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# A COMPREHENSIVE CONCEPTUAL FRAMEWORK FOR ASSESSING THE IMPACT OF AGRICULTURAL RESEARCH AND DEVELOPMENT

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*Information on the impact of publicly funded agricultural research is increasingly needed for the mobilization and allocation of decreasing resources. For these purposes, solid evidence of the social gains of past investments is needed, as well as appropriate criteria for planning and priority setting. Returns on investments in technology development and transfer have mostly been evaluated in economic terms, using the rate of return as a measure of efficiency. However, these means are not equally appropriate for the impact appraisal of all research and development programs. Some impacts are difficult to quantify or only materialize over a longer period of time. For this reason, projects should not be prioritized according to efficiency measures alone. Non-market costs and benefits should be evaluated on an equal footing to their market-based counterparts. This paper proposes a comprehensive conceptual framework for assessing the impact of agricultural research and development. It reviews the concepts and methodologies involved in these kinds of appraisals and refers to their application in empirical impact studies conducted in South Africa to date.*

## 1. INTRODUCTION

Information on the impact of publicly funded agricultural research is increasingly needed for the mobilization and allocation of decreasing resources. For these purposes, solid evidence of the social gains of past investments is needed, as well as appropriate criteria for planning and priority setting. Returns on investments in technology development and transfer have mostly been evaluated in economic terms, using the rate of return as a measure of efficiency. However, these means are not equally appropriate for the impact appraisal of all research and development (R&D) programs (Marasas, 1999, Wessels, 1998 and Anandajayasekeram *et al*, 1996).

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Some impacts are difficult to quantify or only materialize over a longer period of time. The market-based approaches usually followed in rate of return studies fail to adequately account for impacts such as environmental quality; income distribution; agricultural sustainability; changes in the status of women; and human and institutional capacity. This paper proposes a comprehensive conceptual framework for assessing the impact of agricultural R&D. It reviews the concepts and methodologies involved in these kinds of appraisals and also refers to their application in empirical studies conducted in South Africa to date.

## 2. THE CONCEPT OF COMPREHENSIVE IMPACT ASSESSMENT

Impact assessment is a special form of evaluation which measures the intended and unintended changes an intervention causes in the target population (Anandajayasekeram *et al*, 1996). The welfare effects should be functions of the activity that cannot be accounted for in other ways. A specific situation is assessed at a particular time in the past (*ex post*), present or future (*ex ante*). The basic rationale for *ex ante* evaluation is to improve resource allocation and decision-making by using economic principles. *Ex post* impact assessment aids the credibility of public sector research by providing feedback on past accomplishments. This information could be used to justify the mobilization and allocation of future resources.

Three broad categories of impact form part of a comprehensive assessment. These involve the direct research product, as well as the intermediate and people level impact. The latter refers to the adoption and effects of the research output on the target population and society at large. People level impact could include economic, socio-cultural and environmental aspects. The conceptual framework for measuring the various effects is shown in Figure 1 and Table 1. Not all of these components necessarily apply to all projects and are also not of equal importance in the projects where they do apply. Their applicability is dictated by the nature of the project, the objectives of the evaluation and the availability of data.

## 3. THE DIRECT RESEARCH PRODUCT

The direct research product deals with the immediate results of the research process and could involve improved technology, specialized information or a combination of the two (Marasas, 1999 and Anandajayasekeram *et al*, 1996). The scientific context of the research activity should be specified. This could be basic,

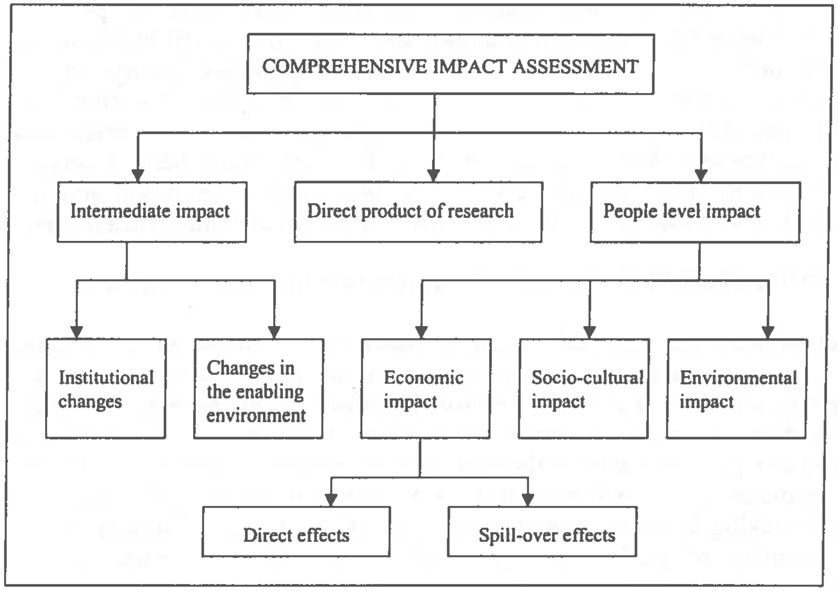


**Figure 1: Comprehensive impact assessment**
*Source: Anandajayasekeram et al (1996)*

**Table 1: Impact types, techniques and methods used in a comprehensive impact assessment**

| Impact types | Techniques | Methods |
|---|---|---|
| Direct product of research | Simple comparison of the intended versus the actual achievements. | Effectiveness analysis using the logical framework approach. |
| Intermediate impact | Simple comparison or trend analysis. | Surveys. |
| Economic impact | Various. | Efficiency analysis using rate of return estimates. |
| Socio-cultural impact | Comparison over time. | Socio-economic or adoption surveys. |
| Environmental impact | Various. Could be qualitative or quantitative and requires bio-physical information. | Environmental impact assessment. |

*Source: Anandajayasekeram et al (1996)*





strategic, applied or adaptive and the intended outputs along this continuum of disciplines would differ (Alston *et al*, 1995).

The direct research product is often assessed by means of an effectiveness analysis. This measures the degree to which an intervention attained its objectives by comparing the actual achievements to the intended effects. Operationally defined goals and objectives, specified outcomes and quantified measurement standards are needed for this purpose. These are also known as "measurable indicators" or "critical performance areas".

The logical framework approach is a useful starting point for effectiveness analysis. This management tool allows for the evaluation of an intervention within the context of its constraints, objectives and assumptions. The method structures the logical linkages between the means and ends of various project components, as well as their impact indicators and means of verification. Although the technique has been used by various foreign assistance agencies during the past 20 years (Sartorius, 1996), it has only recently been applied in South Africa (D'Haese & Mdula, 1998 and Wessels, 1998).

## 4. INTERMEDIATE IMPACT

Research creates the potential for development. However, a range of intermediate processes also influence the farm level impact of R&D. Intermediary impact deals with the series of activities enabling the transfer of the direct research product into practical application by the target groups. This could relate to changes within R&D institutions or within the enabling environment of the target users (Anandajayasekeram *et al*, 1996).

Impact in R&D institutions could involve organizational models and methods, scientific procedures, inter-disciplinary teamwork and institutional strategies such as program planning, evaluation, training and networking. The impact is also linked to human capital development and the availability of physical and financial resources. Human capital includes concepts such as education, training, management, experience and public choice processes. It has economic value because it enables more efficient use of resources and more productive farming enterprises (Van Rooyen & Van Zyl, 1998 and Khatri *et al*, 1996ab).

Intermediate impact is often assessed by means of simple comparisons, surveys or trend analyses over the relevant time periods. This requires baseline information and careful monitoring of the selected indicators. The results of these appraisals can be quantified by means of multi-criteria analysis. As with effectiveness analysis, the logical framework approach is a useful tool to incorporate institutional impacts systematically within the evaluation.

Human capital development is a high national priority in South Africa (White Paper on Reconstruction and Development, 1994). Although several Southern African studies recognize institution building as a desirable pre-condition for future impact, comparatively fewer studies addressed these aspects specifically (Marasas, 1999). Positive intermediate impacts relating to human capital development, the availability of financial resources, infrastructure development and changes in the organization of the research system, have been qualitatively identified in three empirical studies in South Africa (Marasas, 1999, Wessels, 1998 and Niederwieser *et al*, 1997). Farmer education has furthermore been associated with agricultural productivity growth in this country (Van Rooyen & Van Zyl, 1998, Khatri *et al*, 1996ab and Sartorius von Bach *et al*, 1992).

## 5. ECONOMIC IMPACT

Agricultural research is an economic activity in which scarce resources are invested to produce an output of value (Marasas, 1999 and Alston *et al*, 1995). The economic impact of an R&D program is measured by means of an efficiency analysis (Anandajayasekeram *et al*, 1996). The costs and benefits associated with the program are systematically compared and summarized as a single measure of the project value, such as the rate of return or net present value. This allows comparison with alternative investments. The economic impact of R&D can be measured at the macro and the micro level.

The first contributions to measuring the efficiency of agricultural research were made by Schultz (1953) and Griliches (1964, 1958). Various methodologies have since been developed and refined (Anandajayasekeram *et al*, 1996 and Alston *et al*, 1995). The two broad approaches often used in empirical studies include the econometric and surplus approaches (Marasas, 1999, Anandajayasekeram *et al*, 1996, Alston *et al*, 1995 and Echeverría, 1990):

- Econometric methods of efficiency analysis relate measures of output, profit or cost to past investments in research and extension. Production function or total factor productivity approaches are often used to estimate the marginal rate of return. The techniques allow for the separation of the effects of research, extension and complementary services. Econometric approaches are best applied to *ex post* evaluations of aggregate agricultural research programs. Data limitations and econometric problems may limit the usefulness of the methods, especially for disaggregated research programs.





- Surplus approaches to efficiency analysis are based on the concept of economic surplus. A cost benefit framework is used to estimate the average rate of return on the R&D expenditures. This indicates the success of the overall investment, but does not reveal whether resource allocation between different components was optimal. Certain variations of the methods allow welfare implications, such as distributional effects, to be drawn from the analysis. The techniques are suitable for both *ex ante* and *ex post* evaluations and are often used in disaggregated empirical studies. The longer development periods associated with certain R&D programs may limit the usefulness of the methods.

The choice between using econometric or surplus approaches to efficiency analysis is guided by the study objectives; availability of data and resources; level of aggregation; and the time frame of the analysis. Each procedure has advantages and disadvantages and no single method is best for every situation.

Economic impact has been the most emphasized component of empirical assessments to date (Anandajayasekeram *et al*, 1996 and Echeverría, 1990). Empirical efficiency studies on South African agricultural R&D have been conducted at the national level, as well as for specific enterprises and research programs (Marasas, 1999, Marasas & Carstens, 1999 and Thirtle *et al.*, 1999, 1998). Efficient resource allocation and service provision is increasingly being emphasized for agricultural research in South Africa (Discussion Paper for Green Paper on Agriculture, 1998, National Review of Science, Engineering and Technology Institutions, 1997, White Paper on Science and Technology, 1997).

## 6. SOCIO-CULTURAL IMPACT

Socio-cultural impact assesses the effect of research results on the welfare distribution to various groups of society. From an economic perspective, these could include equity in terms of income distribution, as well as security objectives such as income risk, self sufficiency and food security (Alston *et al*, 1995). However, the concept extends beyond economic principles to assess effects on attitudes, beliefs, resource use patterns, gender issues and nutrition (Anandajayasekeram *et al*, 1996).

The methods presently used for socio-cultural assessments vary in their analytical complexity and robustness. These could include qualitative statements, surveys, scoring models, indices, multi-variate analyses, mathematical programming, simulation or market-based comparisons such as hedonic price, contingency valuation and willingness to pay methods (Marasas, 1999, Anandajayasekeram *et al*, 1996 and Alston *et al*, 1995). Several refinements of traditional economic approaches also exist (Marasas, 1999). For example, the surplus approach to efficiency analysis can be adjusted to estimate certain social impacts by disaggregating the supply curve. Systematically incorporated social weights have been developed for the traditional cost benefit framework of analysis.

However, the consistent application of some of these methods is still controversial and several valuation problems associated with social impact assessment remain. The methodology for embodied technological effects reflected in commodity and factor markets are more developed than those for disembodied technologies, such as socio-cultural aspects. Paucity of data is a further limitation in both developing and industrialized countries. For resource allocation decisions, a multi-criteria framework of analysis is suggested to combine efficiency concerns with other standards and approaches.

A positive relationship between improved agricultural productivity and the nutritional status of households and children has been demonstrated in the KwaZulu-Natal province of South Africa (Townsend, 1997). The positive social impacts of R&D through employment creation have been indicated in two technology specific case studies on indigenous wildflowers (Wessels, 1998 and Niederwieser *et al*, 1997). Various types of socio-cultural impacts are increasingly being emphasized as R&D priorities in South Africa (Discussion Paper for Green Paper on Agriculture, 1998, National Review of Science, Engineering and Technology Institutions, 1997 and White Paper on Science and Technology, 1997).

## 7. ENVIRONMENTAL IMPACT

The adoption of agricultural technologies has often resulted in external costs and benefits through their effects on the environment. These could be both positive





and negative (Marasas, 1999, Abler & Shortle, 1996 and Anandajayasekeram *et al*, 1996). Negative environmental externalities vary significantly in type and intensity. Developed and developing countries are both faced with these effects, but their problems differ in economic source, scope and significance (Marasas, 1999, Spio, 1997 and Aihoon & Kirsten, 1994).

Developed countries mainly need to deal with growth and over-development. Developing countries are again faced with poverty, combined with rapid population growth, forcing the poor to exert unsustainable demands on natural resources through soil degradation, over-grazing, deforestation and desertification. On the one hand, Green Revolution technology has contributed to increased agricultural production in some developing countries. On the other hand, it could contribute to environmental degradation through pollution and contamination. These potentially negative effects were especially noted in cases where farmers were not using the technology appropriately.

However, the debate on technology and the environment has shown an interesting shift in opinion during recent years. Agricultural technology is increasingly being viewed not as a source of environmental problems, but as a potential solution for various sectors of society. Several innovations substituting practices associated with negative environmental effects are currently being developed or are in the process of adoption (Marasas, 1999 and Abler & Shortle, 1996). Examples include integrated pest management; crop rotation; improved manure management; more efficient use of fertilizers and pesticides; the regular release of new cultivars with improved resistance; and promising expectations from biotechnology.

The relatively longer time frame over which environmental costs and benefits realize, necessitates predictions of potential scenarios over the longer term. The methodology calls for a different approach than that of pure economic efficiency (Marasas, 1999, Wessels, 1998, Anandajayasekeram *et al*, 1996 and Alston *et al*, 1995). Cost benefit analysis is usually not recommended, because the technique tends to bias the results against welfare conditions being realized over the longer term. The evaluation should be based on an understanding of the true physical and biological effects of a research program. This often requires a complex analysis of physical, chemical, biological, social and economic processes. Market-based comparisons such as hedonic price, contingency valuation and willingness to pay methods could be used. As with social welfare assessments, several valuation problems remain associated with agriculturally related environmental impact measurements. Because of these difficulties, qualitative statements are often used in empirical studies.

Intensive empirical attention has not yet been devoted to the assessment of agriculturally related environmental impacts in South Africa. Environmental externalities associated with specific agricultural technologies have been qualitatively identified in three empirical studies (Marasas, 1999, Wessels, 1998 and Niederwieser *et al*, 1997). Although several studies focused on the economic efficiency of water use for irrigation, attention to the efficiency of dryland water use has been more limited (Beukes *et al*, 1999 and Marasas, 1999). However, environmental issues are increasingly emphasized by the growing concerns for ecologically sustainable development. The Reconstruction and Development Program of South Africa emphasizes the incorporation of environmental considerations in project planning and decision-making, as well as the right of all South Africans to a decent quality of life through sustainable use of resources (White Paper on Reconstruction and Development, 1994). The United Nations and the World Bank have set guidelines for incorporating environmental accounts into the traditional measures of the gross domestic product. Conventional procedures usually fail to account for certain vital resources (Lindert, 1996).

## 8. SPILL-OVER EFFECTS

The applicability of research results over a range of agricultural production conditions, commodities and environments are generally referred to as "spill-over effects" (Anandajayasekeram *et al*, 1996). These "spill-overs" or "spill-ins" could also be known as "externalities" or "multipliers".

Biological technologies, such as improved varieties, have traditionally been assumed to be location-specific with limited direct transferability. However, recent studies provide substantial evidence of agricultural research spill-overs between different countries (Marasas, 1999, Byerlee & Traxler, 1996, Khatri *et al*, 1996ab, Thirtle *et al*, 1995 and Evenson, 1989). The potential for spill-overs has comprised part of the rationale for the existence of the international agricultural research system. Apart from its domestic research, agricultural productivity in a specific country could also depend on the international body of knowledge.

Spill-overs could be price, technology or knowledge related. Price-related effects are derived from price reductions in related industries. Technology-related





effects apply to the transfer or adaptation of the specific technology to a new environment. This depends on its applicability to different circumstances. Knowledge-related spill-overs involve the application of new information within the research process to enable more efficient generation of novel technology. Research spill-overs could be evident across different regions, countries, sectors, commodities or industries and could also occur across different stages of the process, i.e. from basic to applied research.

Although spill-over effects have been duly recognized in the literature, relatively little empirical attention has been paid to these indirect contributions of agricultural research. Most studies have been partial equilibrium in nature and have focused on direct output effects. However, ignoring these aspects could bias rate of return estimates (Thirtle *et al*, 1995). Spill-over effects have mainly been studied by econometric estimation or direct observation (Byerlee & Traxler, 1996). The surplus approach can be modified to account for these effects. Data availability could limit impact estimation between different research jurisdictions and care should be taken to avoid double counting in the measurement procedures (Alston *et al*, 1995).

National policy in South Africa supports strategies of mutual co-operation with other Southern African countries (White Paper on Reconstruction and Development, 1994). A forthcoming study on regional spill-overs implies South Africa and Zimbabwe as the key technology providers. Spill-overs apparently occurred from South Africa to Lesotho, Malawi and Zimbabwe, while reciprocal spill-ins from Zimbabwe and Lesotho to South Africa have been indicated (Thirtle & Townsend, 1997). Spill-ins due to international technology transfers have been shown to significantly affect the productivity and profitability of the South African R&D system (Khatri *et al*, 1996ab). The inter-country, inter-sectoral and inter-commodity transfer of the benefits from specific agricultural technologies has been qualitatively identified in three empirical studies (Marasas, 1999, Wessels, 1998 and Niederwieser *et al*, 1997). The importance of spill-over effects are increasingly emphasized in view of increasing trends towards the globalization and regionalization of R&D initiatives.

## 9. CONCLUSIONS

Agricultural R&D result in various direct and tangible benefits that can be measured by market-based approaches such as rate of return analysis. However, these activities also result in impacts that are more difficult to quantify or that are only realized over longer periods of time. For this reason, projects should not be prioritized according to efficiency measures alone. Non-market costs and benefits should be evaluated on an equal footing to their market-based counterparts. This paper proposes a comprehensive conceptual framework for assessing the impact of agricultural R&D. Multi-criteria analysis, which incorporates a wide range of tools and techniques, could be a useful tool for applying these concepts in planning and evaluation exercises.

Given the constant decline in resources available to agricultural R&D in South Africa, comprehensive impact information should be increasingly used in management decisions. However, unless the process is institutionalized and the mechanism in place to monitor and collect the relevant data as part of project implementation, *ad hoc* appraisals could be very costly.

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