evaluate and compare the performance of targeted programs in order to select the most desirable one(s). This evaluation requires proper performance measures that express the social costs and benefits from the program. The measures that are commonly used for evaluating the performance of poverty alleviation programs are the following:

- Type I error — The "error of inclusion": The size of the *non-poor* population which is covered by the program due to inaccurate targeting, and their share in the *total* population which is covered by the program (also referred to as 'vertical inefficiency').
- Type II error — The "error of exclusion": The size of the *poor* population which is *excluded* from the program due to inaccurate targeting, and their share in the country's *total poor population* (also referred to as 'horizontal inefficiency').

- The budgetary costs of the program — including the program's administrative costs. For agricultural R&D programs, these costs include the costs of conducting the research as well as the costs of disseminating the new technology.
- The effects of the program on the behavior of households and the implications of these effects for the households' welfare and the government budget. [3]
- The effects of the program on poverty reduction.

The performance of the program thus depends on the *criteria* that are used to determine eligibility for the program, the *instruments* that are used to implement the targeted program, and the *performance measures* that are used to evaluate the program.

The extent to which poverty was reduced as an effect of the program is obviously the most direct and self-evident performance measure for evaluating a poverty alleviation program. The specific indicator to be used for measuring the reduction in poverty must be carefully selected, however, and this, in turn, requires a proper selection of the *poverty measure*. If poverty is measured by the Headcount measure, for example, then a program that raises the income of the target population would achieve the greatest reduction in poverty if it is targeted on those areas where the individuals are the *least* poor, leaving out the more extreme poor. For this reason, the Headcount measure is not a suitable performance measure for evaluating a program aimed at alleviating poverty, and this example only highlights the potential problem with using an improper performance indicator.

Among the criteria noted above for evaluating a targeted program, the error of inclusion and the error of exclusion generally received most of the attention, due to their intuitive appeal. However, these criteria do not provide a complete measure for the budgetary implications of a program. Clearly, however, the larger the Type I error, the higher the costs of the targeted program. Likewise, the larger the Type II error, the smaller the cost increase with a non-targeted program which provides the same reduction in poverty. [4]

For geographical targeting in general, and for geographical targeting of agricultural R&D programs in particular, the performance measure is based on a comparison of the performance of the program in one area with its performance in another area (and this comparison may include also a non-targeted program). The performance measure used in this paper for ranking alternative geographically targeted programs is the following:

A program targeted on one geographical area is more beneficial than a program targeted on another area if, with the same budgetary costs, the reduction in poverty with the first program is larger than the reduction in poverty with the alternative program.

The following section presents an analytical model for calculating the gains from a targeted R&D program in terms of these performance measures.

3. The Analytical Model

The impact of an agricultural R&D program targeted on specific crops on a country's poverty depends on the following factors:

- The increase in the yield of these crops as an effect of the technological innovation resulting from the research program,
- The number of poor farmers that adopted the new technology,
- The share of these crops in their farming system,

The geographical distribution of the program's impact on poverty is thus determined by the agro-climatic regions in which these crops are grown and the share of these crops in the farming systems of the poor in these regions. The impact of the new technology that resulted from the commodity program on the yield of the target crop(s) depends on the specific *research project* that was carried out within this program, i.e., the specific factor input (e.g., seeds, fertilizers, machinery) that was the subject of the research.[5] To highlight the contribution of each of these factors, we introduce the following analytical model: Let

$$Q_A = F_A (x_{A1},\ldots,x_{Ap}) \qquad (1)$$

be the production function of crop *A* that is the subject of the research program, $(x_{A1},\ldots,x_{Ap})$ being the quantities of the *p* factor inputs required for production. The technological innovation that resulted from the research program is assumed to have the effect of a *factor augmenting technical change*, i.e., a technological innovation that 'augments' the input (measured in efficiency units) of the production factor that was the subject of the specific research project within the commodity program. Let the increase in input of the *k*-th factor, measured in efficiency units, as an effect of the research project be denoted as Δx_{Ak}. The increase in yield/output as an effect of this increase is given by: $\Delta Q_A = F'_{Ak} \bullet \Delta x_{Ak}$, where $F'_{Ak} = \partial F_A / \partial x_{Ak}$ is the marginal product of F_A with respect to the *k*-th factor input. The extent to which the technological innovation that resulted from the research project 'augmented' the input of that factor is assumed to be function of the direct research expenditures on that project, and given by:

$$\Delta X_{Ak} = \rho_{Ak} \bullet R^{\varepsilon}_{Ak}. \qquad (2)$$

The parameters ρ_{Ak} and ε, which measure the impact of the innovation on the productivity of the *k*-th factor, indicate, in turn, the average and marginal 'productivity' of the research expenditures in this program.[6]

The increase in the income of farmers who adopted the new technology depends on the share of the commodity in their farming system, and on the increase in the output of that commodity as an effect of the innovation.[7] For an individual farmer in the *i*-th geographical region, this increase in income is given by:

$$\Delta Y_i = w_{iA} \bullet P_A \bullet F'_{Ak} \bullet \rho_{Ak} \bullet R^{\varepsilon}_{Ak} \qquad (3)$$

where w_{iA} is the share of commodity *A* in the farming system of that farmer in the *i*-th area. To simplify the notations, we assume that an *area* (denoted in *italics*) is defined as a *farming system within a geographical area.*

The probability that farmers in a given *area* adopt the new technology is a function of the dissemination costs in that *area* and the socioeconomic characteristics of the local farming population.[8] The dissemination costs are a function of the size of the rural population in that *area*, and they are given by: $D_i = \alpha_i\{S_i \bullet N\}$, where S_i is the share of the *i-th area*'s (rural) population in the country's total (rural) population and N is the country's total (rural) population. The proportionality factor α_i, which determines the dissemination costs per household, is primarily a decision variable, but it is also affected by the distance of the *area* from the urban center, the quality of the roads, and possibly also by other *area*-specific characteristics. The probability of adopting the new technology is assumed to be determined as an exponential function of the dissemination costs as follows:

$$A_i = \gamma_i\, [(\alpha_i)^{\nu}\{S_i \bullet N\}^{\theta}] \qquad (4)$$

This formulation assumes that the probability of adoption by an individual farmer is increasing with an increase in the population density in the region, and the parameter $\theta > \nu$ represents the sensitivity to this effect. This parameter reflects the importance of access to information through social learning mechanisms which, in SSA, is often more important than either the extension services or the household's educational endowment.[9]

The *total* increase in the income of the entire poor population residing in that *area* is therefore given by:

$$A_i \bullet \Delta Y_i\{S_i \bullet H_i \bullet N\} = [P_A \bullet F'_{Ak} \bullet \rho_{Ak} \bullet R^{\varepsilon}_{Ak}] \bullet [\gamma_i \bullet (\alpha_i)^{\nu} \bullet w_{iA} \bullet \{S_i \bullet N\}^{(1+\theta)} \bullet H_i] \qquad (5)$$

This increase in the income of the poor will also be (approximately) equal to the reduction in the poverty gap.[10] Two groups of variables determine the size of that increase: One is the group of variables that measure the increase in the income of a farmer who produces commodity *A* as an effect of the technological innovation that resulted from the R&D project; the other is the group of variables that measure the impact of that increase on the overall increase in income of the poor populations in the target *area*, taking into account the rate of adoption of the new technology, the share of commodity *A* in the farming system in that area, and the share of the poor in the overall population in that *area*.

Three alternatives must be considered in evaluating the desirability of a research program targeted on commodity *A* and on *area i*:

- First, targeting the same commodity program on another *area* — by redirecting the dissemination expenditures
- Second, targeting a different commodity program on the same *area* — by redirecting the R&D expenditures
- Third, targeting a different commodity program on another *area* — by redirecting both the R&D and the dissemination expenditures.

Let us examine each of these alternatives sequentially:

First, targeting the same commodity program on another *area*: From Eq. (5) we can conclude, after some algebra, that, *with the same budgetary costs*, a program targeted on *area i* will bring about a larger reduction in poverty than the same program targeted on *area j* if and only if:

$$\gamma_i \bullet w_{iA} \bullet \{S_i\}^{(1+\theta-\nu)} \bullet H_i > \gamma_j \bullet w_{jA} \bullet \{S_j\}^{(1+\theta-\nu)} \bullet H_j \qquad (6)$$

Eq. (6) clarifies that the selection of the *area* for targeting depends not only on the incidence of poverty in that *area*, but also on the likelihood that the farmers in the target *area* will adopt the new technology, and on the share of that commodity in their farming system. Notice that the expression $[\gamma_i \bullet w_{iA} \bullet \{S_i\}^{(1+\theta-\nu)} \bullet H_i]$ can be written as $[w_{iA} \bullet S_i \bullet H_i] \bullet [\gamma_i \bullet \{S_i\}^{(\theta-\nu)}]$, where the first expression indicates the share of the commodity in the farming system of the country's *total* poor population, and the second expression indicates the impact of the *area*'s socioeconomic characteristics on the probability of adoption.

The second alternative is to target the research program on a different commodity, but in the same *area*.[11] From Eq. (5) we can conclude that, *with the same budgetary costs*, targeting a different commodity program on the same *area* will be less beneficial, in the sense that it will bring about a smaller increase in the income of the farmers in that area, if and only if:

$$\Delta Y_i(A) = [P_A \bullet F'_{Ak} \bullet \rho_{Ak}] \bullet w_{iA} > \Delta Y_i(B) = [P_B \bullet F'_{Bk} \bullet \rho_{Bk}] \bullet w_{iB} \qquad (7)$$

The latter condition clarifies that the selection of a proper commodity program depends not only on the prospects of achieving a large increase in yield, but also on the *value* of this increase for the farmers, and on the share of the commodity in the farming system in that *area*. It should be noted, though, that implicit in the condition in Eq. (7) is the assumption that the probability of adoption depends on the socioeconomic and geographic conditions in the *area*, but not on the characteristics of the specific crop. It may be the case, however, that the adoption rates differ between crops due to, for example, significant differences in the costs of the necessary inputs. In India, one of the main obstacles to the adoption of high-yielding cotton seeds by poor farmers is the need for expensive fertilizers and new hybrid seeds each year. Indeed, the specification of the various conditions in our model is primarily illustrative and would have to be re-examined and econometrically tested in empirical studies.

The third alternative is to target the research on a different commodity program in a different *area*. Eq. (5) clarifies that the decision depends on the following measures:

- The impact of the innovation on the income of farmers in that *area* who adopted the new technology, given by: $[P_A \bullet F'_{Ak} \bullet \rho_{Ak} \bullet R^{\varepsilon}_{Ak}] \bullet w_{iA}$. The decision variable that determines this impact is the direct R&D expenditures R_{Ak}. The actual impact of this decision depends, however, not only on the marginal productivity of the R&D project – measured by the increase in yield as an effect of the innovation that resulted from the research – but also on the share of the commodity in the farming system in the *area*, and on its market price. The market price is relevant to farmers who can engage in trade.
- The probability that farmers in the *area* will adopt the new technology, given by: $[\gamma_i \bullet (\alpha_i)^{\nu} \bullet \{S_i \bullet N\}^{\theta}]$. The decision variable that determines this probability is the dissemination costs per household in the *area* — α_i —, but the rate of adoption depends also on area-specific socioeconomic and geographic conditions.
- The size of the general population in the *area*.
- The incidence of poverty in the *area* — as indicated by the Headcount measure.

These conditions emphasize that a successful implementation of an agricultural R&D program that is aimed at reducing poverty depends not only on the choice of crops that are grown in the farming systems of the poor and/or on the choice of geographical areas in which the incidence of poverty is high. Equally important for the success of the program are *area*-specific socioeconomic and geographic characteristics that determine the effectiveness of the dissemination program. Agricultural R&D, therefore, may not be a suitable policy instrument for poverty reduction in *areas* where the rate of adoption of the new technology is likely to be very low. In these *areas,* other policy instruments should therefore be considered. Even in these *areas*, however, the effectiveness of agricultural R&D as a policy instrument for poverty reduction should be evaluated against the costs and benefits of *available* alternative policy instruments aimed at achieving this goal.

The same conclusion applies to other programs as well: The impact of an anti-poverty program targeted on specific areas depends not only on the relative size of the poor population in the target areas, but also on the socioeconomic, agro-climatic, and geographic conditions in these areas, since these conditions determine the program's effectiveness. In some geographical areas, agricultural R&D may prove to be the most effective policy instrument for raising the income of the rural poor, while in other perhaps equally poor areas, other policy instruments could be more effective. The selection of an effective anti-poverty policy therefore requires two types of decision: First, a choice of the area for targeting and second, a choice of the most effective instrument for implementing that policy. These choices cannot be made sequentially, however, since the effectiveness of most programs depends on the socioeconomic and geographic conditions in the area in which they are implemented.

Using the same set of equations, we can also calculate the increase in the *total income* of the population in each *area* as an effect of an agricultural R&D program, and the conditions for selecting the target *areas* in order to maximize the increase in farmers' total income. These conditions are likely to be considerably different from the conditions for maximizing the reduction in the poverty gap, and the differences are larger the larger the difference between the poor and more affluent farmers in their farming systems and in the rate of adoption of a new technology. As a result, the commodity programs and the *areas* that will be selected for targeting poverty-reduction programs are likely to be considerably different from the commodity programs and the *areas* that will be selected in order to maximize the total income of the rural population. A direct result of these differences is that commodity programs targeted on specific areas with the objective of maximizing the increase in *total income* are likely to lead to an increase in *income inequality* among the rural population.

The difference between these two goals — maximizing the increase in total income, and maximizing the reduction in poverty — has important implications for the selection of agricultural R&D as a policy instrument for the reduction of poverty. To illustrate these implications consider the case in which *area j* is the *area* selected on the basis of the criteria for maximizing the increase in total income. Assume, however, that, with the same budgetary costs, a program targeted on *area j* can bring about a larger reduction in poverty. In this case, the larger the difference in the increase in total income between these two programs, the larger the increase in income inequality as a result of targeting the program on area *i* rather than on area *j*. This difference in the increase in total income therefore represents the *opportunity costs* of targeting the program on area *j* in order to achieve the maximum reduction in poverty. This difference also has another interpretation, however: If the economic costs of re-distributive measures aimed at bringing income inequalities back to their previous level are larger than this difference, then a combination of measures that includes targeted agricultural R&D aimed at achieving the maximum increase in *total* income together with re-distributive measures aimed at preventing an increase in income inequality will be *less* desirable than the direct measure of targeting agricultural R&D in order to achieve the maximum reduction in poverty.

4. Poverty Mapping

In the SSA countries, geography is often the single most important factor that determines the incidence and depth of poverty. However, the mapping of poverty in these countries cannot be determined on the basis of agro-climatic conditions alone for two reasons: First, differences in the agro-climatic conditions by themselves are seldom straightforward indicators of differences in the incidence of poverty. The semi-arid regions, for example, where production is intrinsically risky and large areas are too dry for rain-fed agriculture, are generally assumed to be the poorest. In these areas, however, the population pressures on the land are still relatively small, and households' plots tend to be relatively larger. In the more humid regions, by contrast, the fertile lands attract many migrants and, with the rise in population density, the average size of the plots is shrinking, the share of landless rural workers is rising, and, as a consequence, the incidence of poverty is also rising. Second, local factors are equally important. Thus, for example, in many humid regions the soil quality is quite poor and many of these areas are more prone to malaria which can significantly reduce farmers' production capacity. Distance and the quality of the infrastructure are often equally significant factors for crop selection as the agro-climatic conditions. As a result of these additional factors, many studies that examined whether the incidence of poverty in the "low potential" rural areas is *necessarily* higher did not come up with a conclusive result (see Heisey and Edmeades, 1999, for a list of references).

Poverty mapping in the SSA countries can therefore not be determined on the basis of the agro-climatic conditions alone and it must rely on more direct sources of information on income and consumption of the population in the different geographical areas. In the absence of reliable data on income or consumption, indirect indicators such as life expectancy, child mortality, child morbidity, etc. in different geographical areas may also be used. The main source of direct data on income or consumption in a country is the Household Income and Expenditure Survey, which collects detailed data of a representative sample of households in the country's main administrative regions. In many SSA countries, the income data were found to be deficient, however, and the poverty assessment had to be based on the expenditure data. The sample of households in the survey is selected so as to provide a statistically adequate representation not only of the entire population in the country, but often also of the population in the country's main administrative regions. This sample is not sufficient, however, to determine the geographical distribution of poverty in the *agro-climatic* areas — the areas relevant for the analysis of the impact of R&D projects —for two main reasons:

- First, in most cases, administrative regions have considerably different boundaries than the agro-climatic areas. Without additional information, it will not be possible therefore to stratify the sample of households that were included in the Income and Expenditure Survey according to the agro-climatic areas in which they reside..
- Second, the administrative regions are relatively large and often quite heterogeneous in terms of the standard of living. In many SSA countries, there are considerable differences in the standard of living between districts and villages within the same administrative regions as a result of differences in local geographic conditions. The sample size of the survey in these smaller areas is far too small, however, for statistically valid inferences.

Typically, the entire sample of households in the Household Survey in the SSA countries is divided into 5-6 subgroups: 1-2 urban 'areas' (e.g., the capital city and *all* other urban areas), and 3-4 administrative rural regions. The sample size in these subgroups/areas is usually large enough to provide an adequate representation of their populations and thus to allow a statistically valid estimation of the incidence of poverty within these subgroups/ administrative areas. A first-round assessment of the geographical distribution of poverty can therefore be made at the level of these administrative areas. In these assessments, the Type I and Type II errors are likely to be quite high, however. Poverty mapping could therefore be significantly improved, and the targeting errors could be considerably reduced, if the poverty mapping were made for smaller areas and the programs were targeted on those areas in which the majority of the population is poor.

The main objective of this section is to present a method of using the Household Survey data for mapping poverty in smaller geographical areas of districts, sub-districts, or even villages. The method is based on using the Household Survey in combination with data from other sources that provide information on the characteristics of these areas and their populations.

These data sources include other surveys, such as the Agricultural Survey or the Demographic and Health Survey (DHS), that cover only a sample of the population in a sample of districts and/or villages, as well as the population census that covers the entire population and climatic data that cover all districts. The first and most important step in the mapping of poverty within these smaller geographical areas is to bring together the information from the different surveys at the level of the district or the village on the basis of their geographical coordinates and organize the data as a geographical information system (GIS).

The complete method of estimating the standard of living and the incidence of poverty in smaller geographical areas of districts or even villages thus involves the following steps: [12]

1. Construct a large data set from a wide variety of sources in the form of a GIS. This data set includes several strata of information: first, demographic and socioeconomic information at the *household* level from a variety of surveys and from the population census; second, community-level information, including information such as the distance to urban centers, the location of schools and health clinics, the condition of the road infrastructure, the location of the sources of drinking water, etc.; third, region-level information on agro-climatic and geographic conditions, including the location of the main cities towns, the main transport routes, and the distance to the ports. The entire data set is integrated at the level of the district (village) using geo-referencing, and organized in the form of a GIS database.
2. This data-set, together with the detailed data of the Income and Expenditures Survey are used in an econometric analysis to construct a prediction model of the households' per capita consumption — as a function of household-, community-, and region-level variables. In this analysis, the dependent variable is the level of consumption per capita of the households that were included in the survey. The household-level explanatory variables are the relevant characteristics of the corresponding households for which data is available in the Income and Expenditures Survey (e.g., the size of the household, the age distribution, etc.). The community- and region-level explanatory variables are selected from the GIS database for the districts (villages) that were sampled in the Income and Expenditures Survey. These explanatory variables include only those variables for which data on *mean* values per district (village) are available for *all* districts (or *all* villages) in the country. They can include characteristics of the households in the

community from the Census (e.g., average size of the household, dwelling conditions of the average household, etc.), characteristics of the community (e.g., number of households in the community, distance to the urban center, etc.), and agro-climatic data for the region. (see the list of explanatory variables that were used in the study on Burkina Faso in Table 3).

3. The predictions of this model are applied to derive estimates of the *average* level of per-capita consumption of the households in *all* districts (or *all* villages) in the country, including the ones that were not included in the Household Survey, on the basis of these explanatory variables.

4. The estimates of the average level of per-capita consumption in a district (village) determine, in turn, the spatial distribution of poverty. In this mapping, the entire population of a district (village) in which the estimate of per capita consumption is below the poverty line is classified as 'poor'; the entire population of a district (village) in which this estimate is above the poverty line is classified as 'non-poor.' Using several poverty lines for the classification can further refine this mapping of poverty (see below).

The quality of the estimates in the econometric analysis depends first and foremost on the quality and the quantity of the additional data that can be obtained from all other sources on the households, the communities, and the regions. The study on the mapping of poverty at the village level in Burkina Faso started by collecting the data of all the surveys that were available in the various government ministries and professional institutes in that country.[13] It was the first time that such a concerted effort to collect data from all these sources was conducted. Table 2 lists the various surveys that, after screening, were found to have relevant data at an adequate quality and could be used in this study. This table highlights the fact that even in countries like Burkina Faso, that may not be known to have extensive socioeconomic, geographic, and agro-climatic data, there is, in fact, a very substantial data set that can be made available for this type of analysis. Table 3 lists the final set of variables that were used in the econometric analysis.

The classification of villages as 'poor' or 'non-poor' is sensitive not only to the accuracy of the econometric estimation and the available information in the GIS database, but also to the (arbitrary) selection of the poverty line. To reduce the impact of the latter and create a clear distinction between villages that were classified as 'poor' and those that were classified as 'non-poor,' *three* poverty lines were selected for the study in Burkina Faso. These three poverty lines determined, in turn, four categories of poverty for the villages — ranging form the 'extreme poor' to the 'non-poor'— depending upon the estimate of the average per capita consumption of the households in the village. This classification significantly reduced the error of inclusion (Type I) of a program targeted on the 'extreme poor' villages only. The villages in this category in the study in Burkina Faso were 25% of the total number of villages but they included over two-thirds of the rural poor. This classification also reduced the probability that villages that were classified as 'non-poor,' and could therefore be the target of cost recovery programs, will include more than a very small number of poor. Map 1 illustrates the outcome of the analysis by showing the distribution of the villages in one administrative department in Burkina Faso across these four categories of poverty.

The objective of the study in Burkina Faso was to examine criteria for the geographical targeting of government health and education programs. For these programs, village level targeting may be necessary. For targeting agricultural R&D programs, however, village level targeting is far too detailed, and, in many cases the relevant target areas will be the country's agro-climatic regions. In some regions, though, where significant differences exist between farming systems in sub-regions due to local geographic condition, targeting agricultural R&D on smaller geographical areas will be desirable. Even when the target areas are the agro-climatic regions, however, the data of the Household Income and Expenditures Survey cannot be used directly for mapping poverty at this level. If the data in the Survey can be geo-referenced at the level of the village or the district it may be possible to stratify the data according to agro-climatic regions rather than administrative areas. In that case it may be possible to generate the mapping of poverty at the level of agro-climatic regions, provided that the size of the sample of households in each region is sufficiently large. If this is not possible, or if the goal is to determine criteria for targeting at sub-regional levels, the following method can be used to estimate of the standard of living and/or the incidence of poverty in these geographical areas:

- First, conduct the econometric analysis described earlier in order to obtain estimates of the standard of living at the level of smaller administrative areas — the district or the village — for *all* smaller administrative areas in the country.
- The entire population in the smaller administrative area in which the average per capita consumption falls below the poverty line will be classified as 'poor.' The entire

population in all other districts will be classified as 'non-poor.' If more than a single poverty line is used, then several categories of poverty will be determined.

- The next step is to "add up" the small administrative areas (similar to adding up pieces of a puzzle) so as to provide the best coverage of the target area – the agro-climatic region or the sub-region – by these smaller administrative areas. The smaller administrative areas that are contained in the target area may thus be part of different administrative areas.
- The estimate of poverty in the target area will be determined according to the share of the population in the smaller administrative areas which were classified as 'poor'.

5. Concluding Remarks

In 1997, the CGIAR System adopted new policy guidelines that gave the highest priority to the achieving poverty alleviation through resource conservation and management, increasing the productivity of commodity production systems, improving the policy environment, and strengthening national research capacity.[14] The implementation of these guidelines requires a coherent methodology that will provide a comprehensive impact assessment of agricultural R&D programs in terms of their effect on poverty. Most of the analytical work in the past two years on the development of the necessary methodology focused on poverty mapping. The analytical model developed in this paper suggests, however, that poverty mapping is only one component of the required methodology. An equally important component is a detailed mapping of the incidence of the benefits from the R&D program across geographical areas and farming systems. Another necessary component is a method of estimating the incidence of poverty in the target areas for agricultural R&D programs.

The paper also emphasizes that, even when the goal of poverty reduction is given the highest priority, agricultural R&D program may not always be the most effective policy instrument to achieve this goal. In some countries, the underlying socioeconomic and geographic conditions in the areas where the poor concentrate, or the characteristics of the new technology that was developed in the program, may slow down the rate of adoption of this technology and thereby reduce the impact of agricultural R&D program on the poor. In many developing countries, the alternative distributive policy instruments are either non-available or highly ineffective, and targeted agricultural R&D programs can play a significant role in alleviating poverty and reducing income inequalities.

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Table 1. The characteristics of the farming systems in the coastal zone of Kenya.

Production System	Share of production System in Zone (%)	Commodities (and % shares) in the different farming systems
1	35	Coconut (40), mange (30), citrus (10), cashews (10), cassava (5), groundnut (4), bixa (1)
2	20	Maize/beans (40, cassava (30), livestock (10), sesame (10), cowpeas (5)
3	15	Citrus (40), maize/beans (30), livestock (10), sesame (10), cowpeas (10)
4	8	Cotton (25), maize (25), beans (15), cassava (15), groundnut (10), cowpeas (5), livestock (5)
5	6	Rice (100)
6	5	Sisal (100)
7	7	Livestock (90), millet (10)
8	2	Bixa (100)
9	2	Citrus (100)

Source:Kilambya et al. Table 33.

Table 2: Data sources for the study in Burkina Faso

Level of aggregation	***Data Source***	***Acronym***	***Coverage***
Household	Priority Survey (1994): provides data on income and expenditure for 8642 households	PS	survey sample (473 villages)
Village	Priority Survey (1994): community component of the PS which covers infrastructure and communal services	PS	survey sample (473 villages)
Village	National census (1985): demographic data	NC	national
Village	Ministry of Water Management and Infrastructure (1995): data on health and water infrastructure, distances to infrastructure, public administration and social groupings	DGH	25 out of 30 provinces
Village	Ministry of Education (1995): data on primary school infrastructure and teacher/pupil ratios.	EDU	national
Department	Ministry of Agriculture (1993): data on various indicators ranging from average literacy rates to vegetation indices	ENSA	national
Department	Directorate of Meteorology (1961-1995): data on temperature (31 locations), evapo-transpiration (15 loc.) and rainfalls (160 loc.).	METEO	national
Province	Ministry of Agriculture (1993): data on cattle per households	ENSA	national

Table 3: The variables used in the Econometric Analysis in the study in Burkina Faso

*Aggregation Level **	*Variable*
Village	children 0-6 per adult (15-50 years) in household
Village	children 7-14 per adult in household
Village	elderly (50+) per adult in household
Province	literate head in household
Province	% male adults literate in household
Province	% female adults literate in household
Province	livestock units per capita
Village	distance to nearest rural primary school
Village	teachers per child 7-14 years
Village	Distance to nearest health facility
Village	whether nearest facility has safe water
Village	Number of pumps per rural community
Village	Existence of an all-weather road
Department	Cultivated area in department per capita
Department	Average rainfall 80-94
Department	94 absolute value of deviation of rainfall from average
Department	Average length rainy season 82-92
Department	Average vegetation index 82-92
Department	Homogeneity rainy season 82-92

Endnotes

[1] The following figures on the quality of health services in rural communities in Nigeria are indicative of the impact of the quality of the access road to the community. The quality of extension services is also likely to be strongly influenced by the quality of the access road.

Health Services in the Community	Access: Paved Road	Access: Unpaved Road
Health Post	30.8	17.6
Mobile Clinic	21.7	11.5
Health Worker	29.7	15.2
No Health Services	17.8	56.1
All Communities	100	100

Source: Community Survey 1992.

[2] In Ethiopia, the Household Survey of 1988 shows that the average landholding of the households in the lowest quintile was only 5 percent of that of the households in the highest quintile and they have a much higher degree of specialization: The coefficient of variation of the areas allocated to different crops for households in the lowest quintile varied between 0.70 to 0.85, depending on the agro-climatic region, whereas the coefficient of variation for households in the highest quintile varied between 0.4 to 0.5.

[3] Targeted income transfer program often give incentives to households to alter their personal characteristics or change their work effort in order to qualify for the program.

[4] For income transfer programs, Ravallion and Chao (1989) suggested a performance measure which defines the gains from targeting as follows: "*The gains from targeting are the amount by which the budget for a non-targeted program would have to increase in order to achieve the same reduction in poverty that can be attained through targeting.*" They termed this measure the "equivalent gain from targeting." This performance measure may not be a good criterion, however, if the corresponding poverty measure is the Headcount ratio since it would leave out the areas in which households are the poorest. Ravallion and Chao did not constrain the poverty measure in their definition, but in their illustration they used the Poverty Sensitivity measure.

[5] This is clearly a simplifying assumption since there are research projects that are not part of a commodity program.

[6] See Jones, 1995, Kortum 1997, and Segerstrom 1998 for recent writings on the micro-foundations of production functions with new ideas.

[7] It will also depend on the price elasticity of demand if the increase in supply is large enough to affect the market price. In the present analysis we assume that this effect is small in order to simplify the notations.

[8] The probability of adoption may also depend on the socio-economic conditions in the region. In Zambia, new maize varieties developed in the 1980s were adopted by a relatively small proportion of the rural population because the new technique added to peak labor demand (Collier and Gunning, 1999, p. 81).

[9] Burger et al. (1996) show that the adoption of coffee, tea, and improved livestock in Kenya is more strongly influenced by informational variables than by endowments. See also Narayan and Prichette (1996).

[10] The quality of that approximation depends on the extent to which the increase in the income of the poor changes the *number* of the poor in the region.

[11] Another possibility, closely related to this alternative, is selecting a different research project within the same commodity program, namely a project which will be targeted on a different factor input.

[12] For a detailed description of this methodology and an illustration of its application, see Bigman *et al.* (1999a).

[13] Bigman *et al.* (1999a) and (1999b).

[14] Already in 1990, however, the CGIAR accepted guidelines that gave the highest priority to the enhancement of nutrition and well being, especially among low-income people. For further discussion, see Anderson (1998).