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The Strategic Potential of Applied Research: Developing International Public Goods from Development-oriented Projects

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International Crops Research Institute for the Semi-Arid Tropics

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Abstract

International Agricultural Research Centres (IARCs), like the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), are expected to conduct research that produces International Public Goods (IPGs) having wide applicability and accessibility across many countries. However, unless agricultural IPG technologies are developed in consultation with other stakeholders and adapted to suit varying local conditions, the research outputs will either not be adopted or remain underutilized. With the broader mandate of the CGIAR, increasing focus on poverty alleviation and insufficient capacity of national agricultural research systems (NARS) in most developing countries, international institutions engage in research for development to address the range of issues facing the poor in different localities. Increased attention has been placed on issues like participatory downstream research, which has been criticized for placing emphasis on local development agendas at the expense of IPG delivery. This paper addresses the need to embrace a culture of carrying out local level technology development, adaptation and adoption studies within an IPG framework. Using a review of literature as background and impact pathways analysis, it complements discussions on the concept of IPGs and spillovers. A synthesis of past ICRISAT studies reveals that lessons can be drawn to guide the framing of testable hypotheses for development-oriented work that will lead to development of IPGs. Downstream projects will thus serve as laboratories for development of solutions to increase the relevance of research and the effectiveness of diffusion strategies for ultimate achievement of impact and agricultural development.

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Contents

1. Introduction

Scientists at ICRISAT have developed a number of technologies including improved breeding materials, parental lines for hybrids, intermediate to finished crop varieties, natural resource management (NRM) technologies, research methodologies, databases and agricultural equipment or tools among others. After initial testing at the experimental stations (either at ICRISAT or at partner locations) the promising technologies are field tested on farmers' fields on a limited scale. Subsequently, after fine tuning the technologies are introduced on a larger scale in selected pilot sites subject to funding and manpower availability. During this phase, ICRISAT acts as a bridge-broker-catalyst, as the technology adaptation and dissemination are being carried out by the partners or stakeholders, who are part of the research for development value chain. ICRISAT provides backstop support in critical areas. Prior to its introduction on pilot sites, ICRISAT scientists also carry out training and capacity building programs for the partners from State Agricultural Universities (SAUs), Non-Governmental Organizations (NGOs), farmer organizations, and other relevant stakeholders.

This component of ICRISAT work is believed to fall under development research, conducted by local partners with minimal involvement of an international organization. Such a role for an international organization is essential as donors desire to show measurable impacts of technologies at the ground level. Several review teams have suggested that ICRISAT's development research work should generate outputs that have internationality for a much wider application, across crops, ecoregions, countries or regions. The sixth External Program and Management Review (EPMR) of ICRISAT went a step further by including this as one of their recommendations (CGIAR Science Council 2009).

The concept of international public goods (IPGs) in the Consultative Group on International Agricultural Research (CGIAR) and the global agricultural research community has been a subject of discussion in various fora (CGIAR Science Council, 2006, 2008). The general consensus has been that the CGIAR Centers should continue to conduct research focused on the production of IPGs. However, new technologies can only be translated into innovations upon implementation within a socio-economic, institutional and policy environment. This calls for an in-depth study of the technology development, uptake and utilization process and deduction of lessons learnt that will guide the design of subsequent projects for ultimate realization of impact. Tools for identifying testable hypotheses that offer new insights to facilitate scaling up of technologies include analysis of impact pathways and research spillovers across regions. Outputs from development research work can be recognized as IPGs by embracing a culture within institutes to consciously develop indicators that assess how knowledge is generated and the process by which economic and social value can be extracted from it.

Based on comparative advantage of international agricultural research centers, this paper discusses the concept of IPGs and how downstream, applied research can be used to meet this mandate. It sets the pace for more in-depth case studies through discussions with relevant scientists across themes and regions to identify the role of downstream research in producing outputs that are available and applicable across regions and the process through which this can be done based on past experience. It should be noted that although the paper focuses on agricultural research for development within the CGIAR, there have been wide experiences[1] outside of the system.

2. The Research – Development Continuum

International agricultural research is undertaken with the ultimate goal of improving the well-being of the poor in terms of reduced poverty, increased food security and protection of the environment. It is only through implementation and interaction among partner scientists, public and private sector organizations, NGOs, farmers, donors, and other players in specific environments that lessons can be learnt for improvement in research design and institutional arrangements (CGIAR Science Council 2005). Walker et al. (2008) point out that there is a need to identify the 'cause-and-effect' relationships between various actors as well as the conditioning factors that shape the pathway from research to impact. Situations of non-adoption should not be considered as failures, since they provide opportunities for institutional learning and change. It is thus essential to link the delivery system of IPGs produced by international institutes with complementary activities that are the primary responsibility of national and local entities (Sagasti and Timmer 2008).

2.1 Positioning CGIAR centers on the impact pathway

Research for development is expected to follow a pathway that starts with problem identification and research, leading to production of outputs in the form of IPGs that will be subsequently tested, adapted, applied and result in the desired impacts. The strategic planning process should thus include an impact pathway analysis and identification of the roles of each stakeholder in the technology delivery process. Systematic process documentation of the impact pathways involves establishing clear goals and objectives, defining inputs, evaluating outputs, mapping direct and indirect outcomes, and assessing impact.

The CGIAR system was established in 1971 and expanded to 15 future harvest agricultural research centers through the 80s and 90s. They developed new knowledge and improved technologies for major global food crops such as rice, wheat, corn, legumes, oilseeds, millets, cassava and potatoes. National research institutes in developing countries used applied research to diffuse the new knowledge and adjust the technologies to fit relevant ecological and production conditions. The concept of CGIAR as a provider of IPGs began to be clearly voiced in the late 1990s and early 2000s (Sagasti and Timmer 2008). During a workshop on 'Positioning the CGIAR in the Global Research for Development Continuum', it was proposed that the CGIAR should conduct research focused on the production of IPGs (CGIAR Science Council 2006). It was, however, noted that in order that research effectively contributes to development, continuous learning through action research should be part and parcel of the process. Development of institutional capabilities for conducting and coordinating international agricultural research that are applicable widely can in itself be considered an IPG. For instance, the CGIAR is a model for international research networks and has contributed to better international governance practices, and thus can be considered an IPG.

[1] See for example IDRC Sourcebook by Gonsalves et al. 2005

At the local level, endeavors are required for support of regional, national and local entities in the agricultural research system. CGIAR Centers should therefore locate themselves in the middle of the research-development continuum and undertake research for development, and not development activities as such. For example, in order to effectively address the complex demands of integrated natural resource management (INRM), a systems approach is required that is both inter-disciplinary and participatory, and covers the full range of the research continuum. Craswell and Penning de Vries' (2001, cited in CGIAR 2006) conceptualization of the research continnum of NRM (Figure 1) presents the traditional

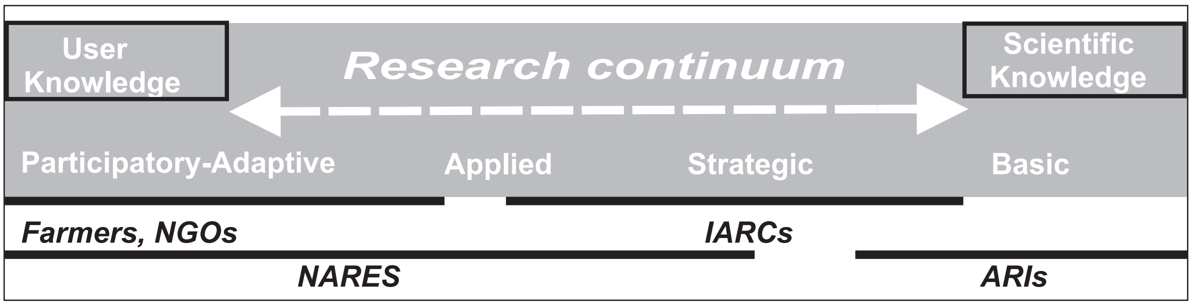

Fig 1: Primary Domains across the research continuum of INRM.
Source: CGIAR Science Council, 2006.

primary domains of advanced research institutes (ARIs), IARCs, NARS, non-governmental organizations (NGOs) and farmers. Nevertheless, a key part of the leadership role of IARCs is in strategic research designed to develop research tools and methodologies, including methodologies for participatory research, which can only be achieved through interactions with downstream players.

2.2 Comparative advantage of international agricultural research centers

The Consultative Group on International Agricultural Research (CGIAR) specifies four types of research viz. basic, strategic, applied and adaptive research[2]. It has been accentuated that the comparative advantage of the CGIAR is in strategic and applied research while working in partnership with advanced research institutes (ARIs) in basic research and with NARS in different countries in adaptive research (CGIAR Science Council 2006). International research institutes, being mission oriented organizations, have a mandate to understand what is required in the overall context and identify the major constraints to the improvement of agriculture. The whole range of activities shown in figure 2 is a learning experience that feeds back to research priority setting and aids in identifying relevant research roles amongst different partners based on their strengths (CGIAR Science Council 2008). Instead of setting rigid priorities, learning strategies should be employed to recognize the current trends and devise alternative solutions.

2 Basic research is designed to generate new understanding, strategic research for the solution of specific research problems, applied research to create new technology and adaptive research to adjust technology to the specific needs of a particular set of environmental conditions.

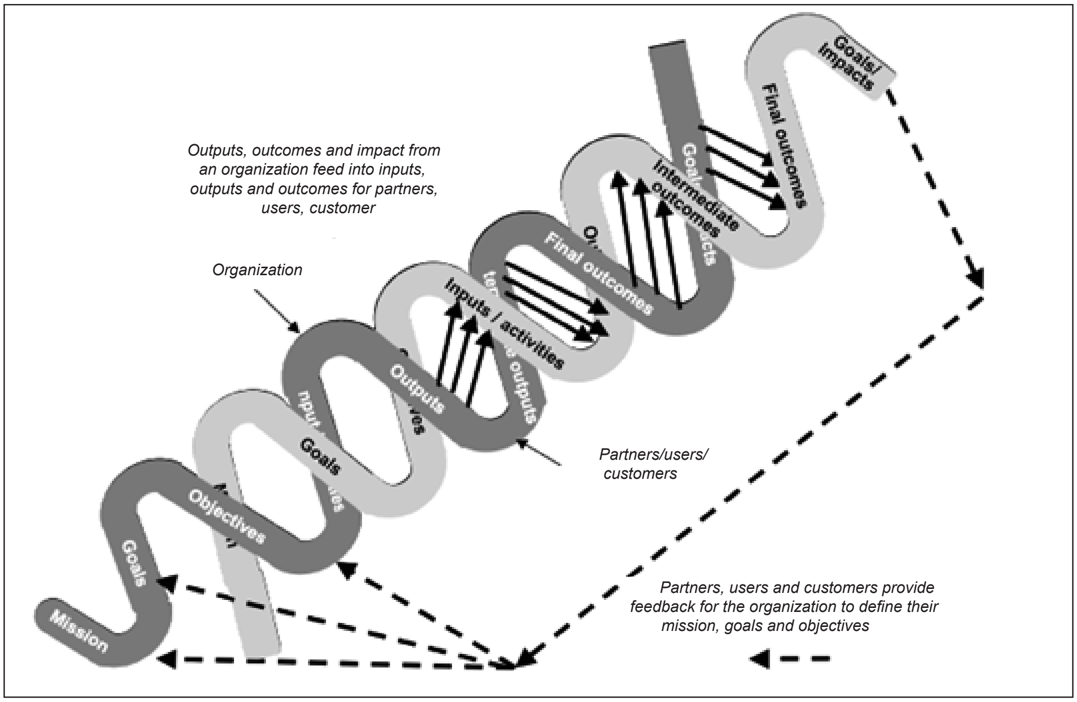

Fig. 2: Interactions and Mutual Influences between an Organization and its Partners.
Source: World Bank 2003; cited by Sagasti and Timmer 2008, pg 23.

3 International Public Goods in the CGIAR Context

Samuelson's (1954) pure theory of public expenditure defines the concept of public goods as used by economists. He identifies two categories of goods namely ordinary private consumption goods, which can be parcelled out among different individuals and collective consumption goods, which all enjoy in common in the sense that each individual's consumption of such a good leads to no subtraction from any other individual's consumption of that good. Pure public goods are differentiated from private goods by virtue of their being non-rivalrous in consumption and non-excludable. Non-excludability implies that it is either impossible or very costly to exclude those who do not pay for the good from utilizing it, and once the good has been produced its benefits (or harm) accrue to everyone. The non-rivalry property means that any one person's use or consumption of the public good has no effect on the amount of it available for others.

Most public goods are impure because they exhibit some attributes of rivalry and excludability (Kanbur 2001). Other categories such as club goods and common pool resources are now recognized (Table 1). Ryan (2006) argues that CGIAR Centers being international institutions have a mandate to produce outputs that are freely available, accessible and relevant to the international community but warns that these IPG characteristics are easy to define but difficult to operationalize within the centers. IARCs face the challenge of identifying where the boundaries of the different types of economic goods lie and how to strike a balance between focusing on these versus goals related to impacts on poverty, food and nutrition security and the environment. He defines IPGs as:

Table 1: Classification of Economic Goods (Source: Ryan 2006).

Consumption	Access	
	Exclusive	Non-Exclusive
Rival	Private (eg, food, clothing, cars)	Common pool (eg, air, water, soil, landscapes, ocean fisheries)
Non-Rival	Club/Toll (eg, INTELSAT, Suez Canal, Panama Canal, private schools, theatres, professional associations)	Public (eg, sunshine, national defense, lighthouses)

"Research outputs of knowledge and technology generated through strategic and applied research that are applicable and readily accessible internationally to address generic issues and challenges consistent with CGIAR goals".

International public goods have to be produced and eventually put to use by national programs, organizations or individuals in a specific location and successful delivery will be influenced by the institutional context including policy and political systems. However, because of insufficient capacities of public extension systems in many developing countries, the production of IPGs should go hand in hand with corresponding investments in national public goods (NPGs) if the expected benefits are to serve the intended purpose. While utilizing existing infrastructure, new institutional arrangements and negotiations are required in mobilizing human capacity, mobilizing financial resources and defining operational policies and procedures. Sagasti

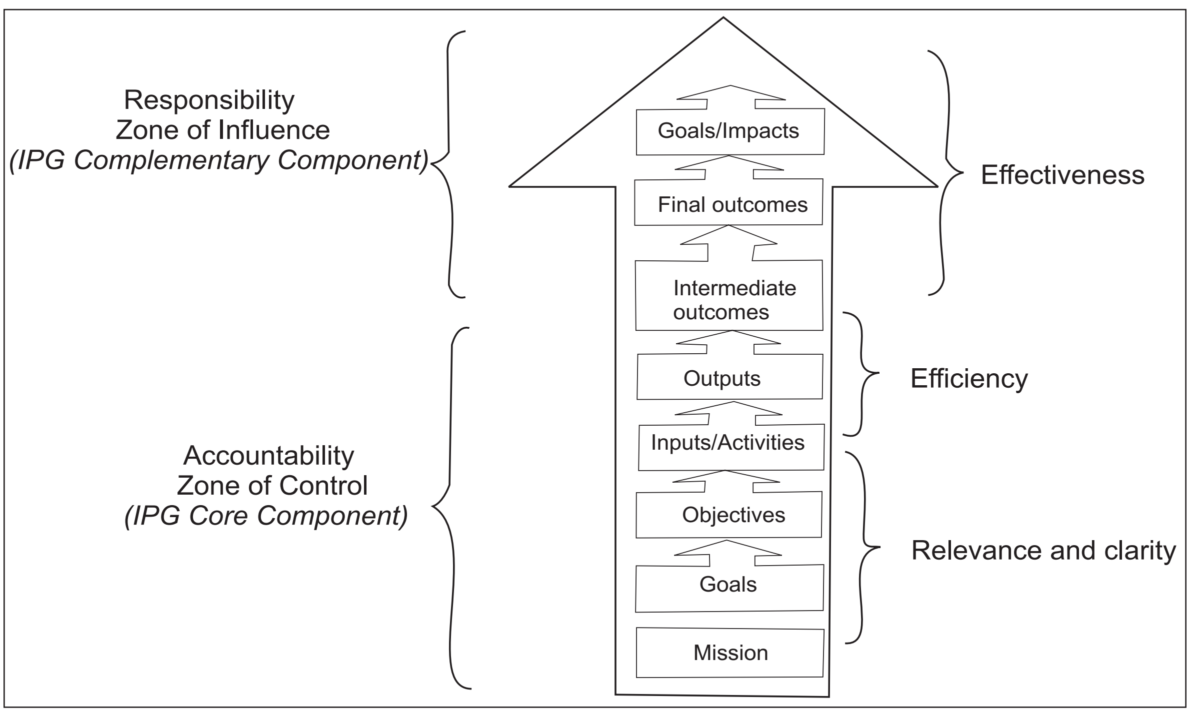

Fig. 3: Results-based Logic Model, Zone of Influence/Zone of Control, Core/Complementary IPG Components and Evaluation Criteria.
Source: World Bank, cited by Sagasti and Timmer, pg 22.

and Timmer (2008) identify the zone of control[3] and zone of influence[4] in the IPG delivery system (Figure 3). CGIAR Centers may indirectly be held responsible for exerting influence on the network of institutions along the pathway and building capacity to ensure the expected benefits materialize. Involvement in some complementary activities including adaptation, dissemination, extension, technical assistance, policy advice, and training is thus required to ensure flow of IPGs from the international to the national and local levels.

3.1 Internationality and spillover impacts of IPGs

The presence of a public good, like a new crop variety, does not guarantee that every member of the public will derive the same level of benefit from it. Preferences and capacity to access and use the public good vary, and hence it is the range over which the benefits apply, rather than the good itself, that determines whether a public good is international or national. A public good may be looked at as a set of complementary private and public goods, involving different types of social actors, rather than a single product (Muraguri 2006). Ballantyne (2008) points out that information and knowledge are not born public, and therefore must be worked upon to ensure that they become public. An availability, accessibility and applicability framework offers pathways to wider accessibility and application of research outputs that are thus more likely to be IPGs.

The results of research are often published in scientific journals that are available internationally. The knowledge and technology options contained in the publication can only be an IPG if it is relevant and has potential for spillover to other countries beyond the specific laboratories, institutions and locations where they were developed. Comparative studies across different countries and development of methodology or technologies that are deliberately tested across countries are good examples of how the research plan and associated activities can set out to include international elements for increasing the likelihood of spillover (Harwood et al. 2006).

The internationality of impacts is an important consideration when characterizing IPGs and we need to look beyond the knowledge/technology generated and consider potential impacts. Although public funding for agricultural research has diminished, small-scale farmers in developing countries still largely rely on the public sector for technology transfer (Pineiro 2007). The production of IPG outputs should be a means to achieving impact for the poor, the food insecure and the environment. The use of funds to produce only the upstream component of IPGs may therefore distort development assistance programs from poverty reduction initiatives.

New agricultural technologies or knowledge are generated in a location to increase yields or to improve efficiency of input use or quality of output. Nevertheless, the location where research activities are carried out is of little significance as far as IPG requirements are concerned as long as the expected outputs are intended to be relevant to many agro-climatic conditions and achievable through spillovers (Ryan 2006). If the spillover potential of research

[3] The zone of control includes the elements of the results chain for which the IARC is directly accountable.
[4] The zone of influence includes the results chain components like outcomes and impacts that lie beyond its direct control.

outputs is high, research programs and the associated infrastructure can be located centrally with an assurance that the results can be transferred and applied in similar environments elsewhere. Technologies are said to have spillover potential if they have applicability to other agro-ecology locations (see Figure 4) or for a different crop. Bantilan and Davis (1991; cited in Deb and Bantilan 2001) identify three types of spillovers, namely: across-location, across-commodity and price spillovers.

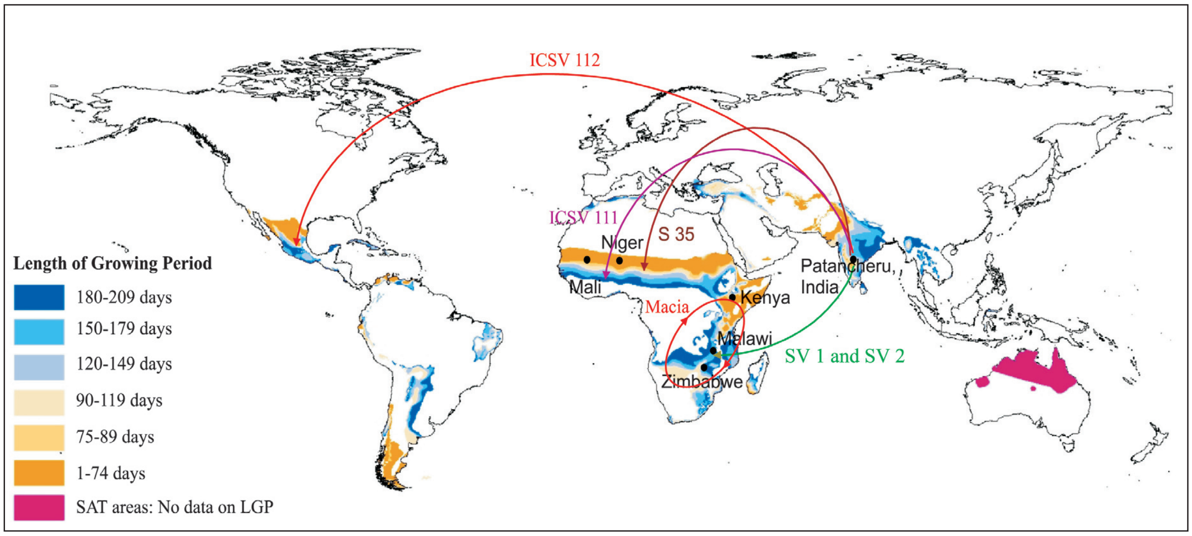

Fig 4: Global flow of selected sorghum varieties developed by ICRISAT and partners.
Source: Shiferaw B, Bantilan MCS, Gupta SC and Shetty SVR. 2004.

Past analyses of spillovers have mainly considered the agro-climatic characteristics of the original and spill-in locations. However, the gap between the actual and the potential spillover benefits can only be closed through working with partners to identify and alleviate the binding socio-economic and institutional constraints. For instance, Deb et al. (2004) note that the extent of technological spillover from finished products like new varieties or hybrids is positively related to the research capability of NARS. These constraints can be understood and lifted through a conscious and systematic effort to experiment and learn lessons from ground level development programs on the entire innovation process comprising technology production, supply and use.

4. The Role of Development Research in the CGIAR

The IPG concept has been easily applied to traditional CGIAR work in areas like germplasm improvement and development of new varieties. However, with the broader mandate of the system, the multitude of complex multi-sector problems faced by developing countries and weaker NARS, more is required. Critics consider the IPG criterion as a conceptual barrier to research since it reflects a highly reductionist approach with unrealistic expectations of the division of labor between research and development to address the realities facing the poor

(CGIAR Science Council 2008). The system has received funding to achieve its mission of alleviating poverty, but has created a virtual wall and limited itself to the research end of the R&D continuum through insistence on producing IPGs. The overall goal of CGIAR research is to improve the welfare of smallholder farmers in developing countries through elimination of poverty, food insecurity, malnutrition, gender inequality, and child mortality, and to foster better institutions, policies and sustainable management of natural resources of particular importance to agriculture. Since the obstacles to achieving impact are greatest where the need is greatest, IPGs should not be a shelter to hide behind the institutional bottlenecks and adopting only the IPG stance could make the CGIAR look dishonest. Some have argued that the most significant transformations led by the CGIAR took place before the advent of "IPGs", when CGIAR Centers were working very closely with the NARS programs, and a functional transfer mechanism existed (CGIAR Science Council 2008). In order to ensure achievement of development goals from research outputs, international research institutes should be the nodal agencies that play a catalytic role to induce the other actors in the innovation system to commit to common objectives and the required resources.

4.1 Capacity of NARS

The CGIAR system needs to justify how far down the research for development path it should go, and who will be responsible for the next steps after IPGs are developed, considering the relatively weakening capacity of NARS in many developing countries. Technologies and knowledge may not be adopted or will remain under-utilized if capability to adapt them to local conditions is lacking or is weak. The CGIAR has been viewed as conducting strategic research but has also had to conduct applied and adaptive research when developing countries lacked their own capacity to do so (Gardiner and Chapman 2006). Contribution of the system through research to reduce poverty will depend on identifying researchable issues, and developing appropriate technologies and positive institutional environments in the regions where the poor live. Janvry and Kassam (2001) suggest that the CGIAR should adopt a regional approach to research planning, priority setting and research implementation to complement its global approach to priority setting in order to increase the effectiveness with which it addresses the heterogeneous nature of poverty in different geographic regions. Pressure on governments to build strong research and extension capabilities can be exerted by donors while IARCs play a capacity building and facilitation role.

4.2 Funding Constraints

Increases in costs have placed all the center budgets under pressure and changes in donor policies have increased uncertainty and risk, which makes partnerships less stable and more difficult to sustain (CGIAR Science Council 2006). Since core funding has declined over the years, there is pressure to expand medium term plans (MTPs) to include regional and bilateral projects that often include substantial capacity building and technology dissemination activities. Within ICRISAT for instance, the proportion of restricted core budget to total budget is low. This scarcity of funds and the need to show impact have further pushed centers down the R&D continuum (Bertram 2006). Such shifts could be avoided if centers could fully cover indirect costs associated with implementation of projects but despite many years of discussion, many projects still fail to cover such costs. Even though centers have been given 'hunting licenses' to find co-funding there is still caution against the shift of core agenda of centers from research to service. Katyal and Mruthyunjaya (2003), for example, observe that IARCs are underfunded and overstretched and the quality of science is being threatened as centers are pulled downstream and compelled to oblige to pet projects of donors. Nonetheless, these bilateral programs are very relevant since they are designed with local needs in mind.

4.3 Lessons from Implementation

Proof-of concept and action research can be good IPG candidates where lessons from out-scaling and up-scaling can have broad applicability in different regions. This approach has been used especially in NRM research to connect the power of science to the practicality of management through an adaptive management approach to improve operational and experimental approaches with continuous learning and change from prior action and outcomes. The research to development continuum encompasses problem identification as the starting point and feedback from implementation as the ending point, in a given cycle of the process (Gardiner and Chapman 2006). Figure 5 illustrates how impacts of development programs feed back to research priority setting. Activities along the R&D continuum offer opportunities for generating international public goods associated with the process and dynamics of technology and policy uptake by partners at all levels (Bertram 2006).

Increasing the search for and the application of knowledge are two sides of the same coin. However, the strategies identified for success can only be effective if they are addressed more extensively in subsequent pre-project and implementation phases. Since all the

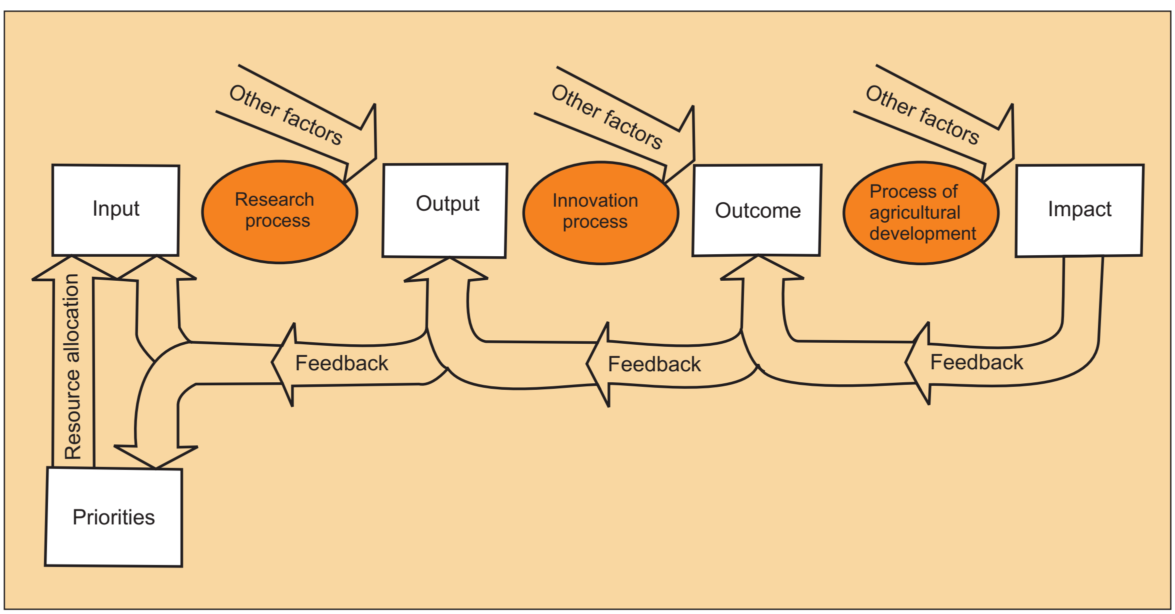

Fig. 5: Feedback from impacts for priority setting.
Source: ISNAR Briefing Paper 66

challenges and opportunities cannot be identified at the outset, the project should have built-in mechanisms to review new issues and plan accordingly. This is a crucial phase for addressing the real priorities of the target group and identifying catalysts for scaling up. Project design is thus an iterative process of learning and can contribute to improvement through the identification of weaknesses. The knowledge generated by a research project that can be later applied for further research is referred to as the option value and this is often omitted in impact assessments (Ekboir 2007).

Segregation of components in the technology delivery process does not fill in the institutional gaps and inventions do not necessarily translate into the required innovations. Gardiner and Chapman (2006) illustrate the research for development cycle specifically relating to NRM featuring the various stages along the cycle and the outstanding issues that would be worthy of analysis. Improved emphasis is required on the role of social capital, extension services, private traders and community organizations in information flow and adaptation of the on-the-shelf technologies to local conditions (Gardiner and Chapman 2006). While development oriented projects have been criticized for being donor-driven, time-bound, and often narrowly focused, they do serve as a primary tool for moving from ideas into action.

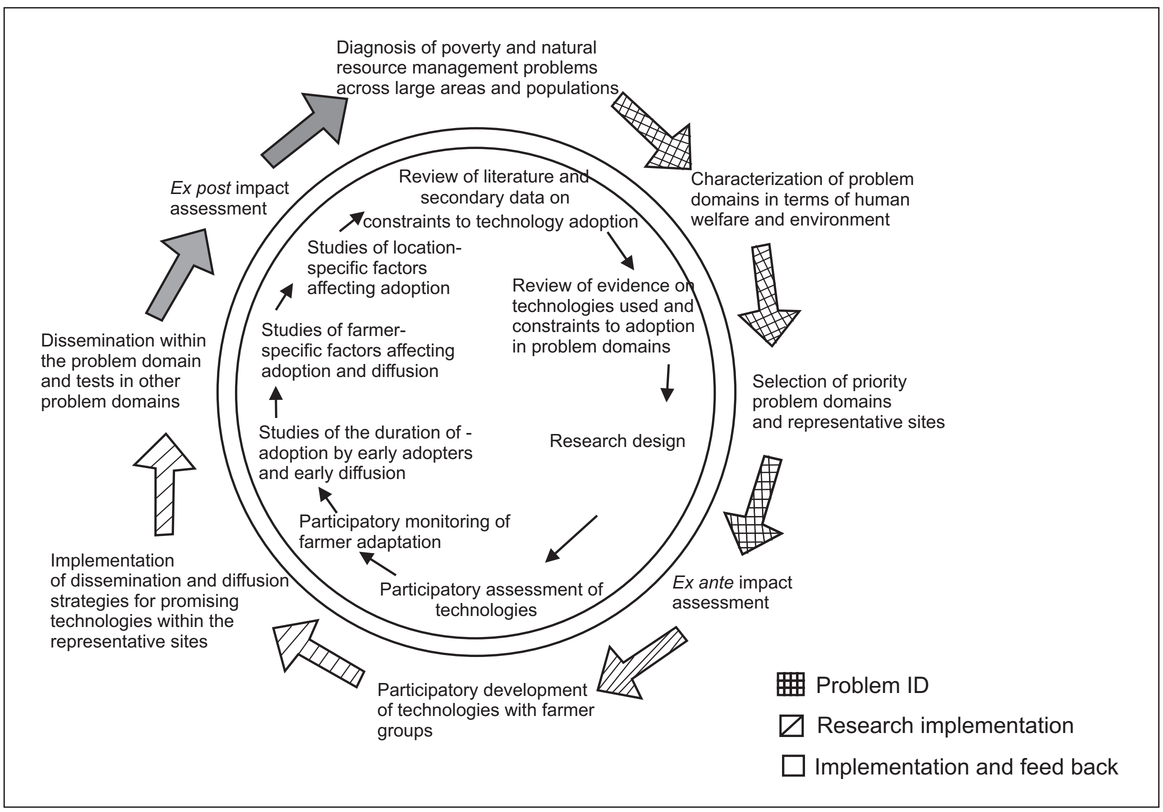

Fig. 6: The research for development continuum illustrated with respect to natural resources management research.

Source: Gardiner and Chapman 2006

5. Innovations systems and partnerships

Innovation involves putting ideas, knowledge and technology from many different sources to work in a manner that brings about a significant improvement in performance and ultimate realization of socio-economic benefits (Hall et al. 2004). Researchers produce information that may be codified (eg, a paper or blueprint), embedded (eg, an improved variety) or tacit (eg, why an experiment failed) and it becomes an innovation once an agent uses it to improve what he/she is doing (Ekboir 2009). Traditional approaches assumed a linear flow of scientific knowledge/technologies from researchers to farmers through a public extension system. This did not capture the complex relationships among heterogeneous agents (researchers, farmers, government, civil society, extension workers, donors, universities, private sector, etc) that condition successful development and utilization of research outputs. Innovation systems concepts are now gaining popularity as a guiding framework for analysis (Hall et al. 2004, Spielman 2005, World Bank 2006). It represents an approach that is flexible and interactive to better fit the changing conditions and enable knowledge generation, use, learning, reflection and innovation in different contexts. Research products may be considered as plausible promises that are shared with other actors who collectively (through a series of actions and reflections) adapt, improve and apply the knowledge (Douthwaite 2006).

Research for the alleviation of poverty thus requires not just the development of agricultural technologies and methods but attention to institutions and to the development of enabling policies. IARCs should seek networks and partnerships within an innovation systems framework along with advocacy to encourage complementary investments at the development end of the R&D spectrum to generate impact (Hall et al. 2000). Potential development lags can be reduced by involving farmers and other stakeholders in research to adoption processes at the appropriate time (Gardiner and Chapman 2006). Operating environments are dynamic and networks need to be re-aligned to suit the evolving circumstances while meeting the mutual as well as individual objectives of partners.

Institution strengthening should be part and parcel of CGIAR activity in its endeavor to act as catalyst, integrator, organizer and disseminator of knowledge and research efforts in partnership with other sources of expertise to serve the needs of the poor (CGIAR TAC 2000). This has been done through the development and dissemination of generic methodological tools for research management, impact assessment/evaluation, policy analysis, training, information and networking to enhance specific components of NARS and meet the research management, research evaluation capacity and organizational needs of specific countries. As an illustration, Pineiro (2007) presents a model for transfer of agricultural technology comprising knowledge management, gap filling research, promotion and regulation of the private sector, as well as environmental impact analysis.

Strong partnerships with a range of institutions that have a solid understanding of local livelihood strategies will enable the generic technologies to be tailored to an enormous range of context specific livelihood strategies (Camara et al. 2005, Duncan 2002). Detailed studies of institutional histories (Shambu Prasad et al. 2005) are required to identify the processes, key institutions and associated linkages and boundary or bridge institutions that are required to increase chances of success. The capacity to manage learning through doing is critical for scaling up to evolve and for further opportunities for scaling up to be continually identified (Janvry and Kassam 2001). Ekboir (2009) points out that the independent but coordinated CGIAR Centers can be an effective system for implementing a strategy of decentralized experimentation with centralized learning but it lacks an effective and flexible structure to learn from downstream projects.

6. International Public Goods from Development Research

From the foregoing discussion, it is clear that there must be a compromise on the positioning of an IARC. Since it may be ineffective to be involved in lots of location-specific work, development research projects need to be carefully selected and organized in such a way that they enhance a center's capacity to produce IPGs. It is often said that experience is the best teacher and this applies to agricultural research for development. McNie (2007) signals the need to carefully consider the context and lessons from past project implementation including the circumstances that shape trends and momentum for change. To increase the probability of success, lessons learnt should be documented, shared and applied in subsequent interventions. However, research managers within the CGIAR have not adequately assessed and documented the institutional innovations of scientists, which have contributed to achievement of impact under newer mandates (Shambu Prasad et al. 2005).

A strategic analysis of case studies of research programs, considered as development activities, will provide guiding principles for engagement and partnerships in the future. The types of interventions identified in different locations that have achieved the best results as well as those that have experienced limiting political, cultural and institutional constraints to adoption are worthy of analysis (CGIAR TAC 2000). The CGIAR Centers can play a critical role in identifying principles of organizational and management arrangements that

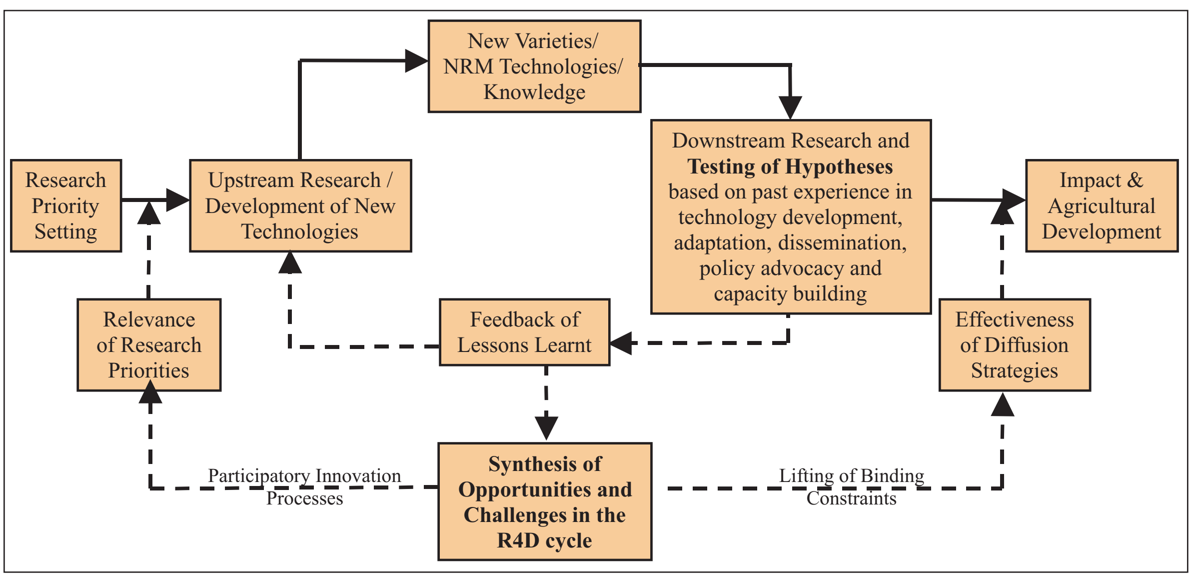

Fig.7: Conceptual framework for generating IPGs from downstream research.

are transferable across locations. Along the same lines, the opportunities and constraints experienced in the innovation cycle, which can only be derived from carrying out research at the downstream end as illustrated in figure 7, constitute international public goods that have applicability in different regions to increase the relevance of research priorities and the effectiveness of diffusion strategies for achieving impact and agricultural development.

The big box in the learning cycle presents opportunities for generating IPGs based on experimentation and feedback as illustrated by the dotted lines. It also serves as the basis for identifying research problems for subsequent projects which, if tackled through interactive technical and institutional innovations in the course of carrying out development-oriented work on a variety of locations, will produce lessons that are applicable at the international level. A synthesis of the lessons can serve as a generic "toolbox" that give essential guidelines to a broad range of clientele worldwide to device complementary solutions based on their own existing structures and context.

Harwood et al. (2006), for example, studied the international applicability of strategic approaches to Integrated Natural Resource Management (INRM) research and identified IPGs that have been generated from research efforts and development of locally adapted technologies. Although natural resources management research is often very location-specific, modern methods and tools, implemented through partnerships of institutions, can apply databases and models for extrapolation across ecosystems. Lessons learnt from one area can also greatly speed the research process in similar ecoregions. They suggest that appropriately designed research with development components generate at least five types of IPGs:

- Tools and methods for research and/or development that have applicability beyond the localized borders, eg, decision support tools like PRA techniques.
- Global and regional approaches for INRM research co-ordination and facilitation services that involve more than one country. The coordinating roles are nearly always governed by consortia partnership arrangements or steering committees.
- Development at both field and landscape levels of management and institution building principles and methods that have applicability in more than one country for suggesting the appropriateness of technologies and policies.
- Contributions to technology development for INRM-based production systems that can be effectively used, with modest adjustments for site-specific conditions, in more than one country.
- Scientific understanding of the nature of ecosystem problems, driving factors and consequences/interactions with poverty and productivity are IPGs. Understanding the principles of managing ecosystems (across spatial and temporal scales) are also IPGs (that is, lessons for technology, institution, and policy interventions).

Bertram (2006) gives an illustration on the effort by CGIAR Centers led by USAID and other development agencies to multiply crop varieties that could better withstand drier conditions when a major drought was forecasted for southern Africa in 1990 (eg, a number of ICRISAT sorghum and millet varieties). Social scientists studied the behavior and resilience of traditional seed systems. This led to an improved understanding of how new technologies are perceived and adopted, and of how relief efforts could be more effective. Work of CIP and IITA on adoption of orange-fleshed sweet potatoes in Mozambique is an example of how a researcher can champion and catalyze the adoption and demand for new technologies. Another illustration is promotion of resource-conserving agriculture in the Indo-Gangetic plain where the work of engaging farmers' organizations, small-scale farm equipment producers, and traders was critical in moving to a more profitable and more environment-friendly production system. Research and development efforts complement each other as exhibited by the rapid deployment of virus-resistant cassava varieties by IITA and its partners ahead of the moving front of an epidemic.

ICRISAT development-oriented work has played an important role in achieving impacts that have been effectively documented and measured through impact assessment. The institute has achieved recognition for innovative technologies, policies and tools that have been published as IPGs. A further potential exists in the development of IPGs on the innovation process and institutional innovations used to deploy improved technologies.

6.1 Generic Lessons from ICRISAT Development Research

Embracing location-specific development work within an IPG framework is possible under a technology adoption/impact assessment umbrella to reconcile the tension between development-oriented work and the delivery of IPGs (CGIAR Science Council 2009). The sixth external program and management review (EPMR) of ICRISAT states that there appears to be a dichotomy between devoting research resources to the achievement of direct, tangible, on-ground impacts (scaling up) versus producing IPGs by testing from proof-of-concept hypotheses about the scaling up process. The achievement of the former implies a greater focus on problems and issues of a more localized nature and documented solutions are legitimate IPG lessons that can be published as best bet guides.

With the recognition that innovation occurs through interaction of a diverse set of actors, ICRISAT, as an IARC, must produce IPGs from its upstream as well as downstream research to facilitate innovation. Wejnert (2002) grouped diffusion variables into three major components, namely the characteristics of innovations, characteristics of innovators and the environmental context. Understanding the innovation process and its associated challenges is required to guide researchers and policymakers in priority setting and design of appropriate policies. Generation and diffusion patterns for innovations depend on complicated, and often unobservable, relationships between different elements like credit constraints, farm size, risk and uncertainty, labor availability, supply constraints and tenancy status among others. Different localities may also show different adoption and diffusion patterns because of differing social, cultural and institutional environments aside from economic factors. Several econometric models have been developed by economists to study the adoption behavior of farmers and to identify the key determinants of technology adoption. Ruttan makes several generalizations about adoption of high yielding varieties (HYVs) during the green revolution but acknowledges that there are many exceptions relating to environments with varying economic, social and political institutions (Feder et al. 1982). Research should therefore go beyond studies of farmer adoption decisions to include institutional innovations to address the wider environmental context and patterns of interaction and learning. Biggs (2008) cites the importance of learning from actor-oriented studies of situations where positive socio-economic and welfare benefits have been realized.

Table 2 presents a typology of observations made from past ICRISAT adoption studies, constraint analyses and impact assessment. The studies estimate the returns to research investment and capture the technology development, adaptation and dissemination strategies that were employed as general observations. The conditioning factors for technology uptake and diffusion are drawn from a comprehensive analysis of lessons learned featuring new innovations along the impact pathway: i) the role of the informal farmer-to farmer seed exchange and community level seed system linkages; ii) role of a champion on technology delivery; iii) quality of new technologies matching user's preferences and quality assurance systems; iv) information reaching farmers early in the technology development process, eg, participation in early stages of plant varietal selection; v) innovations in social capital build-up, collective action and input-output trade contracts for facilitating information, credit and input access; vi) flexibility for technology adaptation according to users' needs and resource endowments; vii) institutional arrangements easing access to selling points and linking producer marketing groups.

Factors	Traits	Conditioning Environment	Institutional Factors	Adopter Characteristics	Sources (crop and location)
Seed availability	Cost of seed	Efficiency in seed multiplication and distribution system	Private agencies	Level of interaction in informal seed systems	Bantilan and Joshi 1996 (Pigeonpea, Maharashtra) Rohrbach et al. 1999 (Pearl millet, Namibia) Ramasamy et al. 2000 (Pearl millet, Tamil Nadu) Rohrbach & Kiala 2000 (Mozambique) Yapi et al. 1999 (Sorghum, Cameroon and Chad) Shiferaw et al. 2005 (Pigeonpea, Tanzania) Camara et al. 2005 (Cereals, Niger) Ndjeunga et al. 2000 (Groundnut and pearl millet, Niger and Senegal) Freeman 2001 (Groundnut, Malawi) Ndjeunga et al. 2008 (Groundnut, Mali, Niger and Nigeria) Joshi & Bantilan 1998 (Groundnut, Maharashtra)
Quality of new technologies	Yield, unit cost savings, drought/ disease tolerance, ease of operation and modification of components	Incentive structures for researchers	Seed quality assurance systems	Applicability of readily available implements/ inputs	Freeman 2001 (Groundnut, Malawi) Yapi et al. 1999 (Sorghum, Cameroon and Chad) Shiferaw et al. 2005 (Pigeonpea, Tanzania) Ntege-Nanyeenya et al. 1997 (Maize, Uganda) Tripp 2000 (Seed Systems in Africa) Shiferaw et al. 2009 (Land and Water Management)
Product quality and safety	Susceptibility to bird attack and grain mold	Storage practices	Product quality assurance systems	User preferences, eg, ease of grinding as well as cooking, taste, risk aversion and preference for local varieties in diet	Yapi et al. 1999 (Sorghum, Cameroon and Chad) Joshi & Bantilan 1998 (Groundnut, Maharashtra) Yapi et al. 2000 (Sorghum and Millet, Mali)
Information		Close interactions amongst community members and with external agents	Extension services, capacity building	Age, experience of farmers and receptivity to new knowledge, participation in on-farm trials	Joshi & Bantilan 1998 (Groundnut, Maharashtra) Bantilan and Parthasarathy 1999 (Pigeonpea, India) Ramasamy et al. 2000 (Pearl millet, Tamil Nadu) Shiyani et al. 2001 (Chickpea, Gujarat) Yapi et al. 2000 (Sorghum and Millet, Mali) Joshi et al. 2002 (Vertisol Technology) Bantilan & Padmaja 2007 (Groundnut, Maharashtra) Shiferaw et al. 2005 (Pigeonpea, Tanzania) Loeffen et al. 2008 (Soil & Water Conservation, Mali) Freeman 2001 (Groundnut, Malawi) Ndjeunga et al. 2008 (Groundnut, Mali, Niger and Nigeria)

Table 2: Typology of factors conditioning technology uptake.

Continued

Table 2: Typology of factors conditioning technology uptake *continued*.

Factors	Traits	Conditioning Environment	Institutional Factors	Adopter Characteristics	Sources (crop and location)
Participation and Collective Action	Tangible economic benefits	Shared objectives, trust, commitment, equality, transparency and accountability	Existing informal groups, participatory technology development	Degree of participation, previous collective effort	Rohrbach et al. 1999 (Pearl millet, Namibia) Shiyani et al. 2001 (Chickpea, Gujarat) Freeman 2001 (Malawi and Zimbabwe) Bantilan & Padmaja 2007 (Groundnut, Maharashtra) Ntege-Nanyeenya et al. 1997 (Maize, Uganda) Shiferaw et al. 2009 (Land and Water Management)
Social Capital			Social Networks	Gender	Bantilan & Padmaja 2007 (Groundnut, Maharashtra) Shiferaw et al. 2005 (Pigeonpea, Tanzania) Freeman 2001 (Malawi and Zimbabwe) Ndjeunga et al. 2008 (Groundnut, Mali, Niger and Nigeria)
Financial Assets	Profitability, payback period	Availability of credit	Access to MFIs, credit co-operatives, SHGs, banks	Available capital, alternative income	Yapi et al. 1999 (Sorghum, Cameroon and Chad) Shiferaw et al. 2005 (Pigeonpea, Tanzania) Joshi et al. 2002 (Vertisol Technology) Camara et al. 2005 (Cereals, Niger)
Human Capital	Ease of mechanization	Labor availability/ cost, family labor availability		Education Level	Ramasamy et al. 2000 (Pearl millet, Tamil Nadu) Joshi et al. 2002 (Vertisol Technology) Shiferaw et al. 2005 (Pigeonpea, Tanzania) Loeffen et al. 2008 (Soil & Water Conservation, Mali) Nkonya et al. 1998 (Maize, Tanzania) Ntege-Nanyeenya et al. 1997 (Maize, Uganda) Mohammad et al. 1999 (Maize, Punjab)
Natural resources and physical assets		Soil fertility, terrain and availability of water/ irrigation	Input supply constraints, land tenure systems	Ownership of land, livestock, equipment & inputs, efficiency in resource/ input use	Joshi & Bantilan 1998 (Groundnut, India) Yapi et al. 1999 (Sorghum, Cameroon and Chad) Yapi et al. 2000 (Sorghum and Millet, Mali) Joshi et al. 2002 (Vertisol Technology) Camara et al. 2005 (Cereals, Niger) Ramasamy et al. 2000 (Pearl millet, Tamil Nadu) Loeffen et al. 2008 (Soil & Water Conservation, Mali) Ntege-Nanyeenya et al. 1997 (Maize, Uganda) Mohammad et al. 1999 (Maize, Punjab)
Leadership		Presence of a champion, experience of researcher	Catalyst institution	Propensity to innovate	Bertram 2006 (Sweet potatoes in Mozambique and resource-conservation in the Indo-Gangetic plain) Rohrbach et al. 1999 (Pearl millet, Namibia) Bantilan & Padmaja 2007 (Groundnut, Maharashtra)
Markets for products and inputs	Market Price	Distance to markets, transaction costs, transport infrastructure	Producer marketing groups	Preference for collective action	Katyal & Mruthyunjaya 2003 Camara et al. 2005 (Cereals, Niger) Ramasamy et al. 2000 (Pearl millet, Tamil Nadu) Ndjeunga et al. 2000 (Groundnut & pearl millet, Niger & Senegal) Shiferaw et al. 2009 (Land and Water Management)

The above typology draws from observations made from ICRISAT adoption and impact assessment studies over the past 18 years. A synthesis of these findings features the following:

- Non-availability of seeds constrained adoption of wilt resistant pigeonpea varieties in Maharashtra state of India in the mid 90s. However, an informal sector evolved to meet the demand for seed and farmer-to-farmer seed distribution remained a major source of varietal adoption. The private sector was earlier constrained by limited availability of breeder seed, which played an important role in seed delivery (Bantilan and Joshi 1996). The adoption study alerted officers of the state of Maharashtra and its seed sector, facilitating the delivery of the variety and its subsequent wide diffusion.
- In a case study of Groundnut Production Technology (GPT), farmers were found to follow a rational, step-wise process of adopting improved varieties, nutrient management, soil management, and other components of the package depending upon information about the technology, niches for the technology, availability of necessary resources or inputs, marginal returns on the technology, risks, and suitability of technology traits. Availability of capital, implements, irrigation facilities, technology traits, information about technology, and soil type are important factors influencing adoption of the Raised Bed and Furrow (RBF) method for groundnut cultivation. The GPT options were observed to be applicable beyond the commodity for which the technology was developed. The study found that farmers partially adopted the concept of crop and resource management research products, and modified the technology options according to their needs, convenience and resource endowments. It was noted that the adoption of different components was associated largely with the RBF method, with adoption of all components being significantly higher among those who had adopted this method. The probability of adopting the RBF was high when farmers had access to technology-generating and technology-transfer systems (Joshi & Bantilan 1998).
- Farmers in Cameroon and Chad were found to be willing to change their management practices for sorghum variety S 35 and not for their local sorghum varieties because the required changes are simple, familiar, and easy to implement locally from available family and animal labor. Furthermore, payoffs for making these changes are substantial, including food security, production efficiency, and unit production cost reduction. The adoption and intensive use of the S 35 technology was constrained by a number of factors, the most important of which were bird attack, lack of improved seed, soil/land infertility, grain mold, and the high cost of grinding (Yapi et al. 1999).
- Success in crop breeding research for Okashana 1 pearl millet variety in Namibia was due to efforts of scientists to consider the preferences of small scale farmers from the earliest stages of the national variety selection effort. Rapid adoption of Okashana 1 was stimulated by public investments in seed production and dissemination. Donor and government support enabled seed to be rapidly multiplied, and sold through the national extension program. Strong assistance from ICRISAT played a significant role in contributing to the success of a national breeding program. The research scientist associated with ICRISAT also took the initiative to invest a large share of his own time and effort in both producing seed and developing seed production capability in the form of a farmers' cooperative (Rohrbach et al. 1999). These efforts were complementary and accounted for measurable returns to the pearl millet breeding program.

- Institutions like the extension network of the Department of Agriculture in western Maharashtra and scientists from Mahatma Phule Agricultural University played an important role in enabling the adoption of ICPL 87 short-duration pigeonpea (SDP) variety (Bantilan and Parthasarathy 1999).
- In a study of adoption, impact, and returns to research investment of improved cultivars of pearl millet in Tamil Nadu, Ramasamy et al. (2000) found that sources of seed and information were of critical importance in the spread of improved cultivars. The study concluded that all agents (public and public sector agencies, and farmers and their relatives) have to play a complementary role to efficiently disseminate improved cultivars to farmers. Education was found to have a positive influence in farmers' adoption of improved varieties while nonfarm income was negatively related with adoption. Improved cultivars are preferred in irrigated conditions though farm size did not have a significant effect on adoption. Distance to the product markets was negatively related to adoption. The presence of private seed sector outlets in the locality favored adoption significantly, and had a very large effect on adoption of improved cultivars.
- An analysis of the economic impact of sorghum and millet research in Mali noted that farmer to farmer channel was the primary source of information and seeds of new varieties even though the farmers insisted that they had a good relationship with the extension services. The major reasons for non adoption were lack of information about improved varieties by farmers and non-availability of the improved seeds when needed and in the required quantity. Soil infertility was also a limiting factor since some of the improved varieties especially the introduced ones required a moderate level of fertilization for their productivity. Small farmers tended to avoid taking risky decisions and were often reluctant to give up the familiar traditional varieties for something new, which may or may not work (Yapi et al. 2000).
- Participatory approaches to understanding farmers' needs relating to different varietal traits and identifying specific varieties played a significant role in the wider acceptance and spread of improved chickpea cultivars in Gujarat. Years of experience in chickpea farming had a positive influence on probability of adoption. Thus, more experienced farmers were increasingly likely to adopt improved chickpea cultivars since they were aware of their benefits (Shiyani et al. 2001).
- Joshi et al. (2002) in a study of the impact of vertisol technology in India suggests that there is need for strong technology dissemination methods to convince farmers of the benefits of improved production and management technology options. Since inadequate credit facilities restricted the adoption of many components of the technology, timely and adequate supply of credit through Self-Help Groups (SGHs) would have been beneficial. Farmers also faced problems of higher price and non-availability of inputs such as improved seed, fertilizers, implements, insecticides/pesticides, etc, which could be resolved by joint efforts by seed companies, agricultural scientists, extension workers and other voluntary organizations. Some of the farmers had dug their own wells, but had no oil engines or electric motors to irrigate the postrainy season or long-duration crop. A majority of the farmers were unaware of banking procedures and had they been educated and made aware of the bank loans available to purchase agricultural implements, a larger area could have been covered under double cropping and improved varieties.
- Groundnut production technology (GPT) adopters in Umra revealed that collective action, social capital and an effective leader were instrumental in high adoption level of the technology in the village. It was only when the farmers came together as a group did they realize the potential of the technology package and its benefits, and their success

motivated other farmers in the village to adopt the technology. Smallholder farmers from nearby hamlets approached this group for advice and women began to form themselves into groups. In contrast to Umra, the adoption of GPT was very low in Ashta. One important constraint expressed by them was the lack of knowledge/information about the technology. As there was no collective action, the cultivators never tried to get the necessary information from the Umra farmers. Lack of collective action led to non-availability of gypsum and micronutrients, which was another reason for the poor adoption. It was concluded that in these typical differentiated contexts, it is the farmers themselves who are actively generating new knowledge all the time, and effective research must be a partnership of some kind between farmers and researchers. Recognition that there are (perhaps informal) groups already in existence, or social networks that operate effectively, is usually a good starting point (Padmaja et al. 2006).

- Shiferaw et al. (2005) in an assessment of the adoption and impact of improved pigeonpea varieties in Tanzania found seven variables to have significant effects in explaining the level of adoption of improved varieties in the district: sex of the household head, area share of maize, education of the household head, knowledge about varieties, perceived profitability of the varieties, expressed socioeconomic constraints, and the level of access to new seeds. The importance of three major policy variables also became apparent; improving returns to technology adoption, relaxing economic constraints and improving access to new seeds in promoting the adoption of improved pigeonpea varieties.
- In Camara et al. (2005), Mazzucato and Ly (1993) reported that in Niger the negative effects of climate on technology adoption and crop intensification were compounded by other factors such as the low market price for cereals, weak transport and market infrastructure, poor seed multiplication system, and the unavailability of seeds, fertilizer and credit. The responses of farmers concerning the main constraints to sorghum and millet technology adoption in West and Central Africa (WCA) were the lack of inputs (seeds and fertilizers), lack of information, bird damage and preference for local varieties.
- Tripp (2000), while addressing strategies for seed system development in sub-Saharan Africa, suggests that NARS may have to establish a post of ‘seed contracting officer’. He also intimates the need for internal changes in incentive structure where rewards to researchers will depend on adoption of their varieties. Research administrators must emphasize that the future of the organization will depend on technology adoption rather than the mere release of varieties or the publication of papers. Neither governments nor external donors will continue to invest in public plant breeding programs that do not result in changes in farmers’ fields. The concluding recommendations include promotion, regional collaboration, availability of seed at a reasonable price, seed system links, regulation of seed quality, improved farmers’ access to information and capacity to market their grain as well as comprehensive and integrated seed policies among others.
- The most important factors that determined the probability of uptake of soil and water conservation technologies in Mali included plot area, plot status, plot position on the toposequence, soil fertility, value of equipment and livestock, age of household head, dependency ratio, literacy and the kinds of crops grown (Loeffen et al. 2008).
- Ndjeunga et al. (2000), while comparing seed systems in Niger and Senegal, conclude that crops of low commercial value like pearl millet are more suitable for informal seed systems and their uptake can be increased by focusing on the informal sector. Input-output trade contracts and ease of access to selling points also stimulate uptake of improved varieties.

- Improved groundnut varieties were more acceptable in Malawi to farmers who have been exposed to them in on-farm variety trials and demonstrations. Farmers stopped growing the new varieties because of consumption of seed stock to satisfy subsistence needs and effects of drought and pests. Informal farmer-to-farmer diffusion especially among farmers with close social networks was the main distribution mechanism for disseminating seeds (Freeman 2001).
- Rohrbach and Kiala (2000) in a study of development options for local seed systems suggest that village seed systems are remarkably efficient in meeting the seed requirements and maintaining varietal diversity, even under drought or flood conditions. They offer recommendations for strengthening local and commercial seed supply systems in Mozambique.
- The major determinants for early adoption of modern groundnut varieties in Mali, Niger and Nigeria were participation of farmers in on-farm trials, build-up of social capital, availability and access to seed and incidence of pest and diseases (Ndjeunga et al. 2008).
- Shiferaw et al. (2009) found that adoption and adaptation of natural resource management innovations in smallholder agriculture depends on flexibility to use of inputs readily available to the farmer, short-term economic gains, a conducive policy and institutional environment with linkages to markets, and community participation and collective action to co-ordinate and regulate resource use and investment decisions.

The concerns that were raised in these studies helped identify important areas for further research. For instance, the recognition that seed availability was a major setback to adoption of new varieties triggered a series of in-depth seed systems studies. Lessons on the importance of participation and collective action influenced ICRISAT to develop the consortium approach to watershed development projects, which has been cited as one of the seven best INRM cases in the CGIAR[5]. The approach has been adopted by the Indian government and several donors, and replicated in others countries in Asia and sub-Saharan Africa.

Based on its experience, ICRISAT has adopted an integrated genetic and natural resource management (IGNRM) approach that is multidisciplinary, participatory and aimed at generating scientific outputs that will improve the well-being of the poor in an equitable and sustainable manner. Synergy across themes has enabled a strategic positioning of the institute as a bridge, broker and catalyst while producing IPGs with potential development impact. Impact pathways are developed ex-ante in medium term plans, that include the research problem, required inputs, expected IPG outputs and their users, potential partnerships as well as anticipated outcomes and impacts as part of a monitoring and evaluation process. The ICRISAT Agri-Science Park (ASP) facilitates public-private partnerships for the development and commercialization of scientific knowledge and technologies generated at the institute and serves as a 'hub' for marketing arrangements that will ultimately benefit the poor.

A number of such IPGs have been produced and shared through social science research in the Global Theme on Institutions, Markets, Policy and Impacts (IMPI) including Village Level Studies (VLS), methodologies for impact assessment, knowledge on changing livelihood strategies and development pathways in the SAT, strategies for improving seed production and distribution systems, institutional innovations for improving markets for the poor and

[5]. SP Wani, personal communication.

crop situation outlook reports. Even though the research is conducted on particular locales, it develops methodologies and lessons that are likely to have broader implications in other locales. The Village Level Studies (VLS), which is now called Village Dynamics Studies, is an IPG and has proved to be one of the most valuable contributions of ICRISAT to the knowledge base on rural household economies. The criteria for selection of sites, poverty indicators and methods of data collection and analysis have been applied in other locations in eastern Africa, and West and Central Africa. The project has helped scientists and PhD students across the world to identify and understand socio-economic, agro-biological and institutional constraints to agricultural development in the semi-arid tropics (Katyal and Mruthyunjaya 2003). The studies have been expanded from six villages in the Indian semi-arid tropics (SAT) to 42 villages, which includes villages in the humid tropics of India and Bangladesh.

These intermediate products are themselves IPGs that improve the efficiency of other research for development programs. IPGs developed in the course of carrying out location-specific research in ICRISAT's agro-ecosystem development research include the consortium approach to watershed management, identification and amelioration of micronutrient deficiency across agro-ecosystems, information and understanding of the SAT environment, innovative soil and water conservation practices, integrated pest management (IPM) protocols for major crops and delivery mechanisms at village level, methods for representative soil sampling in micro-watersheds, detailed datasets of pedons for carbon sequestration in benchmark sites, simulation models for water balance, cropping systems and soil management, remote sensing application technology and meteorological forecasts and analysis of its acceptance by farmers, methods for assessing economic and environmental effects of NRM.

The need for focus on soil fertility management, soil and water management are being addressed by work on fertilizer micro-dosing and African Market Garden (AMG), which is based on low-pressure drip irrigation systems. The AMG, initially tested on-station and around Niamey, has been successfully replicated in many African countries. Another initiative is the Virtual Academy for the Semi-Arid Topics (VASAT), which is experimenting on innovative ways of facilitating information flow and communication on rural development issues. This has enabled technologies to be effectively developed in collaboration with other stakeholders, feedback to be obtained and good relationships to be established. A synthesis of these outputs and lessons learnt across all regions will increase the visibility of the many IPGs produced. Annex A summarizes major IPGs developed from ICRISAT research for the five-year period from 2003-2008.

Even though generalized conclusions cannot be drawn based on one or two locations, the observations do provide lessons for consideration and further in-depth analysis in subsequent projects. Testable hypotheses, based on past experience, can be drawn from a synthesis of these studies and the list highlighted above features a set of seven to start with:

Hypothesis 1: Farmer to farmer exchange is the primary source of seed of improved varieties of the ICRISAT mandate crops; hence strengthening informal seed systems is a key pre-requisite to adoption of new varieties.

Hypothesis 2: Success in diffusion of new technologies depends on the leader's capability in championing and coordinating the application of such technologies.

Hypothesis 3: Adoption of soil and water conservation technologies mainly depends on ease of operation and applicability of implements/inputs readily available to the farmer.

Hypothesis 4: Farmers who participate in participatory varietal selection are more likely to adopt new technologies.

Hypothesis 5: Alternative diffusion mechanisms are viable irrespective of entry points ie, targeting progressive farmers versus targeting marginalized groups.

Hypothesis 6: Watershed management technologies cannot be applied uniformly; existing interventions show better impact in areas with 700-1100 mm annual rainfall.

Hypothesis 7: Farmer to market linkages through producer marketing groups can exploit scale economies and effectively reduce transaction costs.

7. Conclusion

For the full benefits of research for development programs to be realized, investments in national, regional and international research are needed to ensure that public goods are produced. This is because there are local circumstances beyond the control of research centers that influence success in innovation and hence impact of new technologies. Some of the factors that may hinder the applicability of IPGs in a given locality have been discussed. Agricultural research for development needs to address a wide range of issues facing the resource-poor farmers in different countries. For instance, to encourage the adoption of new technologies, public-funded agricultural research organizations such as ICRISAT need to ensure that farmers enhance levels of agricultural production through a combination of improved technologies, improved infrastructure, institutions and policies as well as strong partnerships.

For ICRISAT, a clear research agenda with an IPG framework in all stages of the research for development cycle will enable the testing of hypotheses to confirm proof of concepts by using specific problems at the local level; as well as translating the lessons learnt on the conditioning factors into IPGs. While carrying out research, scientists need to ensure how the research outputs can be implemented across regions and what human, physical and institutional infrastructure, and financial resources are required for implementation. When developing medium to long term research plans, these elements need to be considered in project impact pathways analysis to elucidate the IPG attributes of the research. Comparisons can be made through the ex-post assessment of the actual impact to provide lessons for future planning of IPG research.

The comprehensive analysis undertaken in this study addresses the critical concerns and corresponding approaches for an effective and flexible structure to learn from downstream research. If development research is designed to draw lessons on the critical determinants of technology development, adaptation and application, it may provide information of IPG value. The conclusions made from studies similar to the ones above can only be translated into IPGs if

Annex A: Major International Public Goods developed from ICRISAT research (2003-2008).

Biotechnology and Crop Improvement	Agroecosystems Development	Social Science Research

• Molecular markers, strategies and information analysis systems for marker-assisted selection and its products.
• Integrated decision support system (iMAS) for marker-assisted selection in breeding has also been developed for genomics and molecular breeding.
• Protocols and information/analysis systems for the molecular characterization and gene mining of crops, their pests and diseases and bio-control agents.
• Genomic information of mandate crops and Laboratory Information and management Systems (LIMS) for data capture from high throughput genotyping have been made available to the global research community. Methods and protocols for developing transgenic products are available to scientists.
• Transgenic lines containing stable insertion of genes for resistance to insects (Helicoverpa) in chickpea and pigeonpea; resistance to peanut clump, bud necrosis and rosette virus in groundnut; resistance to *Aspergillus flavus* and aflatoxin contamination in groundnut; elevated levels of beta-carotene in groundnut and pigeonpea; sulfur containing amino acids in pigeonpea and improved drought tolerance in groundnut at different stages of development.
• Largest germplasm collection (118,882 accessions from 144 countries) of its mandate crops and small millets. 94,390 germplasm and improved breeding lines shared with cooperators in 144 countries. Out of this, NARS partners have released 609 varieties in 77 countries utilizing germplasm and breeding lines from ICRISAT. During the last 5-year period (2003-2007) alone, 21 national programs globally released 85 hybrids/varieties.
• Peer-reviewed technical papers, manuals and booklets provide knowledge for enhancing the efficiency of crop improvement, production and management.
• Groundnut improvement and production in Vietnam, pigeonpea and finger millet in Kenya, chickpea and pigeonpea in Myanmar and groundnut, pigeonpea, chickpea, sorghum and pearl millet in India.
	• Consortium approaches to watershed management in Asia and its corresponding policy influence across countries. ICRISAT's watershed research began in a few pilot sites in Andhra Pradesh, India and is significantly expanded to several other states and to four countries in Asia, and is now replicated in sub-Saharan Africa (eg, Rwanda and Southern Africa through ASARECA).
	• Simulation models of water balance, cropping systems and soil management, remote sensing application technology and the suggested crop production technologies for rice fallows constitute an IPG that has applications across regions and countries in Asia and sub-Saharan Africa.
	• The African Market Garden, based on low-pressure drip irrigation systems, was tested first on-station and around Niamey, then in several Sahelian countries. To date, ICRISAT's partners have replicated this model in eight countries, significantly adding to the intensity of work done worldwide.
	• Downscaling short and medium term meteorological forecasts and analysis of acceptance by farmers, establishing C-sequestration potential in semi-arid systems, management and monitoring of aflatoxin contamination in maize and groundnut, fertilizer micro-dosing (phosphorus in West Africa and nitrogen in southern Africa)
	• Identification and amelioration of micro-nutrient deficiency in Asia and precision conservation agriculture doubling cereal yields over 30,000 households in Zimbabwe.
	• Work on desertification in West and Central Africa has become a flagship for ICRISAT and its partners in the region.
		• Village Level Studies (VLS) to provide better understanding of livelihood options, household economics and needs of poor farmers to help design suitable technology and formulate appropriate policy. The VLS has proved to be one of the most valuable contributions to the knowledge base on rural household economies and helps scientists identify and understand socio-economic, agro-biological, and institutional constraints to agricultural development in the semi-arid tropics.
		• Well-documented analysis of changes in resource and social environments through micro-level studies to support the institute's efforts towards science quality, relevance and impact in the semi-arid tropics through deliverables such as:
		  • Knowledge base on rural investment patterns, market opportunities, commodity outlooks and implications for agricultural research priorities in SAT farming systems
		  • Household and village level data and information providing valuable insights on rural SAT development pathwayso
		  • Policy instruments for technology delivery, market development, and agricultural diversification in the SAT
		  • Innovative institutional arrangements and mechanisms for technology exchange, market access and targeting of spillovers based on institutional experience
		  • Synthesized and policy relevant information on technology adoption pathways and impacts
		  • Strategies for seed system development, directly linked with crop improvement activities, covering informal (seed village system) and formal quality seed production and distribution (including hybrid seed production methodologies) and institutional arrangements for seed certification and policy intervention.

Source: ICRISAT 2008. Harvesting the Seeds of Success of ICRISAT's Research. A resource material for ICRISAT's 6th External Program and Management Review (EPMR) the observable pathways and apparent trends are used to formulate research questions from the beginning of projects and tested in multiple locations during implementation. This calls for a development of hypotheses, based on a synthesis of downstream level experiences, on the factors along the research to development continuum that influence the probability of success in agricultural research for development. ICRISAT's IGNRM approach presents an opportunity for generating combinations of products and processes that can be tested in different contexts and extrapolated across regions/ countries based on a thorough analysis of spillover potential.

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About ICRISAT

ICRISAT
Science with a human face

The International Crops Research Institute for the Semi-Arid-Tropics (ICRISAT) is a non-profit, non-political organization that conducts agricultural research for development in Asia and sub-Saharan Africa with a wide array of partners throughout the world. Covering 6.5 million square kilometers of land in 55 countries, the semi-arid tropics have over 2 billion people, and 644 million of these are the poorest of the poor. ICRISAT and its partners help empower these poor people to overcome poverty, hunger and a degraded environment through better agriculture.

ICRISAT is headquartered in Hyderabad, Andhra Pradesh, India, with two regional hubs and four country offices in sub-Saharan Africa. It belongs to the Consortium of Centers supported by the Consultative Group on International Agricultural Research (CGIAR).

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