Background Paper: Research and Development and Extension Services

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Abstract

Investments in agriculture research and extension have consistently demonstrated high rates of return in Asia and 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 a two pronged approach of boosting food production and preventing losses. Priority areas for research identified emphasize attention to smallholder farming systems, practical business models, integration of gender and multi-disciplinary research that is sensitive to nutritional outcomes. In addition, pioneering mechanisms to public-private partnerships are examined towards strategic use of renewed stakeholder commitments to achieve food security and prevent future crisis. Through learning from the past and looking into the future, the 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.

Introduction

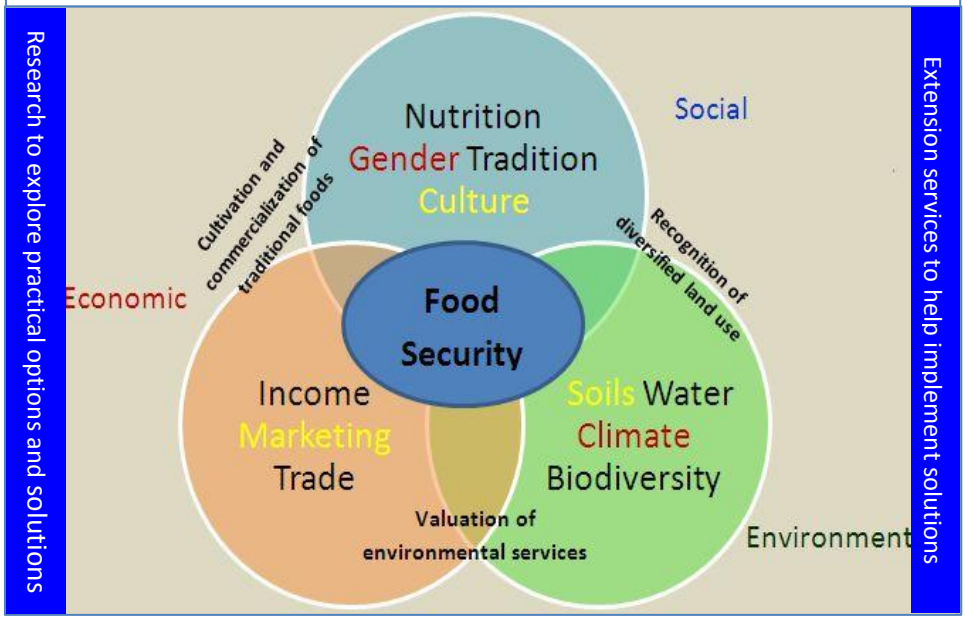
The current global challenges for food security to ensure the availability of and access to food, in both quantity and quality require deliberate and far reaching solutions. Historically, research for development in agriculture and extension services has been strong a driving force for meeting the food supply around the world. The Asia-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 it has only 38% of the world's agricultural land. Despite having a wide range of natural resources, some countries more than others in the region face major challenges of food insecurity, poverty and malnutrition. Huge diversity in size, population, agricultural and economic development of the countries is reflected in the large differences in the agricultural production systems, agro-climatic potential, population density and infrastructure (Beintema and Stads, 2008)[1].

During the past several decades, millions of people across the Asia-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 Millennium Development Goal of halving the prevalence of extreme poverty by 2015. However, the recent dramatic fluctuations in the price 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, 2009)[2]. 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)[3]. Publication of this report and the subsequent food price volatility kindled a positive global response and a collective determination by multiple stakeholders to tackle food security challenges and a recognition about the need for investments in agriculture research and development (R&D) and extension. It was also recognized that resolving the food availability issue is only one part of the solution which has to be complemented with access and utilization of the food to cover the three pillars of food security. As a result, commitments were made by the Group of 8 industrialized nations at L'Aquila, Italy (G8 Efforts Towards Global Food Security, 2009)[4] which led to several initiatives at global level. At the regional level, the Asian Development Bank co-organized an investment forum for food security in 2010 with the Food and Agriculture Organization and the International Fund for Agricultural Development, to

initiate a more focused regional dialogue (ADB, 2011)[5]. Building on the commitment of G8 and specifically in response to the need for investments in research, several collaborative international efforts were initiated by developed countries. One example is the Canadian International Food Security Research Fund established by the Canadian International Development Agency and the International Development Research Centre (CIFSRF, 2010)[6]. Similarly, the Australian Center for International Agricultural Research also has focus of agriculture and food security research for Asia and Pacific. Increasingly, public R&D investments in developing countries channeled through international agricultural research centres and national agricultural research systems are being complemented by private sector investments in agricultural R&D.

Strategic investments in R&D and extension services in Asia and Pacific can play a critical role in addressing numerous challenges along the pathway from agriculture production to consumption and utilization. Understanding research gaps and priorities for action will ensure proper use of funds. This paper examines the role of agriculture research for development which includes applied research as well as extension programs, for boosting agriculture production and productivity levels as well as preventing losses before and after 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 the social, environmental and economic factors to find sustainable ways to address the gaps in knowledge (Figure 1). This paper builds on the complex issues learned over the past in order to extract lessons for the future. It also explores the changing roles of international agricultural research institutions, public and the private sectors and makes the case for strategic investments in research and extension with a long term vision to address the complex issues around food security.

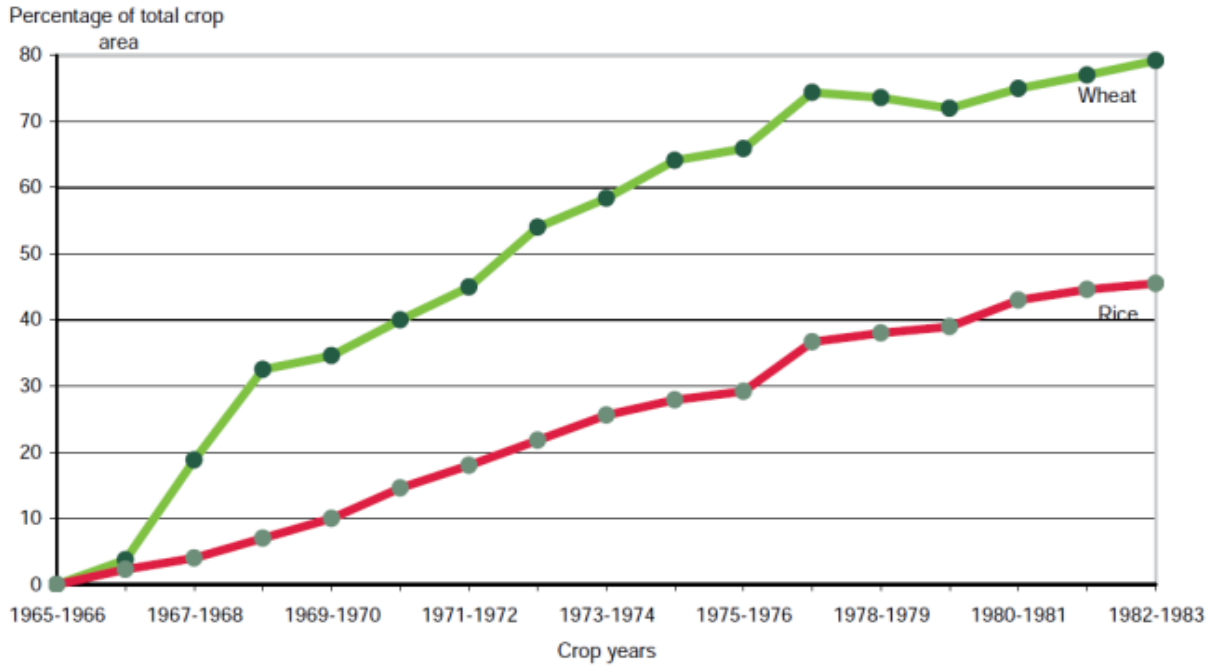
Figure 1: Agriculture Research and Extension for Food Security: Complex Interconnections to Consider (adapted from: IAASTD, 2009. Agriculture at a crossroads – Synthesis report)



Past successes and challenges

Many reviews examined the advancements in agriculture productivity during the past century and demonstrated the value of investments channeled through research. Even from very early years of modern agriculture, the challenge to feed the increasing global populations within the limited land were met as a direct result of strides in agriculture research, development and extension (Waite 1915 and James 1996)[7],[8]. Although industrial countries mainly benefitted from agriculture research in the past, intensive research in Asia that started in 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 South-East Asia and the region benefitted from the boost in agricultural output (Figure 2). In fact the transforming economies in Asia accounted for two thirds of the developing world's agricultural growth (Dalrymple, 1985, UNESCAP, 2009)[9],[10].

Figure 2: Adoption of high-yielding strains of rice and wheat in South and South-East Asia, 1965-83. Source: Dalrymple, 1985



Return on investments: Understanding the impacts of research is useful for donors and policy makers to decide where to invest and prioritize. The speed and scale that improved production in cereals improved food security in the past was remarkable and unprecedented, contributing to a substantial reduction in poverty and the launch of broader economic growth in many Asian countries (Hazell, 2009)[11]. 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 and Thirtle et al, 2003)[12],[13]. The impressive rates of returns in Asia are largely due to the dominating effect of rapid increases in the huge agricultural sectors of China and India (IFPRI 2002)[14]. The Philippines, where the International Rice Research Institute is located, has perhaps benefited most with the highest Rates of Return. Other countries in the region like Indonesia, Thailand, and Viet Nam closely followed with impressive performance of their own, positioning themselves to be net exporters of different food commodities.

In addition to high yielding varieties, research also 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)[15].

Farms in the Asia Pacific region are predominantly smallholder-based, many 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, benefits were primarily with the main cereal crops in lowland regions and did not provide significant improvements for the diverse crops grown in uplands, marginal coastal areas and dry lands (IFPRI/ADB 2007)[16].

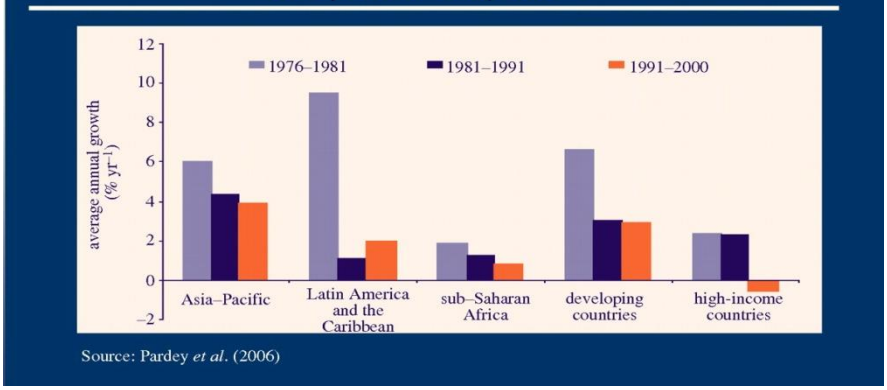
Threat to sustainability of past production gains: Though the past successes and high returns on investments are vital, in recent years agricultural production has experienced a number of challenges as a result of which agricultural growth in Asia-Pacific has stagnated.

Much of the concern about feeding the world in 2050 relates to the slowing of yield growth in the major cereals around the world over the decades casting doubts on the sustainability of past gains which were mainly in irrigated lands and mono-cropping strategies. In addition, the negative impacts on the environment emerged as a concern.

Funding for agriculture R&D:

It has been well established that past investments in agriculture R&D resulted in high returns. However, agricultural research lost the early strong footing as a result of premature belief that the problem of food supply was already 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 under-funded for the past two decades (Timmer 2005)[17]. In addition to the noticeable downward trend in global and regional public investments in R & D (Figure 3), the emphasis given to agriculture by countries in Asia and Pacific varied widely. Beintema and Stads (2008)[18] report that investment for the region as a whole grew by 3.4 percent annually during 1981-2002 but the distribution of R&D spending among countries had been quite uneven, with China, Japan and India accounting for combined total of over 70 percent of regional spending. Higher R&D spending in agriculture was also seen in relatively smaller countries like Malaysia and Vietnam, but not so in Pakistan, Indonesia and Laos. A similar diversity among countries was observed with regard to human resource capacity in agricultural R&D. For example, China employed the largest number of agricultural researchers (over 50,000) and India had the most qualified research staff while research capacity was lowest in Laos and Vietnam. Overall, South Asian countries seem to have better qualified researchers.

Figure 3: Decreasing Regional Public Agriculture R&D Spending Trends. Source: Pardey et al, 2006



Current situation and future opportunities for research

It is now rightly recognized that past success in agriculture R&D with a narrow focus on a few staple cereals is no longer sufficient. Focusing on increased production of staple cereals assumes that the main challenge is the number of calories and that adequate protein and micro-nutrients will implicitly be provided. It misses a key point that the real crisis is also one of a narrow food base and imbalanced diets. High-yielding production often reduces the diversity of foods that are produced in small scale agriculture systems. Efforts to increase food supplies in a sustainable manner will need to consider a better cereal, protein, vegetable, and fruit balance with nutritional improvements as final target. This will require agricultural R & D to be sensitive to more diverse agronomic conditions and more complex farming systems, as well as 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, its relevance to food security and identify ways to adapt to the changing situation. In the context of these changes along with the heightened global commitments to prevent future food crisis, agriculture research can be described as being at cross roads. Since there are a 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.

Research on Agricultural production and productivity

Limits to the new arable land that can be brought into production (much of it relatively fragile) and the challenge of a projected 9 billion population by 2050 (many consumers with changing food preferences driven by higher income) point to increasing productivity of existing cultivable lands and finding ways to better utilize the potential of land as key areas for research investments. In addition, considering the yield potential of the major cereals, diversifying production increases will be one of the keys with which agricultural R & D can meet the future demands in food production. A detailed analysis of present and future land/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 (Table1, FAO, 2009)[19].

Table1: Projected sources of growth in crop production to 2050 (Percent) Source FAO 2009

	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

Crop Diversification: Asia and Pacific 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 potato 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 USA, researchers are testing promising varieties under local growing conditions. China and India are leading the way accounting for about 79 percent of the area and production of potato in the region. There is scope for more research for improved varieties, appropriate production technologies and value addition (Papademetriou 2008 and Thiele et al, 2008)[20],[21].

Box 1: Research to increasing millet production in South Asia
Location: India, Nepal & Sri Lanka

Expected outcomes
- Increased production and consumption of nutritious minor millets and pulses
- Conservation of threatened millet varieties and development of a breeding program
- Development of tool kits on sustainable agricultural practices
- Improved post-harvest technologies to make millet processing easier for women
- Improved efficiency of millet de-hulling technology

Source: International Development Research Centre (2011)

There is also a real opportunity to increase productivity of many neglected and secondary crops that have been by-passed by mainstream agricultural research. These “orphan” crops, such as millets, sorghums, cassava and other root crops, provide the main sustenance for millions of poor households (Naylor et.al. 2004)[22]. The International Centre for Agriculture Research in the Dry Areas has been working for decades on the development disease resistant, yield increasing cultivars of millets and recently there has been a strong interest from the research community and policy makers to revitalize millets as a

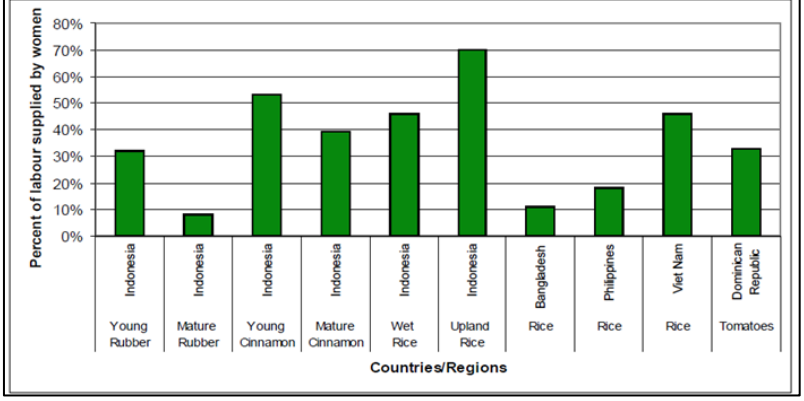
means of addressing food security challenges. Leading universities and non-government organizations in South Asia in collaboration with Canadian researchers are finding ways to bring the under-utilized small grains back into the diets through multi-disciplinary research and policy advocacy (Box 1).

Expanding Agroecological zones: With the rich agro-ecological diversity in Asia and Pacific, the constraints of arable land could be addressed through better use of neglected zones. For example, opportunities to increase productivity from the vast uplands could also improve the livelihoods of high percentage of poor households in these areas. Research will need to finds ways of enhancing productivity within these diversified upland systems. Sustainable intensification of production systems will require an integrated approach which includes better management of natural resources as well as improvement of crop, vegetable, livestock, tree and fish production. For improved agriculture production in uplands, practical challenges of transportation and market access also needs due consideration. A major concern in Asian upland areas arises from the often insecure land rights and encroachment by 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 land tenure and use security as well as agricultural R & D well targeted to the needs of their livelihood systems. Similarly, there is a potential to maximize the dry land and aquatic agriculture ecosystems through research.

Attention to small farms: Although the challenge of producing food in a sustainable manner affects both large and small farms, this applies more to small farms (Thapa and Gaiha, 2011)[23]. For example, small farmers cannot take advantage of higher food prices by expanding production if they have difficulty in 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 revitalizing small-scale sustainable food production by making smallholder farming more productive and sustainable. To avoid 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 also need to become more productive. The commercial transformation of agrifood systems in Asia and the 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 for food safety and quality in both national and international markets.

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 the country and the type of crop (Figure 4). It is often estimated that overall the labour 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 impacts of agricultural development strategies (Meinzen-Dick et al, 2011)[24]. Recognizing the need to integrate gender into

Figure 4 Proportion of labour supplied by women for selected crops and countries. Source: FAO 2011. Role of Women in Agriculture



agriculture interventions, development organizations have engaged in a process of mainstreaming gender into agricultural development programs and research (World Bank, 2009)[25]. Using gender sensitive indicators in experimental or quasi-experimental research methods of evaluation increased the understanding on how households make decisions. Such information is being used by policymakers to make necessary changes to programs, for example, the national program for education, health and nutrition in Mexico and the micro credit program in Bangladesh have been modified to strengthen women's decision making (Quisumbing and McClafferty, 2006)[26]. However, in practice, agricultural R & D continues to under-deliver 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, IDRC2012)[27].

Box 2: Strengthening the programming and delivery of gender equity outcomes in CIFSRF projects: 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.

Preventing post-harvest losses

Large portion of research efforts are devoted to increasing productivity of crops. However, with the limited amount of cultivable land available for production, another area that deserves attention is reducing post-harvest 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.

Post-harvest food losses span across 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 post-harvest and processing levels which are usually reused in alternate ways (e.g., as animal feed), while in industrialized countries, losses often occur at retail and consumer levels which are mostly wasted. The causes of post-harvest losses in low-income countries are mainly connected to financial, managerial and technical limitations in harvesting techniques, storage and cooling facilities, infrastructure, packaging and marketing systems. The Save Food Initiative being led by the Food and Agriculture Organization in collaboration with donors, international agencies, financial institutions and private sector partners has laid out plans to address many of these issues (FAO, 2012)[28] 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-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 needs attention (APO 2006)[29]. Advanced science can offer options. For example, with modern scientific developments to extend the shelf life of fruits and reduce the huge seasonal losses, researchers from India and Sri Lanka recently started testing nanotechnology-based packaging system. Using a safe, plant-derived chemical compound (hexanal) in combination with bio-wax formulation that helps to reduce post-harvest damage, a simple and low cost delivery system to prolong freshness and improve the quality of highly perishable fruits is being developed (IDRC, 2012)[30].

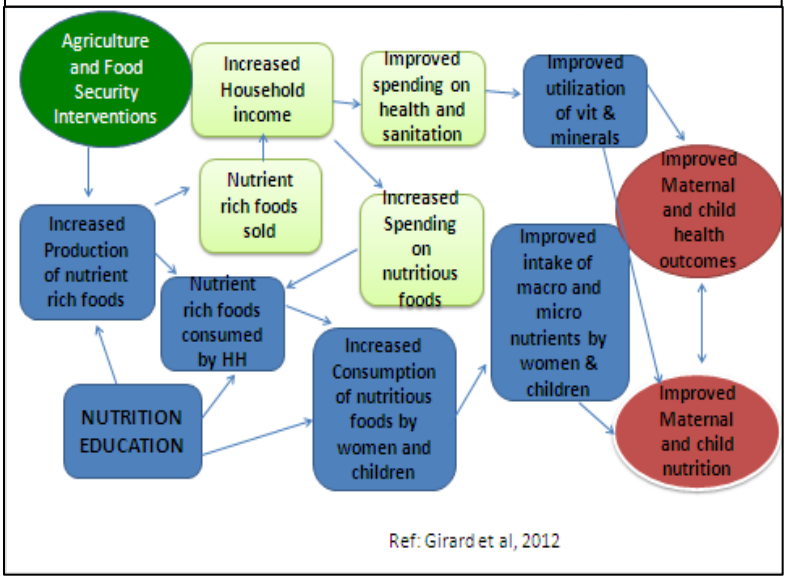
High post-harvest losses are often reported in dramatic fashion in the public press. Research efforts have identified post-harvest technologies that seem to have potential to reduce large losses, but they are not often adopted by farmers. This could be due to lack of information regarding the costs and financial returns of these technologies or it may be that technologies are expensive to adopt and hence the payoff for farmers not high enough relative to other investments (Kitinoja et al, 2011)[31]. Many of the available data on post-harvest losses are dated and cited out of context. To better understand the nature of post-harvest systems and realistically assess the opportunities and benefits of ways to reduce losses, the International Centre of Insect Physiology and Ecology has initiated a study of various commodities in Sub-Saharan Africa (IDRC, 2012)[32]. It is possible that Asia and Pacific region could also benefit from a collection of similar evidence.

Climate change and water considerations: Agriculture is extremely vulnerable to climate change and water. Climate change will impact agriculture in Asia and Pacific in many ways, particularly in areas vulnerable to natural disaster. 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)[33]. 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, International Rice Research Institute in collaboration with the UK Department of International Development has developed and tested a rice variety (Scubarice) in Bangladesh and India that can survive two weeks of complete submergence in water (Lasco et al, 2011)[34] while the germplasm of sorghum is being studied by the International Crops Research Institute for the Semi-Arid Tropics for better adaptation to extreme weather

Food utilization and changes in dietary patterns: The utilization pillar of food security refers to the households' use of the food to which they have access and individuals' ability to absorb nutrients. Even when food is available in the household, its utilization may be hampered by factors including inadequate water supplies, poor sanitation and an overall lack of knowledge about healthy diets. While much economic progress has been made among countries in the Asia-Pacific region, the region remains home to 62 per cent of the world's undernourished. In several countries, including Indonesia and India, 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)[35]. On the other hand, as countries are emerging out of poverty, an unhealthy transition towards

Figure 5 Understanding impact pathways is important in planning research and measuring results



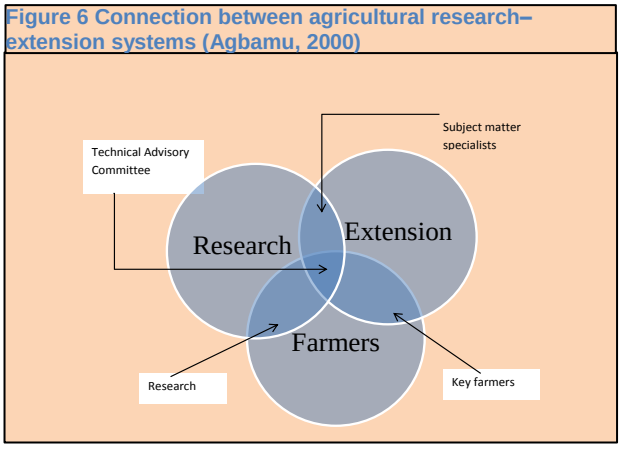
diets of highly refined foods, and of meat and dairy products containing high levels of saturated fats is occurring (Popkin, 2004, Friel and Baker, 2009)[36],[37].

Solutions, though not easy, lie in improving food systems to produce balanced diets, developing safe production practices, ensuring sanitation and investing in interdisciplinary research that considers the cross-cutting factors (Nugent, 2011)[38]. Since proper utilization of food that leads to maintaining a healthy and active life is the final goal of achieving food security, research planning will benefit by paying attention to the pathways through which agriculture and food security interventions are likely to translate into health and nutrition outcomes and identifying appropriate indicators to measure (Figure 5).

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 planning of research should have strong consideration to bridge the data disconnects and build a strong evidence base. For meaningful investments, there is a clear need for research that generates evidence on the relationship between agriculture interventions, income and nutrition (Girard et al, 2012)[39]. In response, a rigorous research approach is being coordinated in Cambodia by Helen Keller International in collaboration with University of British Columbia to explicitly document the pathway of an agricultural intervention consisting of integrated homestead food production and women's empowerment to household food security and nutrition outcomes (IDRC 2012)[40]. The research rigor is strengthened by randomization and establishing control households which allows testing the benefits of the interventions against the control.

Extension Services

Figure 6 Connection between agricultural research–extension systems (Agbamu, 2000)



The conventional definition of agricultural research includes both applied research and extension (Anderson (2007)[41]. 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 6, Agbamu, 2000)[42]. Innovative technologies and good practices can be translated to increased yields and improved food security only when it is properly communicated to farmers (Singh, 2002)[43].

An analysis of national extension systems in Asia and the Pacific Region (Qamar, 2006)[44] shows that agricultural extension today is passing through a major transformation as a result of dissatisfaction with the public systems perceived to be outdated to respond to changes like globalization, decentralization and information technology revolution. In some countries agricultural extension uses a common pattern where technical prescriptions derived from controlled conditions are disseminated using top-down extension approaches with little attention to local conditions, often making the content unworkable. In other countries, despite 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, 2008)[45]. Extension systems in many countries are struggling to shift to more integrated, farmer-oriented approaches to rural innovation that emphasize the importance of interactive, mutual learning between formal and informal knowledge systems which are integrated and multi-disciplinary.

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 agriculture research combined with extension, of which 18 were from extension-only investments, showed an average rate of return of 47 per cent for research and extension investments, while for extension-only investments this was 80 per cent (Alston et al. 2000)[46]. 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 synthesise both quantitative and qualitative information relating to effectiveness of agricultural extension interventions and the underlying pathways (3ie, 2010)[47]. Results from this study could help in better understanding of the impact and contradictory effects of different agricultural extension models.

Extension methods: In agriculture extension the local and national context is crucial to understand and improve 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 have a preference for first hand, or specialised sources of information such as extension experts (Feder at al, 2004)[48] .

Among the different methods of extension that have been tested, the Farmers Field School model has been accepted as a good methodology due to its participatory feature. For example, a participatory seed selection and multiplication project in Nepal increased crop yields using new varieties of crops by about 45% and improved the stability in household food access. A special feature of this project was that it reached poor and woman-headed households and lower caste households much better than the regular extension services (Tiwari et al., 2010)[49]. Likewise, farmers in China, India and Pakistan were reported to have used less pesticides and better practices after training program in integrated pest management of cotton. A surprising observation was the lack of diffusion effect from trained farmers to their neighbours (IOB, 2011)[50]. Similar insignificant diffusion of knowledge to other farmers who reside in the same village as the trained farmers was reported in Indonesia (Feder et al, 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, its acceptance of by the farmers is critical for any extension method. An interesting comparison was made between a six-year participatory seed selection and multiplication project in Nepal and a three-year seed distribution relief programme 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 farmers had not received sufficient information and training on seed selection (IOB, 2011). Other barriers to adoption of sustainable agriculture practices include social barriers, land tenure, infrastructure, and incompatibility of technology.

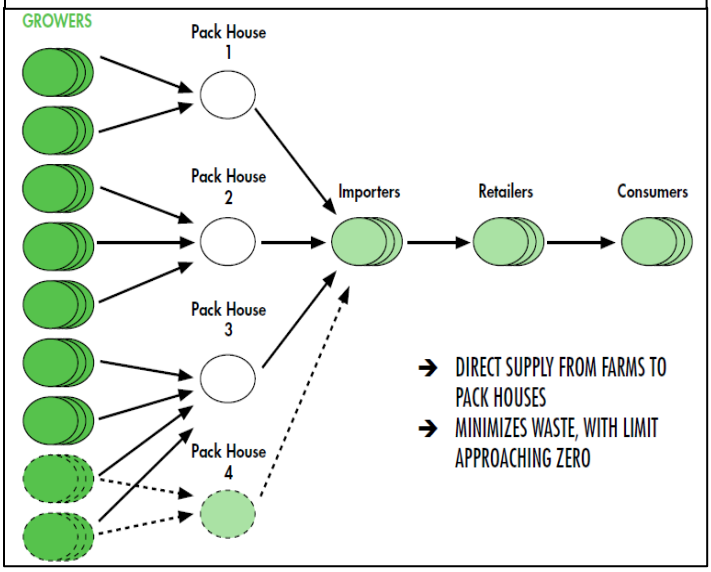
Box 3: Recommendations to reform agriculture extension system in China

- Most demanded technologies by farmers are new varieties, pest management, fertilizer application, farm management and market information
- There is a very significantly positive impact of farmers' social networks on the adoption of agricultural technology
- A good incentive reform requires institutional (personnel and organizational) reforms to be implemented in advance
- The participatory pilot policy reform needs a strong local government commitment and close coordination between the project team and agricultural bureaus
- A meaningful reform needs more engagement of different farmers, both demonstration farmers and non-demonstration farmers, and extension workers in the process of reform
- 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 year) pilot reform process is needed
- A successful reform also requires more investment in basic extension conditions and human capital.

While countries with new extension systems are struggling to establish themselves, well established systems are also facing tremendous challenges. For example, the agriculture and technology extension system in China has been facing great challenges with a general consensus that the system needs a thorough reform. During the 1990s, China'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)[51] identified that lack of innovative extension approaches negatively affected farmer's adoption of new technologies and suggested that reforms need much more efforts in terms of institutional and organizational reforms and human capacity building than the policy makers have planned for. Some of the findings and recommendations from this study (Box 3) are relevant to other countries in the region.

Women in extension: Although extension services are moving away from top-down, technology-driven, male-dominated approaches to demand driven gender-sensitive approaches, the impact of these reforms on female farmers is still unclear. A recent study (IFPRI, 2009)[52] 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 socio-cultural norms and adapt the program accordingly (Quisumbing and Pandolfelli, 2010)[53]. To ensure incorporating gender concerns in agriculture, extension personnel may require training in gender analysis and gender-sensitive agricultural planning methods (Sulaiman and Hall 2004)[54].

Figure 7 Linking small farmers to markets - potential role for extension (Source: Uathaveekul, 2011



Linking small farmers to markets through extension: Though agriculture extension services have traditionally focused on production aspects, looking ahead and addressing new challenges requires extension to play an expanded capacity development role which 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 et al, 2006).[55]. There is an emerging body of literature analyzing how smallholder farmers in developing countries can be linked to modern supply chains (AsiaDHRRA, 2008)[56]. 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 post-harvest control immediately after harvest minimize losses and improve quality (Uathaveekul 2011, Figure 7)[57]. 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.

Another asset to improving extension methods is the communication technology which is rapidly expanding and increasingly accessible in even remote areas. These developments allow timely sharing of research recommendations and 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)[58]. Though this is promising, it is essential to develop and test appropriate models keeping the farmers' needs and capacity in view.

Public and private investments in agriculture research and extension

In light of the strong case for agriculture R&D and extension along with the current commitments of many stakeholders to invest to 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 had generally taken 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 the governments. The emerging role of private sector also needs innovative thinking considering that the mode of operation of public and private sectors are very different but there is a need to find ways to work together.

Role of CGIAR and NARS: Public investment in research and development including the investments through the international agriculture research institutions has historically driven technological change in agriculture. It is estimated that in developing countries the public sector finances around 90 percent 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 three decades, the CGIAR's mandate had increased significantly, growing from 4 research centres with a narrow focus on productivity to a global network of16 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. Asia and pacific has certainly seen the benefits of research in several ways. One example that had enormous impact is the adoption by farmers of the modern rice varieties developed by the International Rice Research Institute which was estimated to have yielded an annual return of US$10.8 billion, nearly 150 times the combined annual investment in rice research by the institute and the national systems (Sombilla, 2008)[59].

Despite many more achievements, resources have not kept pace with this broadening portfolio of CGIAR. There was also a realization that public sector agencies and international agricultural research centers are operating within quickly changing natural and societal environments. In response, CGIAR underwent a major transformation starting in 2008. Sweeping changes transformed the loose coalitions into a streamlined global partnership where donors and all the 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 national level is still 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. Distribution of spending among countries is uneven, with China, Japan, and India 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 is reported in the region in the functioning and management of agricultural research (Mathur et al, 2011)[60].

While donors can support agriculture R&D in developing countries, national governments have a complementary role to contribute funding and ensure an enabling environment, such as easily available credit, stable output prices, and access to fertilizer and ensure that seeds for farmers are in place (Sen and Hoare, 2005)[61]. A step in the right direction is the recent declaration by the relevant Ministers of Asia Pacific Economic Cooperation (APEC) [62] recognizing the need for strengthening of domestic research capacity as well as the importance of engaging all stakeholders including farmers and disseminating the innovative technologies in an efficient manner.

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 et al, 2010)[63]. The potential role that private sector can play has now become a topic for serious consideration.

Pray (1998)[64] analyzed the question about whether the private sector can fill the gap of declining research in agriculture 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 focused 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 agricultural sector in many developing countries. As a result, such farmers have been largely passed over by the private sector's estimated US$862 million research investment in the developing world (Pardey et al, 2006)[65].

In spite of this difference of interests and often motivation, considering the array of complex challenges in agriculture 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 generation 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 finding common ground. Naseem et al (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 & 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 which include effective regulatory regimes and enforcement procedures to govern intellectual property rights, biosafety systems, tax exemptions, subsidy programs, and international trade regimes; physical and communications infrastructure to accelerate the flow of information and knowledge among researchers; privatization of state-owned input-supply firms that crowd out private investment; and harmonization of regional and international regulations to create larger market opportunities.

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

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

Recognizing the need for greater private sector investment in agriculture, the G20 summit in Toronto in 2012 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, Canada, the United States, the United Kingdom, Australia and the Bill & Melinda Gates Foundation in collaboration with the World Bank are working with other like-minded donors on the Agricultural Pull Mechanism Initiative (World Bank, 2012)[66]. Table 2 summarizes the pull mechanism in comparison with traditional development projects.

Table 2	**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 use of funds and needs to pass financial management assessment (due diligence test).	Government is recipient and holds fiduciary responsibility for 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 (pre-qualified) 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

The initiative, officially launched in Los Cabos, Mexico, on June 18, 2012 changed its name from Agricultural Pull Mechanism to AgResults (World Bank 2012)[67]. The initiative aims to achieve significant improvements in the wellbeing 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:

- Incentivizing the adoption of on-farm storage technology for smallholder farmers;
- Encouraging innovative distribution of a breakthrough technology to reduce aflatoxin contamination; and
- 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 post-harvest losses, increasing livestock productivity and improving nutrition. All these issues are very relevant to Asia and Pacific and it will be interesting to see how the initiative unfolds in the region.

Conclusion:

The challenge is clear. The world must produce 40 per cent more food by 2050, with limited land and water, using less energy, fertilizer and pesticide while coping with rapid changes in many spheres. With a close relationship established between the investments in R&D and agriculture production, the path to addressing the food crisis seems obvious. Though past successes in research no longer have all the

answers, science has contributed greatly in the past to finding solutions, and it can do so into the future if the 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 at household and individual level.

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

- Research that is interdisciplinary and addresses the diverse needs and context of smallholder farming systems
- Research for Development which is demand-driven considering farmer concerns and results-based strategic action plan
- Research that considers developing cost-effective business models and financing options for each technology and market
- Research that includes considerations of nutrition pathways and gender dimension to agriculture interventions
- Research that generates strong evidence for policy and programming
- Research optimizing 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 the benefits, a coordinated action is needed. It is important to consider multi-stakeholder collaborations for investments on foods security among development partners and share innovations and good practices to 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 crisis situations can be proactively addressed.

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