# BACKGROUND PAPER: RESEARCH AND DEVELOPMENT AND EXTENSION SERVICES IN AGRICULTURE AND FOOD SECURITY

*Annie S. Wesley and Merle Faminow*

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## ABSTRACT

Investments in agricultural research and extension have consistently demonstrated high rates of return in Asia and the Pacific. However, the recent global food crisis exposed the vulnerability of food supply systems and reversed many past achievements in the fight against hunger and malnutrition. It also demonstrated the need for continued innovation. In view of the emerging economic, climatic, and political scenarios in the region, this paper explores the role of applied research for development and extension services through the two-pronged approach of boosting food production and preventing losses. Priority areas for research emphasize attention to smallholder farming systems, practical business models, the integration of gender, and multidisciplinary research that is sensitive to nutritional outcomes. In addition, pioneering mechanisms to public–private partnerships are examined towards the strategic use of renewed stakeholder commitments to achieve food security and prevent future crisis. By learning from the past and looking into the future, this paper makes a case for sustained investments in research and extension to address the numerous challenges along the pathway from agriculture production and distribution to consumption and utilization.

Keywords: food security, agriculture, research and extension, the Asia and Pacific region

JEL Classification: Q16

# I. INTRODUCTION

The current global challenges of ensuring the availability of and access to food, in both quantity and quality, require deliberate and far-reaching solutions. Historically, research for development in agriculture and extension services has been a strong driving force for meeting food supply around the world. The Asia and Pacific region is the largest supplier as well as consumer of the world's food and agricultural products. This region, where agriculture is one of the key economic sectors, houses about 58% of the world's population in 39 countries, but has only 38% of the world's agricultural land. Despite the wide range of natural resources in the region, some countries more than others face major challenges of food insecurity, poverty, and malnutrition. The huge diversity in the size, population, and agricultural and economic development of the countries reflect the large differences in their agricultural production systems, agroclimatic potential, population density, and infrastructure (Beintema and Stads 2008).

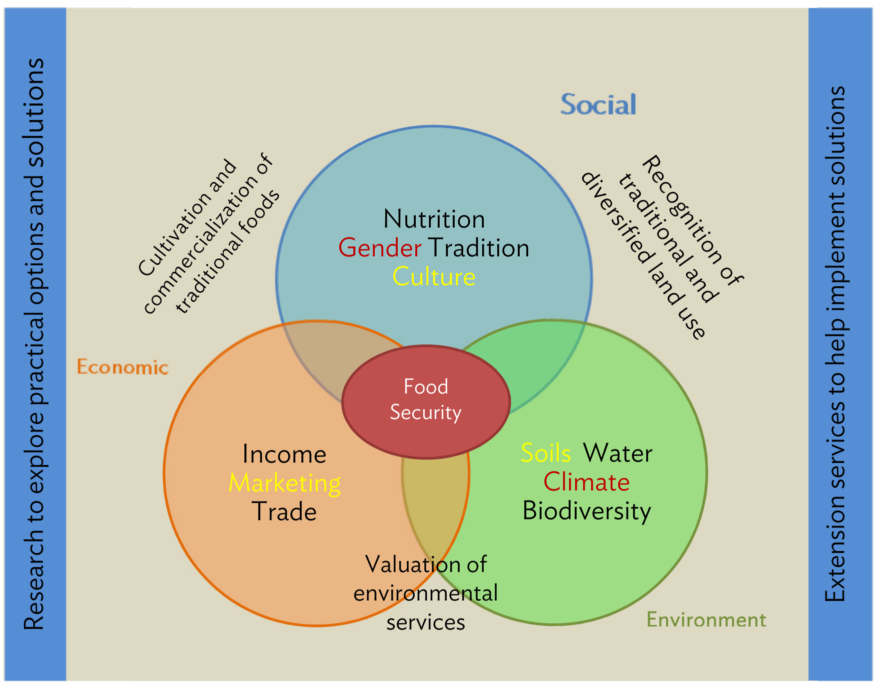
During the past several decades, millions of people across the Asia and Pacific region have benefited from dramatic improvements in agricultural productivity, reduction of poverty, and higher per capita incomes. The region was on track to achieve the United Nations Millennium Development Goal of halving the prevalence of extreme poverty by 2015. However, the recent dramatic fluctuations in the prices of rice and other staples indicated the sensitivity of these gains to rapid price increases, and showed that the region's food supply system is more fragile and imbalanced than what was previously believed (Weinberger et al. 2009). The World Development Report (2008) concluded that improving the productivity, profitability, and sustainability of smallholder farming using "agriculture for development" is the main pathway out of poverty, with innovation through science and technology being one of the key instruments (World Bank 2008). The publication of this report and the food price volatility during 2007–2008 kindled a positive global response and a collective determination by multiple stakeholders to tackle food security challenges, and the recognition of the need for investments in agricultural research and development (R&D) and extension. It was also recognized that resolving the food availability issue was only one part of the solution that has to be complemented with access to and utilization of food to cover the three pillars of food security. As a result, commitments were made by the Group of Eight (G8) Industrialized Nations (2009) at L'Aquila, Italy that led to several global initiatives. In the region, the Asian Development Bank (ADB) co-organized an investment forum for food security in 2010 with the Food and Agriculture Organization of the United Nations (FAO) and the International Fund for Agricultural Development (IFAD), to initiate a more focused regional dialogue (ADB 2011). Building on the commitment of G8 and specifically in response to the need for investments in research, several collaborative international efforts were initiated. One example is the Canadian International Food Security Research Fund established by the Foreign Affairs, Trade and Development Canada (formerly Canadian International Development Agency—CIDA) and the International Development Research Centre (IDRC).[1] Similarly, the Australian Centre for International Agricultural Research focused on agriculture and food security research for the Asia and Pacific region, and more recently, Africa. Increasingly, public R&D investments in developing countries channeled through international agricultural research centers and national agricultural research systems were being complemented by private sector investments in agricultural R&D.

Strategic investments in R&D and extension services in the Asia and Pacific region can play a critical role in addressing numerous challenges along the pathway from agricultural production to consumption and utilization. Understanding research gaps and priorities for action will ensure the

[1] See http://www.idrc.ca/EN/Programs/Agriculture_and_the_Environment/Canadian_International_Food_Security_Research_Fund/Pages/default.aspx

proper use of funds. This paper examines the role of agricultural research for development, which includes applied research as well as extension programs, for boosting agricultural production and productivity levels, and preventing losses before and after the harvesting of crops. The scope of R&D and extension to achieve long-term food security encompasses many spheres of science and practical application including consideration to social, environmental, and economic factors to find sustainable ways of addressing knowledge gaps (Figure 1). This paper builds on the complex issues learned in the past in order to extract lessons for the future. It also explores the changing roles of international agricultural research institutions and of the public and private sectors, and makes the case for strategic investments in research and extension with a long-term vision to address the complex issues surrounding food security.

**Figure 1: Agricultural Research and Extension for Food Security: Complex Interconnections to Consider**




Source: Adapted from IAASTD 2009.

## II. PAST SUCCESSES AND CHALLENGES

Many reviews have examined the advancements in agricultural productivity during the past century and have demonstrated the value of investments channeled through research. Even from the very early years of modern agriculture, the challenge of feeding increasing global populations with limited land was met as a direct result of strides in agricultural research, development, and extension (Waite 1915, James 1996). Although agricultural research benefited mainly industrial countries in the past, intensive research in Asia starting in the 1960s developed new varieties of rice and wheat. With the application of fertilizer and irrigation, these varieties revolutionized agriculture. As a result, improved varieties of rice and wheat were adopted very quickly in South and Southeast Asia, and the two subregions benefited from the boost in agricultural output. In fact, the transforming economies in Asia accounted for two-thirds of the developing world's agricultural growth (Dalrymple 1985, UNESCAP 2009).

## A. Return on Investments

Understanding the impact of research is useful for donors and policymakers to decide where to invest and prioritize. The speed and scale that improved cereal production and improved food security in the past were remarkable and unprecedented, contributing to a substantial reduction in poverty and the launch of broader economic growth in many Asian countries (Hazell 2009). A persuasive body of evidence demonstrates that, regardless of methods of measurement, benefits from productivity growth as a result of agricultural R&D exceed the costs by a factor of 10 or more (Alston 2010; Thirtle, Lin, and Piesse 2003). The impressive rates of returns in Asia are largely due to the dominating effect of rapid increases in the huge agriculture sectors of the People's Republic of China (PRC) and India (IFPRI 2002). The Philippines, where the International Rice Research Institute (IRRI) is located, has perhaps benefited the most having the highest rates of return. Other countries in the region like Indonesia, Thailand, and Viet Nam closely followed with impressive performances of their own, positioning themselves to be net exporters of different food commodities.

In addition to developing high-yielding varieties, research played a critical role through technologies that reduced production costs without necessarily increasing crop yields, such as those involving reduced tillage and integrated pest management (Pender 2008).

Farms in the Asia and Pacific region are predominantly smallholder-based, with many being subsistence production systems. The productivity improvements benefited the rural poor because new technologies were not scale dependent and could be used on small farms. However, the benefits were evident primarily in the main cereal crops in lowland regions and did not provide significant improvements in the diverse crops grown in uplands, marginal coastal areas, and dry lands (IFPRI and ADB 2007).

## B. Threat to the Sustainability of Past Production Gains

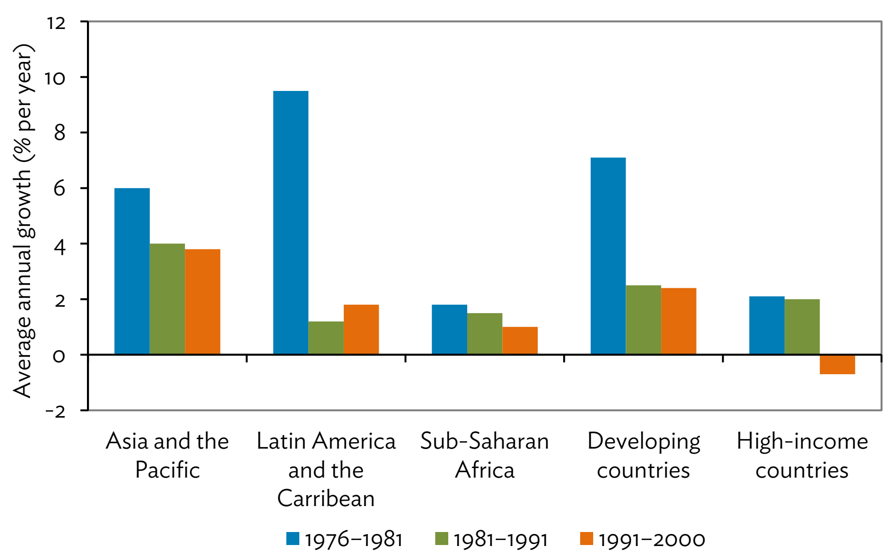
Though past successes and high returns on investments are vital, agricultural production in recent years has experienced a number of challenges, as a result of which, agricultural growth in the Asia and Pacific region has stagnated.

Much of the concern about feeding the world in 2050 relates to the slowing yield growth of major cereals around the world over the decades, casting doubts on the sustainability of past gains, which were mainly in irrigated lands and monocropping strategies. In addition, the negative impact of monocrop farming on the environment, such as soil degradation and loss of biodiversity, emerged as a concern.

## C. Funding for Agricultural Research and Development

It has been well established that past investments in agricultural R&D resulted in high returns. However, agricultural research lost its early strong footing because of the premature belief that the problem of inadequate food supply has already been solved. Unfortunately, R&D budgets more or less followed world commodity prices on their downward track. The crucial basic and adaptive research that identifies scientific solutions and translates the science into locally adapted practices has been underfunded for the past 2 decades (Timmer 2005). In addition to the noticeable downward trend in global and regional public investments in R&D (Figure 2), the emphasis given to agriculture by countries in the Asia and Pacific region varied widely. Beintema and Stads (2008) report that investment for the region as a whole grew by 3.4% annually during 1981–2002, but the distribution of R&D spending among countries had been quite uneven, with the PRC, India, and Japan accounting for a combined total of over 70% of regional spending. Higher R&D spending in agriculture was also seen in relatively smaller countries like Malaysia and Viet Nam, but not in Indonesia, the Lao People's Democratic Republic (Lao PDR), and Pakistan. Diversity was also observed with regard to human resource capacity in agricultural R&D. For example, the PRC employed the largest number of agricultural researchers—over 50,000—and India had the most qualified research staff, while research capacity was lowest in the Lao PDR and Viet Nam. Overall, South Asian countries seem to have better qualified researchers.

Figure 2: Decreasing Regional Public Agricultural Research and Development Spending Trends




Source: Pardey et al. 2006.

## III. CURRENT SITUATION AND FUTURE OPPORTUNITIES FOR RESEARCH

It is now rightly recognized that despite its past success, agricultural R&D, with a narrow focus on a few staple cereals, is no longer sufficient. Focusing on the increased production of staple cereals assumes that the main food security challenge is the number of calories they contain, while the adequate provision of protein and micronutrients is assumed to be automatic. It misses a key point that the real crisis is also the narrow food base and imbalanced diets. High-yielding production often reduces the variety of foods that are produced in small-scale agricultural systems. Efforts to increase food supply in a sustainable manner will need to consider a better cereal, protein, vegetable, and fruit balance with nutritional improvements as the final target. This will require agricultural R&D to be sensitive to more diverse agronomic conditions and more complex farming systems as well as to continue to give attention to environmental sustainability. In addition, rapid changes in many spheres, including economic, political, and climatic, warrant a closer look at the current situation and its relevance to food security, and the need to identify ways to adapt to the changing situation. In the context of these changes along with heightened global commitments to prevent future food crises, agricultural research can be described as being at a crossroads. Because of the wide range of issues that merit attention, it is important to identify some areas on which research could be focused to advance development and sustainability goals. The following section analyzes the current situation and identifies research priorities.

## IV. RESEARCH ON AGRICULTURAL PRODUCTION AND PRODUCTIVITY

Limits to the new arable land, much of it relatively fragile, that can be brought into production; the challenge of a projected 9 billion population by 2050; and consumers' changing food preferences, driven by higher income, point to increasing the productivity of existing cultivable lands and finding ways to better utilize the potential of land, as key areas for research investment. In addition, considering the yield potential of major cereals, diversifying production will be one of the keys by which agricultural R&D can meet future demands in food production. A detailed analysis of present and future land and yield combinations for 34 crops under rainfed and irrigated conditions in 108 countries gives a baseline projection of potential sources of agricultural production growth by region for the three main categories of supply response (Table 1).

Table 1: Projected Sources of Growth in Crop Production, 2050

| | Arable Land Expansion | Increases in Cropping Intensity | Yield Increase |
|---|---|---|---|
| All developing countries | 21 | 10 | 69 |
| Sub-Saharan Africa | 25 | 7 | 68 |
| Near East/North Africa | -7 | 17 | 89 |
| Latin America and Caribbean | 30 | 17 | 53 |
| South Asia | 6 | 9 | 85 |
| East Asia | 2 | 16 | 81 |
| World | 9 | 16 | 75 |

Source: Food and Agriculture Organization of the United Nations 2009.

### A. Crop Diversification

The Asia and Pacific region can increase food production through crop diversification, making the best use of alternatives to rice and wheat. For example, potato has emerged as one of the important food crops in the region. Since it gives an exceptionally high yield and produces more edible energy and protein per unit area and time than many other crops, it fits well into multiple-cropping systems prevalent in the region. Since many potato varieties are bred for conditions in Europe and the United States (US), researchers are testing promising varieties under local growing conditions. The PRC and India are leading the way, accounting for about 79% of the land area allotted and production of potato in the region. There is scope for more research on improved varieties, appropriate production technologies, and value addition (Papademetriou 2008; Thiele et al. 2008).

There is also a real opportunity to increase productivity in many secondary crops that have been neglected and bypassed by mainstream agricultural research. These "orphan" crops, such as millet, sorghum, cassava, and other root crops, provide the main sustenance for millions of poor households (Naylor et al. 2004). The International Center for Agricultural Research in the Dry Areas (ICARDA) has been working for decades on the development of disease-resistant, yield-increasing cultivars of millet, and recently, there has been a strong interest from the research community and policymakers to revitalize millet production as a means of addressing food security challenges. Leading universities and nongovernment organizations in South Asia, in collaboration with Canadian researchers, are finding ways to bring the underutilized small grains back into the South Asian diets through multidisciplinary research and policy advocacy (Box 1).

**Box 1: Research on Increasing Millet Production in India, Nepal, and Sri Lanka: Expected Outcomes**

(i) Increased production and consumption of nutritious minor millets and pulses,
(ii) Conservation of threatened millet varieties and development of a breeding program,
(iii) Development of tool kits on sustainable agricultural practices,
(iv) Improved postharvest technologies to make millet processing easier for women, and
(v) Improved efficiency of millet dehulling technology.

Source: IDRC 2011.

## B. Expanding Agroecological Zones

With the rich agroecological diversity in the Asia and Pacific region, the constraints of arable land could be addressed through better use of neglected zones. For example, opportunities to increase productivity in the vast uplands could also improve the livelihoods of the high percentage of poor households in these areas. Research will need to find ways of enhancing productivity within these diversified upland systems. The sustainable intensification of production systems will require an integrated approach, which includes better management of natural resources as well as the improvement of crop, vegetable, livestock, tree, and fish production. For improved agricultural production in the uplands, practical challenges of transportation and market access also need due attention. A major concern in Asian upland areas arises often from insecure land rights and encroachment of large-scale farmers growing plantation crops. Upland communities often comprise ethnic minorities that are poor, increasingly food insecure, and politically marginalized. People living in these upland regions can contribute to meeting the food security challenge in Asia, but this will require security of land tenure and use as well as agricultural R&D that are well targeted to the needs of their livelihood systems. Similarly, there is potential to maximize dry land and aquatic agriculture ecosystems through research.

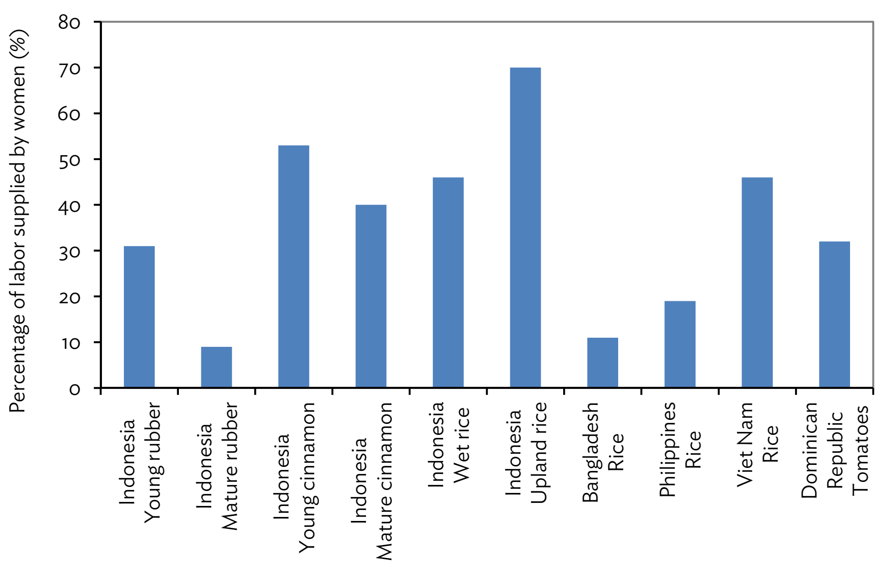
## C. Attention to Small Farms

Although producing food in a sustainable manner is a challenge to both large and small farms, this applies more to small farms (Thapa and Gaiha 2011). For example, small farmers cannot expand production to take advantage of higher food prices if they have difficulty accessing services and credit. Similarly, when new technologies require higher capital inputs or mechanization, small farmers are at a disadvantage. A research priority should be to revitalize small-scale sustainable food production by making smallholder farming more productive and sustainable. To prevent various kinds of shocks that farmers are vulnerable to, a significant part of smallholder food production should continue to be biodiverse based on multiple, multilayer, and mixed cropping, but should also be more productive. The commercial transformation of agrifood systems in the Asia and Pacific region is a reality that poses new challenges, especially to small producers, traders, and processors. They must be competitive and responsive to market demand while supplying regular volumes and complying with standards of food safety and quality in both national and international markets.

## D. Women's Contribution in Agriculture

The role of women in agriculture receives considerable lip service but needs more pragmatic and realistic attention in research. The contribution of women to food production is significant, though this varies by country and the type of crop (Figure 3). It is often estimated that overall, the labor burden of rural women exceeds that of men, and includes a higher proportion of unpaid household responsibilities related to preparing food and collecting fuel and water. Studies indicate that ensuring women's control over production, income, and assets represents the surest path to enhancing the impact of agricultural development strategies (Meinzen-Dick et al. 2011). Recognizing the need to integrate gender into agricultural interventions, development organizations have engaged in the process of mainstreaming gender into agricultural development programs and research (World Bank 2009). Using gender-sensitive indicators in experimental or quasi-experimental research methods of evaluation increased the understanding of how households make decisions. Policymakers are using such information to make necessary changes; for example, the national program for education, health, and nutrition in Mexico, and the microcredit program in Bangladesh have been modified to strengthen women's decision making (Quisumbing and McClafferty 2006). However, in practice, agricultural R&D continues to perform below expectations in benefiting women. An interim analysis of research projects under the Canadian International Food Security Research Fund (CIFSRF) found some projects' integrated gender components better than the others. Efforts to strengthen the programming and delivery of gender equity outcomes were initiated as a corrective action (Box 2).

**Figure 3: Proportion of Labor Supplied by Women for Selected Crops and Countries**




Source: FAO 2011.

**Box 2: Strengthening the Programming and Delivery of Gender Equity: Expected Outputs**

(i) Improved capacity in gender analysis and increased application of systematic gender analysis and gender equity in CIFSRF projects,
(ii) More rigorous and systematic gender analysis visible in project technical progress reports and publications,
(iii) Improved tools for monitoring and tracking CIFSRF project gender outcomes,
(iv) A range of communication products and synthesis reports on gender equity analysis and impacts, and
(v) Practical strategies for gender integration in food security research and implementation.

CIFSRF = Canadian International Food Security Research Fund.
Source: IDRC 2012d. Project 107211: Strengthening the Programming and Delivery of Gender Equity Outcomes in CIFSRF Projects. Project document, IDRC, Ottawa, Canada.

## V. PREVENTING POSTHARVEST LOSSES

Large portions of research efforts are devoted to increasing crop productivity. However, with the limited amount of cultivable land available for production, another area that deserves attention is reducing postharvest losses. Given that many smallholder farmers in the region are food insecure, a reduction in food losses could have an immediate and significant impact on their livelihoods.

Postharvest food losses span the supply chain from harvest down to final household consumption. Food losses in industrialized countries are as high as in developing countries, but with a difference. In developing countries, more than 40% of the food losses occur at postharvest and processing levels, and are usually reused in alternate ways (e.g., as animal feed); while in industrialized countries, losses often occur at retail and consumer levels; and are mostly wasted. The causes of postharvest losses in low-income countries are mainly connected to financial, managerial, and technical limitations in harvesting techniques, storage and cooling facilities, infrastructure, and packaging and marketing systems. The Save Food Initiative being led by the FAO in collaboration with donors, international agencies, financial institutions, and private sector partners has laid out plans to address many of these issues (FAO 2012); and there is scope for more research and extension in this area.

Science and technology can make a major contribution by providing practical solutions that range from careful harvesting and packaging to more advanced storage technologies. Given that the Asia and Pacific region contributes to more than 50% of the world's acreage under fruits and vegetables, challenges in harvesting, preparation for marketing, storage, and transportation need attention (APO 2006). Advanced science can offer options. For example, with modern scientific developments to extend the shelf life of fruits and reduce huge seasonal losses, researchers from India and Sri Lanka recently started testing a nanotechnology-based packaging system. Using hexanal—a safe, plant-derived chemical compound—in combination with a bio-wax formulation that helps to reduce postharvest damage, a simple and low-cost delivery system to prolong freshness and improve the quality of highly perishable fruits is being developed (IDRC 2012c).

High postharvest losses are often reported in dramatic fashion in the public press. Research efforts have identified postharvest technologies that seem to have the potential to reduce large losses, but farmers do not often adopt them. This could be due to the lack of information regarding the costs and financial returns of these technologies, or it may be that they are too expensive to adopt, and hence, the payoff for farmers are not high enough relative to other investments (Kitinoja et al. 2011).

Much of the available data on postharvest losses are dated and cited out of context. To better understand the nature of postharvest systems and realistically assess the opportunities and benefits of ways to reduce losses, the International Centre of Insect Physiology and Ecology (ICIPE) has initiated a study on various commodities in Sub-Saharan Africa (IDRC 2012b). It is possible that the Asia and Pacific region could also benefit from a collection of similar evidence.

## A. Climate Change and Water Considerations

Agriculture is extremely vulnerable to climate change and water. Climate change will affect agriculture in the Asia and Pacific region in many ways, particularly in areas vulnerable to natural disasters. Higher temperatures could reduce yields of desirable crops while encouraging weed and pest proliferation. Changes in precipitation patterns and floods affect agriculture and could stimulate crop failures in the short run and production in the long run. One analysis projecting future scenarios in the context of changing climate and food production indicated reduced calorie intake and increased child malnutrition (Nelson et al. 2009). Projections are not predictions, of course, but this does point to the need for research targeted at building climate resilience in agricultural systems as well as ensuring enough crop diversity in farming systems as a climate hedge.

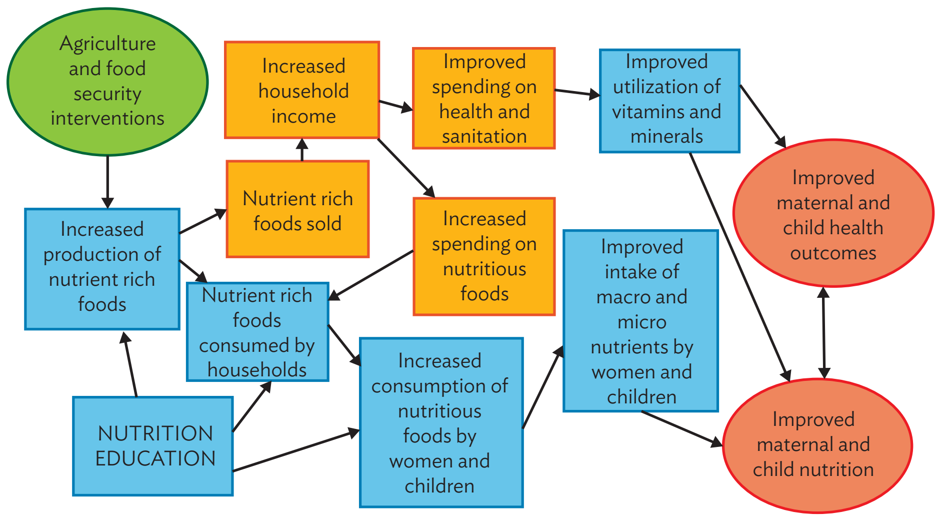
Researchers are working on crops that can withstand extreme weather. For example, IRRI in collaboration with the United Kingdom (UK) Department of International Development has developed and tested Scuba rice, a rice variety that can survive 2 weeks of complete submergence in water, in Bangladesh and India (Lasco et al. 2011). On the other hand, the germ plasm of sorghum is being studied by the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) for better adaptation to extreme weather.

## B. Food Utilization and Changes in Dietary Patterns

The utilization pillar of food security refers to a household's use of the food to which they have access and an individual's ability to absorb nutrients. Even when food is available in the household, its use may be hampered by factors including inadequate water supply, poor sanitation, and an overall lack of knowledge about healthy diets. While economic progress has been made among countries in the Asia and Pacific region, the region remains home to 62% of the world's undernourished. In several countries, including India and Indonesia, the total number of undernourished people has actually increased since 1990, while Bangladesh, India, and Nepal are three of the top four countries in global ranking of underweight children (FAO 2008). On the other hand, as countries are emerging out of poverty, an unhealthy transition toward diets of highly refined foods, and meat and dairy products containing high levels of saturated fats is occurring (Popkin 2004, Friel and Baker 2009).

Solutions lie in improving food systems to produce balanced diets, developing safe production practices, ensuring sanitation, and investing in interdisciplinary research that considers crosscutting factors (Nugent 2011). Since the proper utilization of food that leads to staying healthy and active is the final goal of achieving food security, research planning will benefit by paying attention to the pathways by which agriculture and food security interventions are likely to translate into health and nutrition outcomes, and by identifying appropriate indicators to measure (Figure 4).

Figure 4: Nutrition Impact Pathways




Source: Girard et al. 2012.

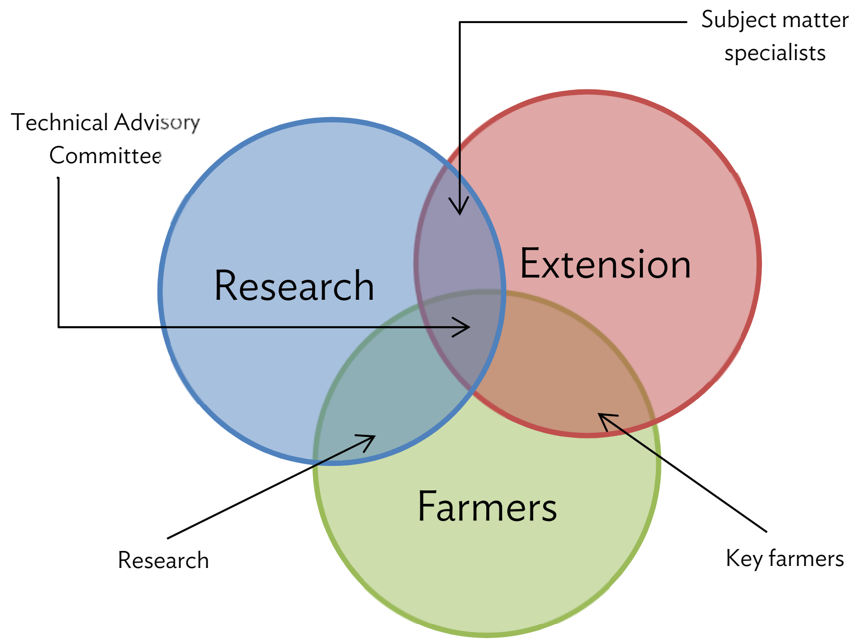
## C. Research Evidence and Measuring Results

Research evidence is the key to informing policies on food security as well as determining priorities for donor investments. Therefore, research planning should strongly consider bridging the data disconnect and building a strong evidence base. For meaningful investments, there is a clear need for research that generates evidence on the relationship between agricultural interventions, income, and nutrition (Girard et al. 2012). In response, Helen Keller International, in collaboration with the University of British Columbia, is coordinating a rigorous research approach in Cambodia to explicitly document the pathways of an agricultural intervention consisting of integrated homestead food production and women's empowerment to household food security and nutrition outcomes (IDRC 2012a). The research rigor is strengthened by randomization and establishing control households, which allows the testing of the interventions against the control.

# VI. EXTENSION SERVICES

The conventional definition of agricultural research includes both applied research and extension (Anderson 2007). Essentially, extension services act as a bridge between scientists, who strive to resolve problems in the practice of agriculture through research, and the farmers who need the solutions (Figure 5). Innovative technologies and good practices translate to increased yields and improved food security only when they are properly shared with farmers (Singh 2002).

Figure 5: Connection between Agricultural Research and Extension Systems




Source: Agbamu 2000.

An analysis of national extension systems in the Asia and Pacific region (Qamar 2006) shows that agricultural extension today is undergoing a major transformation as a result of dissatisfaction with public systems perceived to be outdated in responding to changes like globalization, decentralization, and information technology revolution. In some countries, agricultural extension follows a common pattern where technical prescriptions derived from controlled conditions are disseminated using top-down approaches with little attention to local conditions, often making the content unworkable. In other countries, despite a relatively well-organized network of extension systems, success is hampered by inappropriate material, declining budgets for field activities, and inadequately skilled and poorly motivated staff (Friederichsen 2009). Extension systems in many countries are struggling to shift to more farmer-oriented approaches to rural innovation that emphasize the importance of interactive, mutual learning between formal and informal knowledge systems which are integrated and multidisciplinary.

## A. Impact of Extension Services

It is difficult to assess the impact of extension services as the indicators—e.g., adoption of technology and farm productivity—are also influenced by many other factors that have compounding effects. An analysis of 512 estimated rates of return for agricultural research combined with extension, 18 of which were from extension-only investments, showed an average rate of return of 47% for research and extension investments, while for extension-only investments, this was 80% (Alston et al. 2000). As with other reviews, the quality of the studies included in the analysis is varied, and only a few followed high-quality impact evaluation methodologies. To fill this gap in rigorous methodology, a review is underway by the International Initiative for Impact Evaluation to synthesize both quantitative and qualitative information relating to the effectiveness of agricultural extension interventions and the underlying pathways (International Initiative for Impact Evaluation [3ie] 2010). Results from this study could help in better understanding the impact and contradictory effects of different agricultural extension models.

## B. Extension Methods

In agricultural extension, the local and national context is crucial to understanding and improving the system. An initial question to ask is how do farmers get information? Surveys indicate that a key general source of information for farmers is other farmers, but for more complicated technical matters, farmers prefer firsthand or specialized sources of information, such as extension experts (Feder, Murgai, and Quizon 2004).

Among the different methods of extension that have been tested, the Farmer Field School model has been accepted as a good methodology because it is participatory. For example, a participatory seed selection and multiplication project in Nepal using new varieties of crops increased yields by about 45% and improved stability in household food access. A special feature of this project was that it reached poor and female-headed households and lower-caste households much better than the regular extension services (Tiwari et al. 2010). Likewise, farmers in PRC, India, and Pakistan were reported to have used less pesticides and better practices after a training program on the integrated pest management of cotton. A surprising observation was the lack of diffusion effect from trained farmers to their neighbors (IOB 2011). A similar insignificant diffusion of knowledge to other farmers who reside in the same village as the trained farmers was reported in Indonesia (Feder, Murgai, and Quizon 2004). These results imply that farmer-to-farmer approaches like the Farmer Field Schools approach, while potentially useful, are not a panacea.

It is also significant to note that irrespective of the merits of the technology or a solution, farmers' acceptance is critical to any extension method. An interesting comparison was made between a 6-year participatory seed selection and multiplication project in Nepal and a 3-year seed distribution relief program in Zimbabwe. The project in Nepal was successful in its scaling up and continuity because the new varieties were relevant to the needs and interests of farmers. In contrast, only 12% of the beneficiaries in Zimbabwe decided to reuse and plant the open pollinated maize varieties the following year because the new varieties were not appreciated and the farmers had not received sufficient information and training on seed selection (Ministry of Foreign Affairs of the Netherlands, Policy and Operations Evaluation Department 2011). Other barriers to the adoption of sustainable agriculture practices include social barriers, land tenure, infrastructure, and the incompatibility of technology.

While some countries are struggling with new extension systems, those with well-established systems are also facing tremendous challenges. For example, the agriculture and technology extension system in the PRC has been facing great challenges with the general consensus that the system needs a thorough reform. During the 1990s, the PRC's extension system, one of the largest and most effective in the world, nearly collapsed. A study led by the Center for Chinese Agricultural Policy and Chinese Academy of Science (Huang 2009) identified the lack of innovative extension approaches as negatively affecting farmers' adoption of new technologies and suggested that much more effort is needed in terms of institutional and organizational reforms and human capacity building than policymakers have planned for. Some of the findings and recommendations from this study (Box 3) are relevant to other countries in the region.

**Box 3: Findings and Recommendations to Reform the Agricultural Extension System in the People's Republic of China**

(i) Most technologies demanded by farmers are new varieties, pest management, fertilizer application, farm management, and market information.
(ii) Farmers' social networks have a very significant, positive impact on the adoption of agricultural technology.
(iii) A good incentive reform requires institutional reforms—personnel and organizational—to be implemented in advance.
(iv) The participatory pilot policy reform needs the strong commitment of the local government and close coordination between the project team and agricultural bureaus.
(v) A meaningful reform needs more engagement of different farmers—both demonstration farmers and non-demonstration farmers—and extension workers.
(vi) A radical reform approach is hardly accepted and implemented. For the participatory pilot policy reform, a gradual and longer period—e.g., more than 2 years—is needed.
(vii) To be successful, a reform requires more investment in basic extension conditions and human capital.

Source: Huang 2009.

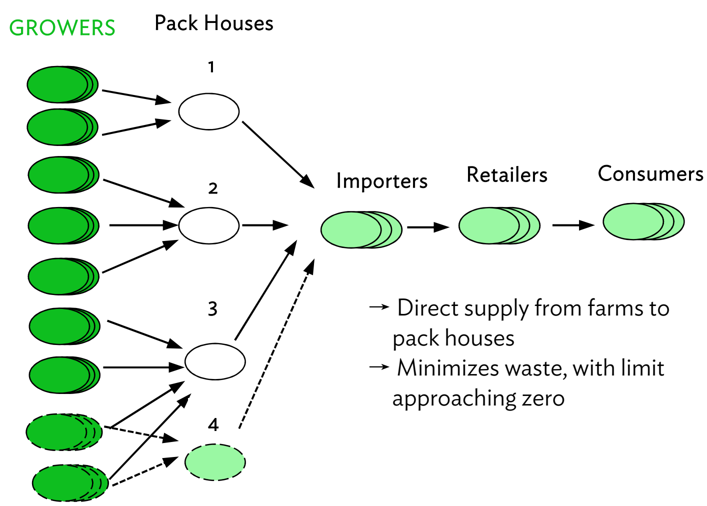
## C. Women in Extension

Although extension services are moving away from top-down, technology-driven, and male-dominated approaches, to demand-driven, gender-sensitive approaches, the impact of these reforms on female farmers is still unclear. A recent study (World Bank and IFPRI 2010) in Ethiopia, Ghana, and India found that despite efforts to promote farmer-based organizations as vehicles for agricultural extension, female farmers in all three countries had less access than male farmers because women were not perceived as agricultural decision makers. In India, where this "perception bias" is particularly strong, no female extension workers were employed in the study area. Efforts to recruit and train female extension agents will be more successful if they take into account sociocultural norms and adapt the program accordingly (Quisumbing and Pandolfelli 2010). To ensure that gender concerns are incorporated in agriculture, extension personnel may require training in gender analysis and gender-sensitive agricultural planning methods (Sulaiman and Hall 2004).

## D. Linking Small Farmers to Markets through Extension

Though agricultural extension services have traditionally focused on production aspects, looking ahead and addressing new challenges require extension to play an expanded capacity development role. This includes integrating marketing and value chain aspects into existing extension systems as well as building linkages between farmers and other agencies to support the bargaining position of farmers (Sulaiman, Hall, and Raina 2006). There is an emerging body of literature analyzing how smallholder farmers in developing countries can be linked to modern supply chains (Asian Partnership for the Development of Human Resources in Rural Asia [AsiaDHRRA] 2008). For example, Swift Company in Thailand developed a new supply chain model for fresh produce, which undertakes the daily delivery directly from small farmers organized under the company's contract farming model. Collection points and postharvest control immediately minimize losses and improve quality (Uathaveekul 2011). This example also points to the changing nature of agricultural extension where the private sector undertakes initiatives when there is potential for win-win solutions. Increasingly, public extension systems in Asia will need to be selective, focusing on clients and sectors where there is a need for the public sector, while stepping aside when the private sector can act.

Figure 6: Swift Company's Supply Chain




Source: Uathaveekul 2011.

Another asset to improving extension methods is communication technology, which is rapidly expanding and becoming increasingly accessible even in remote areas. These developments allow the timely sharing of research recommendations, which can be used to address the "last mile" problem of disseminating information to farmers. Innovative strategies for combining Internet, telecommunications, video, and print technologies at appropriate levels are bridging this gap and empowering farmers to make better production and marketing decisions (McLaren et al. 2009). Though this looks promising, it is essential to develop and test appropriate models, keeping the farmers' needs and capacities in mind.

# VII. PUBLIC AND PRIVATE INVESTMENTS IN AGRICULTURAL RESEARCH AND EXTENSION

In light of the strong case for agricultural R&D and extension along with the current commitments of many stakeholders to invest in improved food security and nutrition, it is useful to analyze the pattern of current public and private investments at national and international levels. Historically, applied research in agriculture generally took place either through the Consultative Group on International Agriculture Research (CGIAR), other national and international research institutions, or the National Agricultural Research Systems (NARS) funded by governments. The emerging role of the private sector also needs innovative thinking considering that the public and private sectors need to work together despite their different modes of operation.

## A. Role of the Consultative Group on International Agriculture Research and National Agricultural Research Systems

Public investment in research and development, including investments through international agricultural research institutions, has historically driven technological change in agriculture. It is estimated that in developing countries, the public sector finances around 90% of total agricultural research.

The CGIAR is the world's largest publicly funded global research partnership that advances science to help foster food security, poverty reduction, and sustainable natural resource management. Over the course of 3 decades, the CGIAR's mandate has increased significantly, growing from four research centers with a narrow focus on productivity to a global network of 16 centers with an expanded agenda.

A meta-analytic cost–benefit analysis showed that the work of the CGIAR in various sectors has produced a substantial improvement in the livelihoods of the poor in developing countries. The Asia and Pacific region has certainly seen the benefits of research in several ways. One example that had an enormous impact is the adoption by farmers of the modern rice varieties developed by the IRRI, which was estimated to have yielded an annual return of $10.8 billion—nearly 150 times the combined annual investment in rice research by the institute and the national systems (Sombilla 2008).

Despite many more achievements, resources have not kept pace with this broadening portfolio of the CGIAR. The realization that public sector agencies and international agricultural research centers are operating within quickly changing natural and societal environments resulted in a major transformation in the CGIAR starting in 2008. Sweeping changes transformed the loose coalitions into a streamlined global partnership where donors and all research centers work together under a common framework in order to make a unique scientific contribution to agricultural development for the poor.

Funding for agricultural research at the national level is still done predominantly through government allocations, although a number of countries now have a dual funding system where a portion of the government allocations are disbursed through a competitive funding system. The NARS in the Asia and Pacific region are quite heterogeneous. The distribution of spending among countries is uneven, with the PRC, India, and Japan accounting for the lion's share of the region's agricultural research expenditures. Following the Asia-Pacific Association of Agricultural Research Institutions expert consultation on "Research Management Mechanisms of National Agricultural Research Systems," considerable progress has been reported in the region in the functioning and management of agricultural research (Mathur, Paroda, and Sebastian 2011).

While donors can support agricultural R&D in developing countries, national governments can play a complementary role: to contribute to its funding, ensure an enabling environment—such as easily available credit, stable output prices, and access to fertilizer—and guarantee that seeds for farmers are in place (DFID 2005). A step in the right direction is the recent declaration by the relevant ministers of the Asia-Pacific Economic Cooperation (APEC 2012), which acknowledged the need for strengthening domestic research capacity as well as the importance of engaging all stakeholders, including farmers, and disseminating the innovative technologies in an efficient manner.

## B. Emerging Private Sector Investments

With diminished investments in research over the years, there has been a clear recognition that technological change can no longer be advanced solely by public sector investment in agricultural R&D (Naseem, Spielman, and Omamo 2010). The potential role that the private sector can play has now become a topic for serious consideration.

Pray and Umali-Deininger (1998) analyze the question of whether the private sector can fill the gap of declining research in agricultural research systems in developing countries. Since the private sector has very different goals and accountabilities, it is not surprising that traditionally, most private

R&D investment in developing countries focus on a small set of crops and technologies in response to the needs of large-scale, capital-intensive farm operations. Although this model is important from the perspective of food availability, private investments may overlook the needs—and commercial potential—of the small-scale, resource-poor farmers who dominate the agriculture sector in many developing countries. As a result, such farmers have been largely passed over by the private sector's estimated $862 million research investment in the developing world (Pardey et al. 2006).

In spite of this difference in interest and often motivation, and considering the array of complex challenges in agricultural R&D, mutually beneficial ways for the public and private sectors to work together often exist. The private sector has emerged as a major force in the production and ownership of new technologies in the areas of plant biology, information, and communications, suggesting that access to these technologies by developing countries will depend on the ability of the private and public sectors to find common ground. Naseem, Spielman, and Omamo (2010) examined various options that may foster private sector participation in R&D, paying particular attention to the role of economic incentives. Several mechanisms arose in the analysis, notably, intellectual property rights, trade and foreign investment liberalization, advance purchase commitments, and rewards. Several key elements of an enabling environment by the public sector to promote private investment in agricultural R&D were proposed, including effective regulatory regimes, enforcement procedures to govern intellectual property rights, biosafety systems, tax exemptions, subsidy programs, and international trade regimes. It also includes physical and communications infrastructure to accelerate the flow of information and knowledge among researchers, the privatization of state-owned input-supply firms that crowd out private investment, and the harmonization of regional and international regulations to create larger market opportunities.

As with research, funding for extension has also been drastically reduced, opening ways for innovative thinking. The private sector has already entered the space of agricultural extension through contract cultivation and buy-back arrangements. In addition, some private sector entities are coming up with solutions from a different angle, by creating their own nonprofit operations to reach small farmers.

The limited experience so far points to the fact that the private sector is interested in and often effective in R&D for the improved food security of vulnerable populations in developing countries. However, there is still a significant lack of trust and understanding between public and private sectors, in addition to fundamental differences in their modes of operation.

Recognizing the need for greater private sector investment in agriculture, the G20 summit in Toronto in 2010 launched the idea of applying "pull mechanisms" to spur the development of products and services with results-based payments. In order to investigate these mechanisms further, Australia, Canada, the US, the UK, and the Bill and Melinda Gates Foundation, in collaboration with the World Bank, are working with other like-minded donors on the Agricultural Pull Mechanism Initiative (World Bank 2012a). Table 2 summarizes the pull mechanism in comparison with traditional development projects.

Table 2: Pull Mechanism in Comparison with Traditional Development Projects

| | Pull Mechanism Project | Traditional IDA Projects |
|---|---|---|
| Purpose | Overcome market failures; create sustainable markets for socially desirable goods for development impact | Tackle development problems through grant- or concessional loan-funded projects |
| Main partner | Private sector | Governments, public sector |
| Funding mechanism | Payments for results or goods delivered | Up-front payments for project plans to credible institutions |
| Fiduciary framework | Implementing agency has fiduciary responsibility for the use of funds and needs to pass the financial management assessment (due diligence test) | The government is the recipient and holds fiduciary responsibility for the use of funds |
| Final beneficiary eligibility criteria | Based on third-party verified index (triggers), not on the status of the recipient | Based on status (poverty, social, etc.) |
| Procurement | Payment awards go to prequalified companies that achieved certain results in a certain timeframe | Payments go to prequalified companies that produce the best technical and/or cost bid for a specific award to be made during and after the production of the requested goods or services |

IDA = International Development Association.
Source: Agricultural Pull Mechanisms (AGPM) Initiative: Overview, April 2012.
http://siteresources.worldbank.org/CFPEXT/Resources/AGPM_OVERVIEW_April.pdf

The initiative, officially launched in Los Cabos, Mexico on 18 June 2012, was renamed AgResults (World Bank 2012b). It aims to achieve significant improvements in the well-being of the poor and vulnerable in developing countries with a fund of up to $100 million. An initial set of pilots, focusing on maize production in Sub-Saharan Africa, include:

(i) Incentivizing the adoption of on-farm storage technology for smallholder farmers,
(ii) Encouraging the innovative distribution of a breakthrough technology to reduce aflatoxin contamination, and
(iii) Building a market for new vitamin A-enhanced varieties of maize.

Additional pilots will be explored in the coming years, potentially including livestock vaccines and fertilizer innovation as well as new ideas related to increasing crop yields, decreasing postharvest losses, increasing livestock productivity, and improving nutrition. All these issues are very relevant to the Asia and Pacific region, and it will be interesting to see how the initiative unfolds in the region.

## VIII. CONCLUSION

The challenge is clear. The world must produce 40% more food by 2050, using limited land and water, and less energy, fertilizer, and pesticide, while coping with rapid changes in many spheres. With a close relationship established between investments in R&D and agricultural production, the path to addressing the food crisis seems obvious. Though research has had its successes in the past, it no longer has all the answers. Science has contributed greatly in the past to finding solutions, and it can continue to do so in the future if investments are made. The challenge for the research community is to develop resilient agricultural systems using rational, affordable strategies that not only increase production but also achieve food security for households and individuals.

Many efforts are already underway and though there is no single solution, agricultural R&D coupled with knowledge dissemination and an enabling policy environment is a crucial building block. Some research priorities that can be summarized from this review include:

(i) Research that is interdisciplinary and that addresses the diverse needs and context of smallholder farming systems,
(ii) Research for development which is demand-driven and considers farmer concerns and results-based strategic action plans,
(iii) Research that considers developing cost-effective business models and financing options for each technology and market,
(iv) Research that includes considerations of nutrition pathways and gender connecting to agricultural interventions,
(v) Research that generates strong evidence for policy and programming, and
(vi) Research that optimizes the contributions of the public and private sectors.

The emerging economic scenarios intensify the call for more agricultural R&D to effect higher production growth and strengthen the resilience of the agriculture sector against imminent threats. It is encouraging that many stakeholders are interested in playing a role in addressing the current food crisis. To maximize benefits, coordinated action is needed. It is important to consider multi-stakeholder collaborations for investments in food security among development partners, and to share innovations and good practices for sustainable and inclusive food security. It can be concluded that with a well-planned research agenda and sustained support for agricultural R&D, both financially and politically, future food crises situations can be proactively addressed.

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## Background Paper

*Research and Development and Extension Services in Agriculture and Food Security*

This paper explores the role of applied research for development and extension services through a two-pronged approach of boosting food production and preventing losses. Evidence presented in the paper seeks to demonstrate how strategic investments in research and extension services in the Asia and Pacific region can play a critical role in addressing challenges along the pathway from agricultural production to consumption and utilization.

### About the Asian Development Bank

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