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Regional Report
on
Agricultural Research for Development in the Asia-Pacific Region

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Acronyms

ACIAR	The Australian Centre for International Agricultural Research
ACP	Africa-Caribbean Pacific
ADAP	Agricultural Development in the American Pacific
ADB	Asian Development Bank
ANGOC	Asian Non-Governmental Organization Consortium
ANRR	Agricultural and Natural Resources Research
A-P	Asia-Pacific
APAARI	Asia-Pacific Association of Agricultural Research Institutions
APAFRI	Asia-Pacific Association of Forestry Research Institutions
AQIS	Australian Quarantine and Inspection Service
AR4D	Agricultural Research for Development
ARI	Agricultural Research Institutes
ARS	Agriculture Research System
ASEAN	Association of South East Asian Nations
ASTI	Agriculture and Science and Technology Indicators
AVRDC	The Asian Vegetable Development Centre
Bt	*Bacillus thurienqensis*
BRRI	Bangladesh Rice Research Institute
C4	Carbon 4 (a photosynthesis pathway)
CAAS	Chinese Academy of Agricultural Sciences
CABI	Commonwealth Agricultural Bureaux International
CCRI	Cocoa and Coconut Research Institute
CDD	Community-driven Development
CGIAR	Consultative Group on International Agricultural Research
CIFOR	Center for International Forestry Research
CM	Crop Management
CMSA	Community Managed Sustainable Agriculture
CNY	Chinese Yawn
CRI	Coffee Research Institute
CSO	Civil Society Organisation
CTA	The Technical Centre for Agricultural and Rural Cooperation
DAFF	Department of Agriculture, Fisheries and Forestry
DALY	Disability Affect Life Years
DPI	Department of Primary Industry
DPR	Democratic Peoples Republic
E Consultation	Electronic Consultation
EEZ	Exclusive Economic Zone
EU	European Union
F2F	Face-to-Face
FAO	Food and Agriculture Organisation
FIVIMS	Food Insecurity and Vulnerability Information and Mapping System
FORDA	Forestry Research and Development Agency
FS	Food Security
FTE	Full Time Equivalent
GCARD	Global Conferences on Agricultural Research for Development
GDI	Gender Development Index
GDP	Gross Domestic Product

GFAR	Global Forum for Agricultural Research
GM	Genetically Modified
GMO	Genetically Modified Organism
GR	Growth Rate
GTZ	German Technical Cooperation
GVA	Gross Value for Agriculture
ha	Hectare
HDI	Human Development Index
IARC	International Agricultural Research Center
ICM	Integrated Crop Management
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
ICT	Information and Communication Technology
IFAD	International Fund for Agricultural Development
IFPRI	International Food Policy Research Institute
IMPACT	The International Model for Policy Analysis of Commodities and Trade
INM	Integrated Nutrient Management
IPR	Intellectual Property Right
IPCC	Intergovernmental Panel on Climate Change
IPM	Integrated Pest Management
IRIEC	Indonesian Research Institute for Estate Crops
IRRI	International Rice Research Institute
ISAAA	The International Service for the Acquisition of Agri-biotech Applications
IWM	Integrated Water Management
IWMI	International Water Management Institute
JIRCAS	Japanese International Research Center for Agricultural Sciences
Kg	Kilogram
Km	Kilo-metre
LIBIRD	Local Initiatives for Biodiversity Research and Development
LIFDCs	Low Income Food Deficit Countries
MDG	Millennium Development Goal
MP	Mega Programme
MT(mt)	MetricTon
NAARAP	NGO Association for Agricultural Research In Asia-Pacific
NAIP	National Agricultural Innovation Projects
NARI	National Agricultural Research Institute
NARES	National Agricultural Research, Extension and Education System
NARS	National Agricultural Research System
NATP	National Agricultural Technology Project
NCF	National Commission on Farmers
NGO	Non-Governmental Organisation
NPF	National Policy for Farmers
NREGA	National Rural Employment Guarantee Act
NRM	Natural Resource Management
NZ	New Zealand
NZAID	New Zealand Assistance for International Development
OPRA	Oil Palm Research Association
P&S	Prioritization and Strategy
PC	Producer Company
PCARRD	The Philippine Council for Agriculture, Forestry and Natural Resource Research and Development
PETRRA	Poverty Elimination through Rice Research Assistance Project

PM	Pest Management
PNG	Papua New Guinea
PPP	Public Private Partnership
PRC	Peoples Republic of China
PRSP	Poverty Reduction Strategy Paper
QPM	Quality Protein Maize
R&D	Research and Development
REE	Research, Education and Extension
RR	Roundup Ready
SAARC	South Asian Association for Regional Cooperation
SAVERNET	The South Asia Vegetable Research Network
SHG	Self Help Group
SME	Small and Medium Enterprise
SPC	Secretariat of the Pacific Community
SPREP	South Pacific Environment Programme
SRF	Strategy and Results Framework
TFP	Total Factor Productivity
UG99	Uganda 99 (a race of wheat rust)
UNDP	United Nations Development Programme
USDA	United States Department of Agriculture
VOP	Value of Output
WFS	World Food Summit
WHO	World Health Organisation
WTO	World Trade Organisation

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PREFACE

Agriculture continues to be the engine of inclusive and accelerated economic growth and livelihood security in the developing Asia-Pacific comprising over 55 and 70 percent of world's total and agricultural population, respectively. Despite the land availability being one-fifth of that in the rest of the world, the region is today's and tomorrow's largest supplier of the global food and agricultural products. The Green Revolution ushered in the region in the 1960s was an unprecedented success in multiplying food and agricultural production and productivity and in more than halving the percentages of hungry and poor by the year 1995.

The Green Revolution has now waned. The region is experiencing stagnation or slowdown in agricultural production and productivity during the past decade or so. Food insecurity and poverty, particularly rural poverty, accounting for two-third of the world's hungry and poor, exacerbated by the soaring food and fuel prices, global economic downturn, volatile markets and climate change–induced vulnerability, have resurfaced as the foremost development concerns in the region. Rural-urban and farmer – non-farmer income divides and fast declining and degrading land, water and biodiversity resources have further aggravated the problem. The small farmers, comprising over 80 percent of the farming households, have gotten hungrier and poorer over the years.

Given that the "Trickle Down" and "Market Magic" approaches have failed the majority hungry, undernourished and poor, it is now being increasingly realized by most agriculture-based and transforming economies and concerned international systems that there is no greater engine for driving growth and thereby reducing hunger and poverty than investing in agriculture, especially in research and innovation. On this premise, ADB, APAARI and GFAR jointly organised Asia-Pacific Consultations and in-depth analyses to identify priority research and development needs in agriculture and natural resources for reorienting and reshaping agricultural research agendas and capacities for development (AR4D) in the region. The process involved (i) E Consultation, (ii) Sub-regional (South Asia, Southeast Asia, China and the Pacific) and Regional reviews and studies on AR4D, (iii) Face-to-Face (F2F) Consultation, and (iv) Suggestions contained in recent literature and arising from discussions with selected experts/academics.

This Report internalizes the main outcomes of the above four processes. The following key issues and approaches have been addressed: (i) the priority development needs which are closely linked with the state of agricultural development; (ii) the priority agricultural research agendas in delivering defined development impacts, particularly to address the needs of resource-poor smallholder farmers, producers and consumers; (iii) the key blockages, barriers and bottlenecks that prevent research from benefiting the poor and the best ways to resolve them and to ensure enabling investment, policies, institutions and capacities; and (iv) unusual mechanisms and partnerships required in innovation pathways turning research into development impacts at scale and ways to align CGIAR's research towards national, regional and global development goals.

The author acknowledges the outstanding contributions of the sub-regional consultants: Drs. Mruthyunjaya and Praduman Kumar (South Asia), David A. Raitzer, Johannes Roseboom, Mywish K. Maredia, Zenaida Huelgas and Maria Isabel Ferino (Southeast

Asia), Xu Yinlong (Peoples Republic of China), and Alan R. Quartermain (The Pacific). The guidance and intense indulgence of Drs. R.S. Paroda (APPARI), Lourdes Adriano (ADB), and Ajit Maru (GFAR) has been the main driving force and source of inspiration in completing this study/report. The Report has greatly benefited also from the insightful inputs from Drs. Mark Holderness (GFAR) and Katsuji Matsunami (ADB). Contribution of the E and F2F Consultants, echoing the ground realities, duly internalized in the Report, has been instrumental in focusing on the needs of the resource-poor smallholder farmers and in recommending the "business unusual" to meet the challenges.

The author benefited immensely by participating in the GFAR's 23rd Steering Committee Meet, Alexandria, Egypt, November 13-15, 2009, particularly from his discussion with his counterparts from Central Asia and the Caucasus, Europe, Latin America and the Caribbean, Sub-Saharan Africa and West Asia and North Africa, and especially with Dr. Ismail Serageldin, former Chairman, CGIAR, Prof. Adel El-Beltagy, Chair, GFAR, Prof. Monty Jones, In-coming Chair, GFAR, Dr. Uma Lele, Lead Consultant, GFAR Global Team for GCARD, and Dr. R.D. Ghodake, Ex-Chair, APAARI. Their strong endorsement of Asia-Pacific's AR4D focus on investing in the poor, undernourished and the smallholder farmer augurs well with the region's input to the GCARD process.

The author believes that the generous support of the ADB in preparing this Report at this critical juncture of agrarian crisis will trigger modality and mentality changes to attain the desired science- and innovation-led agricultural transformation. The findings and recommendations, after due discussions and considerations, may help the governments, development partners, the ADB in particular, international organisations, especially FAO, GFAR and CGIAR, regional organisations, particularly APAARI, NGOs and the Civil Society in reorienting agricultural knowledge, technology and innovation and in implementing topical action plans to reduce hunger and poverty and facilitate equitable ecological, environmental and economic sustainability in Asia-Pacific region.

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Asia-Pacific Region

EXECUTIVE SUMMARY

Context

The Asia-Pacific region underpins the global agrarian economy. Encompassing South Asia, Southeast Asia, East Asia and the Pacific sub-regions, the region is the largest supplier of the world's food and agricultural products. It houses about 58% of the world's population and 74% of the agricultural population, but, has only 38% of the world's agricultural land. Consequently, land availability per person in agriculture in the region (0.3 ha) is almost one-fifth of that in the rest of the world (1.4 ha), and over 80% of the world's small and marginal farmers belong to this region.

The Green Revolution ushered in the region in the 1960s, an unprecedented success in multiplying food and agricultural production and productivity and in more than halving the percentages of hungry and poor by the year 1995, has now waned. The region is experiencing stagnation or slowdown in agricultural production and productivity during the past decade or so. Food insecurity and poverty, particularly rural poverty, accounting for two-third of the world's hungry and poor, exacerbated by the soaring food and fuel prices, global economic downturn, volatile markets and climate change–induced vulnerability, have resurfaced as the foremost development concerns in the region. Rural-urban and farmer – non-farmer income divides and fast declining and degrading land, water and biodiversity resources have further aggravated the problem. The small farmers have gotten hungrier and poorer over the years.

In agriculture-based developing and transforming economies, as in most of the A-P countries, there is no greater engine for driving growth and thereby reducing poverty and hunger than investing in agriculture, complemented by programmes that assure people to claim their entitlements. The internal rate of return on investment in agricultural research has been remarkably high (Alston *et. al.*, 2000), averaging about 20 to 40 percent in Asia-Pacific. Most of the Asian and one or two Pacific countries have established fairly good national agricultural research systems comprising research, education and extension (REE). However, except for China and India, investment in agriculture in the region, particularly in REE, has declined or stagnated during the last one decade or so.

Agricultural research, technologies and innovations must lead to the development of technologies rooted in the principles of economics, equity, and environment to increase productivity, income and livelihoods in perpetuity. Technology and innovation systems that are changing rapidly must go well beyond just raising yields and should be dynamically geared to meet the challenges of increasing resource scarcity and the structural transformation of the economic and social role of agriculture. Notwithstanding the centrality of generation and transfer of new and improved technologies for attaining sustained productivity gains, science today is thus called upon to address also the new challenges of market volatility, soaring food and energy prices, economic downturn and global climate change.

It may further be recognised that the scaled-up impact of technology and innovation systems on accelerated and inclusive development depends on more than technology adoption, which, in turn, depends on more than technology generation – underpinning the importance of socio-economic understanding, human resource capital and institutional support. Generation and adoption of technologies and innovations should be rooted in the goals of poverty alleviation, economic growth and environmental conservation.

Identification of AR4D Priorities

The AR4D priorities in Asia-Pacific region were assessed through the following four reiterative activities: (i) *E Consultation* : over 300 responses from 50 countries, comprising voices of – 93 scientists from NARS, 66 from NGOs, 47 from CGIAR, 35 from public sector and extension agents, 17 from CSOs and Farmers' Organizations, 15 from private sector and industry, and 27 unclassified, (ii) *Sub-Regional and Regional Reviews and Studies*: Sub-regional and regional reports on AR4D in A-P were commissioned from South Asia, Southeast Asia, China and the Pacific and the Asia-Pacific Region as a whole, (iii) *Face-to-Face Consultation* : involving 75 stakeholders from 17 countries and representing APAARI members NARS, CGIAR, IARCs, GFAR, ARIs, universities, NGOs, farmers/farmer organisations, the private sector and donor organizations from the region, and (iv) *Recent reports/literature on the subject and wisdom* of selected scientists/academics.

Participation from China, particularly in the E Consultation, was negligible. Given the obvious importance of China in the global agrarian economy and its agricultural transformation, voices from China must be heard as the GCARD process progresses. Participation of some of the major groups of stakeholders, such as private sector, was also rather thin, and this gap should be corrected in order to have a balanced picture.

Key Feedbacks from E Consultation and F2F Consultation on AR4D in Asia-Pacific

The following key feedbacks were received through the E and F2F Consultations:

- Needs of the resource-poor smallholders not well addressed (except generally in case of rice) by the AR4D agenda in the past;
- Inability of majority of resource-poor farmers to adopt high-input-cost and high-risk technologies, and this fact not internalized in the past research agendas;
- Underinvestment in Agriculture & AR4D, particularly in horticulture, livestock and fisheries, rainfed areas, socio-economic and NRM research, maintenance research and human capital formation;
- Climate change adaptation, uncertainty and vulnerability, scarcity and declining quality of water, declining soil fertility, agro-biodiversity erosion, increasing biotic stresses, increasing threats of bio-insecurity, market volatility and income divides are frontline issues; and
- Besides fighting stubbornly high hunger and poverty, synergizing productivity, sustainability and inclusiveness, closing technology transfer gaps at various levels, and strengthening linkage of farmers with markets and value chain are key drivers for AR4D.

Sub-Regional Priority AR4D Needs

South Asia

Based on the sources of literature review, analysis of evidences, the E Consultation and the F2F Consultation, the following priority research needs were identified by the South Asian Group (Mruthyunjaya and Kumar, 2009):

1. Commodity-based:
    - Rice;
    - Wheat;
    - Local staple cereals;
    - Pulses;
    - Livestock;
    - Horticulture (Fruit and Vegetables); and
    - Fisheries.
2. Overarching research areas:
    - Climate change management;
    - Natural Resource Management (NRM);
    - Integrated Farming System
    - Socio-economics, policy and value chain management;
    - Germplasm conservation and improvement;
    - Post-harvest management, agro-processing and value addition;
    - Quality improvement and safety; and
    - Rural non-farm employment and income generation.

The Group had also suggested complementary approaches and policies (reflected in the regional scenario) and specifically suggested three to four times increase in funding support to agricultural research, extension and education in South Asia from US$1.6 billion in 2002 to US$4.6 billion in 2020 (at current price) towards attaining food and nutritional security, poverty alleviation and social empowerment. It had observed that prioritization exercises need to explicitly target poor as otherwise their needs are under-funded.

Southeast Asia

The Southeast Asian sub-regional study (Raitzer, et. al., 2009) quantified expected and historical levels of benefits for the poor and the environment from different areas of research and contrasted relative expected impact potential with current relative allocations across research areas. The analysis found key gaps between current investments and expected impacts for productivity enhancing research on rice, vegetables, fruit and aquaculture, with the rice gap the most pronounced. The following were identified as priority research needs for Southeast Asia:

1. In terms of target agricultural products, productivity enhancing research for:

- Rice;
- Vegetables;
- Fruit; and
- Aquaculture.

2. In terms of research activities:

- Crop genetic enhancement; and
- Post-harvest processing, particularly for quality.

As an additional issue raised in the consultations and review of changes in the context for agricultural research, integration among disciplines in research organization and conduct was identified as important to the effectiveness of future research efforts.

Pacific

Over 80 percent of the island populations are directly dependent on the sustainable use of renewable natural resources for sustenance, health and prosperity. Although the 22 island countries differ widely in ecology, demography, economy and culture, the development emphasis in all the countries is on combating hunger, malnutrition, poverty and environmental degradation.

The Pacific sub-region had highlighted (Quartermain, 2009) the following challenges: (i) small population and economies, (ii) inappropriate policies and weak institutional capacity in both public and private sector, (iii) remoteness from and low competitiveness in international markets – high costs of transportation and labour, (iv) susceptibility to natural disasters and climate change, (v) fragility of land and marine ecosystems, (vi) limited fertile soil and fresh water supply, (vii) high import dependency, (viii) non-adoption of technologies from research, (ix) vulnerability to exogenous shocks, and (x) special problems of atolls.

The continuing research priorities were crop production and improvement, livestock, forestry, fisheries, natural resource management, biosecurity and income growth. In addition, the following priorities were identified for greater attention:

- Value-adding (inclusive) for niche markets (domestic and export) to be considered within a value chain approach, and alleviation of non-communicable diseases (NCDs);
- Crop improvement, especially horticultural crops to support value-adding and climate change readiness and also for nutritional security;
- Climate change management through mitigation and adaptation (modeling sadly lacking);
- Community-based systems for managing all natural resources, integrated farming system, forest retention, coastal or reef fisheries, including stocks assessment;
- Bio-security and trade facilitation – market access and farmer-market linkage; and
- Sustaining livelihoods in atolls.

Supportive policy actions and approaches were also suggested and have been internalized in the regional scenario.

AR4D Challenges in Asia-Pacific Region as a Whole

The following continuing pressing needs and new and emerging challenges deserve high attention:

- ***Continuing Challenges***
  - Limited resource base, particularly land (cultivates only 38% of global arable land) and water (scarce both in terms of quantity and quality);
  - Fast declining water and agro-biodiversity resources with environmental footprint of agriculture intensifying;
  - Majority of producers are small and marginal farmers who cultivate on the average about 0.3 ha per person (versus average of 1.4 ha per person with the rest of the world);
  - There are fairly good number of NARES, despite dwindling resources received, and there are emerging NARES in India and China that can and have started playing lead roles in the region; and
  - Continuing challenges that need to be addressed head on are: (i) more than 60% of hungry and extremely poor are in Asia and Pacific, (ii) the undernourished in the region is the highest globally and is still rising, and (iiii) the number of poor is highest and rising too in South Asia.
- ***New Challenges***
  - Food and nutritional insecurity further aggravated;
  - Global economic downturn and market volatility;
  - Climate change with projected intense and more frequent extreme weather resulting in increased risks, bio-insecurity and vulnerability; and
  - Competing land use: foodgrain *vs* fuel *vs* feed.

Priority Criteria for AR4D in Asia-Pacific (feedback from the E and F2F Consultations) noted the following considerations for identifying and selecting the AR4D:

- Focus on development needs of the resource-poor smallholder farmers;
- Synergize productivity, sustainability and inclusiveness (pro-poor and gender inclusive): these in turn are the drivers for sustained structural transformation and industrialization;
- Promote demand-driven and market-based AR4D; AR4D should ensure that it particularly addresses the food and agri- and food and nutrition-based needs of the poor and especially the extremely poor (hungry) consumers, women and children; AR4D should aim for Food and Nutritional Security as the highest priority;
- Multi-stakeholder led AR4D; need for ownership of those who will directly contribute to the value chain; and
- Maximize use of partnerships for science, technology/innovations, ICT; as well as ensure wide outreach among smallholders.

Thematic Research Priorities for Asia-Pacific

With the above backdrop and keeping in view the sub-regional priorities, the thematic research priorities for the Asia-Pacific region are listed below:

- Sustained productivity enhancement particularly in food staples and those that will diversify incomes at the farm sector, with special reference to smallholder farmers, and yield improvement through use of science and technology;
- Improve value chain development and management, weakest links in the chain are infrastructure that link farmers to markets and should be strengthened, market outreach should be augmented through building networks and partnerships;
- Increase resilience in two major areas: climate change, and those resulting from economic shocks;
- The above AR4D agenda has spatial dimensions:

	South Asia	Southeast Asia	Pacific
Sustained and Increased Productivity			
Food Staples	Rice, wheat, local staple cereals, pulses	Rice	Local roots and tubers, bananas, sago and nuts
Diversified crops/livestock	Horticulture, fisheries, livestock	Vegetable, fruit, aquaculture	That ensure inclusive value adding for niche markets: Vegetables, fruits, fisheries and livestock
Integrated farming system research	Cereals-pulses-horticulture-agroforestry-livestock-aquaculture integrated farming	-	Root crops-livestock-fisheries integrated farming
Through science and technology	Germplasm conservation & improvement	Genetic improvement utilizing the potentials of genomics and bioinformatics	For nutritional security, value-adding Sustaining atoll livelihoods
Improved Value Chain Development (Weak links in the chain)			
Infrastructure: farmer-market links	Post-harvest, agro-processing, management ICT Safety & Quality	Post-harvest, particularly for quality	Post-harvest Transport ICT Safety & Quality
Markets & networks/partnerships	Public-private-partnerships (PPPs) South-south cooperation	–	Niche markets (domestic, foreign) Trade facilitation
Increased Resilience			
Climate change management	Adaptation & mitigation	Averted agricultural expansion through productivity improvement; germplasm adaptation	Adaptation & mitigation Need for increased capacity on modeling/forecasting
Economic Shocks	Rural & non-farm jobs Risk management	Food affordability/ agricultural productivity	Special concerns of atolls

- The other priority research agendas are:
    - Integrated farm and natural resources (land, water, livestock, agro-biodiversity) management and enhanced sustainability, including those of homesteads/farmsteads, special focus needed on land degradation and water erosion and scarcity;
    - Innovative institutional and financing arrangements for revitalizing innovation sharing and extension systems to enhance access of research outcomes by small and resource poor farmers, and that strengthen NARS in frontier areas of agriculture science and links with extension services; and
    - Those that will stimulate or spin-off to off-farm and non-farm employments.

For all AR4D: cross-cutting themes are good governance and gender sensitivity.

Do the CGIAR's Mega Programs respond to the AR4D Agenda of Asia-Pacific?

There was a consensus that these MPs are not responsive to AR4D of the region. Key areas for improvement of the MPs are:

- The process will need to seek greater involvement of the regional fora and NARS;
- MP proposal seems to create more complexity and the structure introduces more bureaucracy;
- It is difficult to see how current structure will achieve the required vertical integration and horizontal synergy and harmonization;
- AR4D of South East Asia and Pacific are left out; and
- There was overall agreement that MPs portfolio did not excite the F2F participants.

Moving Forward will need a "Business Unusual" Modality and Mentality:

The “business as usual” has failed the poor and the hungry. The following major reiterative actions are needed for an effective AR4D system:

- With the existing, albeit low and declining, resources for AR4D, there is much room for their efficient and effective use and allocation:
    - Apply strategy results framework;
    - Be performance-based. Ensure quantifiable, time bound and transparent/ accountable monitoring system and indicators; Evaluate and periodically provide feedback;
    - Need for good governance in use and allocation: ensure accountability and transparency; and
    - Introduce competitive funding.

- Success is more ensured if there is strong ownership of the AR4D. This can only be done if multi-stakeholders/communities actively participate from planning to implementing and monitoring (impact assessments, etc.). There is also need for action research that combines different disciplines (e.g., socio-economic research).

- The responsibilities and accountabilities of NARS and CGIAR should be differentiated. The NARS in individual countries should lead research priority setting with focus on poverty reduction, capacity development and gender issues. The capacity of NARS, especially of the weaker ones, should be strengthened to bridge existing wide yield gaps and to up-scale and out-scale proven successful technologies.

- A decision-making framework should be in place to empower national programmes to allocate responsibility to determine their own priority research and technologies from technology providers, including CGIAR/IARCs. The international programmes, especially the CGIAR, should devolve some of the people-based programmes to NARS.

- The NARS which are acutely short of necessary finances and other resources may not be able to generate research products in cutting-edge areas. The CGIAR should provide global public goods in the frontier areas of agricultural research and environmental sustainability and enable weaker NARS to participate effectively in global agricultural innovation systems.

- The NARS should connect beyond Ministry of Agriculture and expand NARES by converging related programmes in agriculture and concerned non-agriculture ministries/departments, such as Ministry of Finance, Ministry of Planning, Ministry of Rural Development, Ministry of Science and Technology, Department of Biotechnology etc. Further, regular monitoring, impact assessment and mid-course corrections should be built in all AR4D programmes.

- Unilateral development of AR4D has limited impact. There is need to build partnerships and networks with CSOs, NARES, private sector, farmers' groups, etc. harnessing the comparative strengths of the partners. Cross-country NARES (like big brother-small brother types) should be explored. Enhanced south-south collaboration, sub-regional developments (e.g., Greater Mekong sub-region) should be tapped for:

  - Value chain development and management, especially those that can link farmers to markets, farmers to technologies (envisage a technology supermarket where farmers can have a choice of technologies and select at competitive prices), knowledge flow and delivery; and

  - Innovative business models for financing (through risk management), sustainable water and land use, and improve resilience and funding these measures (e.g., a Climate Change Adaptation Fund).

- There is need for aggressive advocacy and communication to increase AR4D funding for Asia and Pacific for it to continue (but in a more efficacious fashion) its global food supplier and poverty alleviation roles. Specifically:

- AR4D needs of the developing Asia and Pacific are about US$18 billion/year (current levels), raising from the present allocation of US$6 billion. Obviously will require funding sources from unconventional sources like private sector (supermarkets, agribusinesses, financial markets, development banks).

- Immediately though, Asia Pacific Governments will need to commit to their national AR4D needs. They should, in the next 5-8 years, commit to increase AR4D support to 1% of their respective gross value for agriculture (GVA). Governments should also assure adequate and readily available funds for infrastructure, staff salaries and basic R&D facilities and operations.

AR4D is not a sufficient condition for achieving inclusive food and nutritional security and overall growth of agriculture sector. Policy actions and infrastructure investments are also required:

i. Increase investment in agriculture and AR4D with focus on undernourished, poor, and resource-poor farmers and inclusiveness (women, youth and vulnerable) and emphasise income and productivity growth and alleviation of vulnerability;

ii. Ensure entitlement of the poor to land, water, biodiversity, socio-economic safetynets and markets;

iii. Integrate land and water use planning and management of natural resources, biodiversity, inputs and biotic and abiotic stresses, including climate change, transboundary diseases, and biosecurity;

iv. Build infrastructure needs for efficient value chain networks/highways and provide enabling policies for value chain management and partnerships, and innovative institutional links;

v. Accelerate human resource development, capacity building and re-tooling of NARES and technical staff;

vi. Strengthen capacities – infrastructure, ICT, rural/urban markets, human resource capital – trainings and skill development of actors in value chain to meet new and emerging needs;

vii. Facilitate trade and market collaboration and strive for fair trade, pro-poor input-output pricing, access to domestic and international markets and management of market volatility, linking farmers with markets, supporting Producers' Companies and improving terms of trade for agriculture;

viii. Build innovative partnerships, such as farmers participatory plant breeding, to strengthen REE, innovation systems, community-based management of natural resources and mutual enrichment and use of traditional and modern technologies and knowledge systems;

ix. Provide informed options/opportunities to exit farming, particularly to those who are under acute farming-related distresses and to those marginal farmers who despite their best efforts are not able to have their two hands meet; and

x. Congrue and synergise policies and programmes of ministries of agriculture with those of relevant non-agriculture ministries to forge wider links and to benefit from the overall macro-economic policies and programmes, and also promote South-South cooperation.

Given that South Asia has the highest concentration of the world's hungry and poor, and the condition has been persisting for the past 20 years or so, a special conference under the GCARD process may be convened to analyse the situation and to formulate an action plan to remedy the malady and ultimately to alleviate the suffering.

The island countries, more than 20 in the region, face the most serious threat from the climate change. A separate conference under the GCARD process on climate change management for island countries may be organised to agree on immediate actions to be taken to avert the crisis and to find long term solution.

Conclusion

Asia-Pacific agriculture must liberate the region from the twin scourges of hunger and poverty and from the curse of carrying over 70% of world's undernourished children and women. It must continue to supply its region and world with adequate food and agricultural commodities. Given that the land, water and agro-biodiversity resources have been fast declining and degrading and the environmental footprint of agriculture has been intensifying, the task is difficult, but not insurmountable.

Accelerated science and innovation-led agricultural growth must be inclusive and address the needs and aspirations of resource-poor smallholders. Most importantly, it must bridge the income divide between farmers and non-farmers which continues to widen from 1:2 about 40 years ago to 1:4 now. Developing Asia-Pacific would need to triple its investment in AR4D, requiring US$ 18 bn/year to generate and adopt agricultural research, technologies and innovations which must be rooted in the principles of economics, equity, and environment to increase productivity, income and livelihoods in perpetuity.

1. INTRODUCTION AND BACKGROUND

1.1 The Scope of the Report

The Global Conference on Agricultural Research for Development (GCARD), steered by the Global Forum on Agricultural Research (GFAR), through regional and other consultations aims to identify pathways to transform agricultural research into large scale development impact. The consultation outcomes will feed into the GCARD 2010 due to take place on March 28-31, 2010 in Montpellier (France) towards shaping the global agricultural research and innovation system driven by tangible development outcomes, particularly addressing the needs of the poor and smallholder farmers. The six regional consultations in six different regions (Asia-Pacific, Central Asia and the Caucasus, Europe, Latin America and the Caribbean, Sub-Saharan Africa and West Asia and North Africa) were implemented during July to November 2009 and were designed to capture the contribution and perception of veritable stakeholders through a set of activities.

In the Asia-Pacific[1], the AR4D priorities were assessed through the following four reiterative activities: (i) *E Consultation* : over 300 responses from 50 countries, comprising voices of – 93 scientists from NARS, 66 from NGOs, 47 from CGIAR, 35 from public sector and extension agents, 17 from CSOs and Farmers' Organizations, 15 from private sector and industry, and 27 unclassified, (ii) *Sub-Regional and Regional Reviews and Studies* : Sub-regional and regional reports on AR4D in A-P were commissioned from South Asia, Southeast Asia, China and the Pacific and the Asia-Pacific Region as a whole, (iii) *Face-to-Face Consultation* : involving 75 stakeholders from 17 countries and representing APAARI members NARS, CGIAR, IARCs, GFAR, ARIs, universities, NGOs, farmers/farmer organisations, the private sector and donor organizations from the region, and (iv) *Recent Reports/Literature on the Subject and Wisdom of Selected Scientists/Academics*.

This document is the synthesis for Asia-Pacific as a whole, integrating the outputs of the above four sets of activities. The Asian Development Bank (ADB) and the Asia-Pacific Association of Agricultural Research Institutions (APAARI), in partnership with GFAR, were the main pillars of support and guidance in completing the Asia-Pacific consultations and in streamlining the region's input to the GCARD process. ADB had actively funded the GCARD initiative with the specific aim of identification and prioritization of the agricultural and natural resources research (ANRR) needs, strategies and action plans for Asia and the Pacific to strengthen inclusive and environmentally sustainable growth. The APAARI has been the pioneering regional body in priority setting for AR4D. Thus, with the commitment of these two regional institutions, the completion of this document is the beginning of new phase of harmonizing and mainstreaming the region's AR4D efforts for faster and effective adoption of innovations for large scale development impact with focus on the poor, hungry and the resource-poor smallholder farmers.

[1] The Asia-Pacific region in this report is taken to comprise 8 South Asian (Afghanistan, Bangladesh, Bhutan, India, Maldives, Nepal, Pakistan and Sri Lanka), 8 Southeast Asian (Cambodia, Indonesia, Lao PDR, Malaysia, Myanmar, Philippines, Thailand and Vietnam), 3 East Asian (China, DPR Korea and Mongolia) and 22 Pacific Island (including Fiji, Papua New Guinea, Samoa, Solomon Islands, Tonga and Vanuatu) developing countries.

The following key questions have been addressed in as many and analogous chapters:

- What are the priority development needs which are closely linked with the state of food and agricultural development?
- What are the needs and priorities for agricultural research in delivering defined development impacts, particularly to address the needs of resource-poor smallholder farmers?
- What mechanisms and partnerships are required in innovation pathways turning research into development impacts at scale and how can CGIAR's research be aligned towards national and global development goals?
- What are the key blockages, barriers and bottlenecks that prevent research from benefiting the poor?
- How best should these be resolved and what enabling investment, policies and capacities are most needed, and what are the unusual approaches and paradigm shifts to achieve equitable ecological, environmental and economic sustainability in Asia-Pacific region?

1.2 Main Agricultural Features of Asia-Pacific

The Asia-Pacific region underpins the global agrarian economy. It is a major supplier of most of the important food and agricultural commodities, accounting for production and consumption of over 90 percent of the world's rice, 70 percent of vegetables, 60 percent of seed cotton and 45 to 50 percent of cereals, oil seeds and pulses (Table 1). With 3.5 billion people, the region accounts for about 58 percent of the world's population. Of these, 2.45 billion live in rural areas, 70 percent of the region's humanity. Agriculture (crops, livestock, fishery, forestry, and the associated natural resources endowments and distribution systems) is a source of livelihood for nearly 2 billion, about 80 percent of the rural people in the Asia-Pacific. Thus, the region accounts for 74 percent of the world's agricultural population (Figure 1).

But, the region has only 38 percent of the world's agricultural land of which, fortunately 32 percent is irrigated against only 10 percent in the rest of the world, thus accounting for two-third of the world's irrigated area (Figure 2)[2]. Land availability per person in agriculture in the region (0.3 ha) is almost one-fifth of that in the rest of the world (1.4 ha), and over 80% of the world's small and marginal farmers belong to this region. Thus the region's agrarian landscape is dotted essentially by smallholders, nearly 40 percent of whom are resource-poor, numbering about 500 million farm people (farmers and their families).

Agro-ecological, size, socio-economic, cultural and demographic heterogeneity is a defining characteristic of the region. It includes the world's top two largest (in population terms) countries, China (population over 1.3 billion) and India (population over 1.1 billion) as also the smallest countries, namely, Niue with a population of only 2000 and Nauru and Tuvalu, each with less than 10,000. In terms of economic development also

[2] Agro-ecological indicators (total population, agricultural population, ratio of agricultural land to agricultural population and percentage of irrigated land to agricultural land) are given in Annexure I.

the region is equally diverse, encompassing four high income countries (Australia, Japan, New Zealand and South Korea), a large number of upper-middle and middle income countries (most of the Southeast Asian countries and China) and several low-income countries (most of the South Asia, plus Cambodia, Laos, Myanmar from Southeast Asia). The South and Southeast Asian (including China) sub-regions have been recording one of the highest GDP in the recent decade.

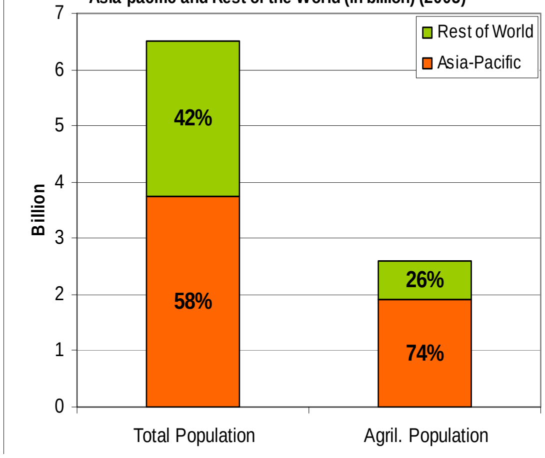


Figure 1. Total population and agricultural population of Asia-pacific and Rest of the World (in billion) (2005)

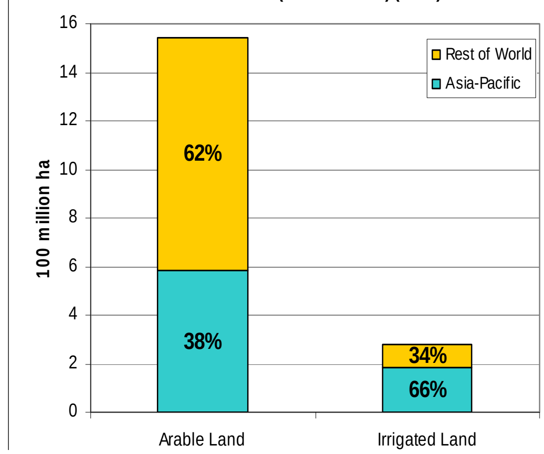


Figure 2. Total arable and irrigated land in Asia-Pacific and Rest of the World (100 million ha) (2005)

Source: FAO, 2007

Table 1. Production of major crops and commodities, 2006

Commodity	China	India	Asia-Pacific	World	Share of A-P in the World %
Rice (1000 mt)	182042.0	136510.0	573335.7	631415.5	90.80
Cereals (1000 mt)	429374.5	239130.0	1049224	2157494	48.63
Potato (1000 mt)	70338.0	23910.0	121754.4	314375.5	38.72
Pulses (1000 mt)	5556.5	14264.0	27344.9	60412.6	45.26
Oil crops (1000 mt)	16454.5	9946.4	76804.9	153841.0	49.92
Fruits (1000 mt)	89123.3	43034.7	210107.0	476661.7	44.07
Vegetables (1000 mt)	434920.7	85401.9	583873.4	828510.7	70.47
Seed Cotton (1000 mt)	17142.0	10691.6	41166.8	67486.1	61.00
Sugarcane (1000 mt)	87768.0	281170.0	591650.0	1339329.3	44.17
Cattle Population (1000 heads)	115229.5	185000.0	480555.5	1382202.3	34.76
Meat Total (1000 mt)	87133.3	6053.0	124460.4	278118.1	44.75
Milk Total (1000 mt)	32179.5	95675.0	221913.0	641593.6	34.58

Source: FAO, 2007

The Asia-Pacific region contains all the three worlds of agriculture – one agriculture-based, one transforming and one urbanized (World Bank, 2008). Cambodia, Lao DPR, Myanmar, Nepal, PNG and Tonga constitute the first category. Agriculture in these countries still accounts for 25 to 50 percent of the total GDP (Annexure II) and employs 65 to 70 percent of the total labour force, being as high as 93 percent in Nepal. These countries require a productivity revolution in smallholder farming to achieve their development goals. The remaining developing countries comprise the second category whose agriculture contributes less than 20 percent of the GDP, but employs nearly 55 to 60 percent of the workforce. These countries are transforming fast and the group is generally characterised with rapidly rising rural-urban income disparities with serious social and political implications. The four developed countries of the region, namely, Australia, Japan, New Zealand and South Korea, comprise the urbanized world of agriculture, whose agriculture contributes only 3.4, 1.3, 9.5 and 3.4 percent of their GDPs, respectively. This report relates to the first two categories only.

South and Southeast Asia each have 11 farming systems (Annexure III and IV).

In South Asia, four, namely, rice-wheat, rainfed mixed, rice-rice, and highland mixed, in that order, are most important. These four systems engage 87 percent of the agricultural population, 33, 30, 17 and 7 percent, respectively. The rice-wheat system has the highest potential for growth and poverty alleviation, while the other three have moderate potential. Livestock and horticultural crops are integral parts of most of the farming systems (Weatherhog et al., 2001). Globalization provides comparative advantages to adopt integrated farming systems, geared to niche export markets for horticultural, livestock, and fish products. Even within the sub-region, consumption/head of both meat and dairy products is forecast to double in the next 30 years. The urbanization trend - increasing from the 28 percent in 2001 to 53 percent in 2030 - and the increased demand for off-farm employment, may require increased mechanization.

The irrigated- land-area proportion is expected to grow slowly, from 40 percent in 2001 to 44 percent in 2030 (FAO, 2006a). On non-irrigated land, soil erosion, and overgrazing, if not arrested, will further degrade the natural resource base. Water resources must be managed more efficiently from basin level to farm level to avoid a “water crisis” over major parts of the sub-region. If significant climate changes were to occur, low lying coastal areas will come under intensive pressure from sea level rise, storms and flooding and rainfed semi-arid areas are likely to be seriously affected by increased rainfall variability.

In Southeast and East Asia, four systems, namely, lowland rice, upland rice intensive mixed, temperate mixed and tree crops mixed, in that order, are most important. These four systems account for 89 percent of the agricultural population: 44, 28, 14 and 3 percent, respectively. The tree crops mixed system has highest potential, while the other three have moderate potentials. Livestock and horticultural crops are important components of all the four systems. Under lowland rice, aquaculture is also important (Ivory, 2001).

In this most populous sub-region of the world, the population is projected to grow to 2.31 billion by 2030. The proportion of urbanization is expected to rise from the current 37 percent in 2001 to 53 percent by 2030 (FAO, 2006a). The quality of the diet will change with significant growth in consumption of meat (65 percent increase by 2030), milk and dairy products (90 percent), thus underpinning strongly the need for promotion of synergistic linkages between crop-agroforestry-livestock sectors for growth in agricultural GDP and poverty reduction.

Crop yield in the sub-region is projected to grow only by 1.2 percent per annum, up to 2030. Rice production is projected to increase by only 0.7 percent per annum up to 2030 and wheat by 1.4 percent per annum during the period 2000-2015. Total cereal production is expected to reach 708 million tons by the year 2030. The production of oil crops, fruits and vegetables is expected to increase substantially by 2030. The past and future trends for bovines and small ruminant production in the sub-region are similar; they project increases annually of 1.3 percent up to 2030. The potential for increasing the supply of feeds for ruminants is anticipated to be a significant constraint; it calls for a system-wide integration between the crop and livestock sectors in land use and allocation among crops. Animal feed supplies will come from large increases in maize production at the expense of rice and wheat production.

The Pacific sub-region of interest is made up of the 22 island members of the Secretariat of the Pacific Community (SPC). The geography, populations, cultures, economies and politics of these 22 island countries and territories are extremely diverse. Of great importance is the distinction that must be made between high islands and low atolls, sometimes within a country, and the commonality of an access to marine resources. Also the very small size of so many of the countries means that domestic markets for crops are very small and it is impossible for such countries to develop or maintain any reasonably functional research and development capacity. The vast distances between countries make cooperation difficult with slow, expensive or inconvenient communication systems. The sub-region covers over 30 million square kilometers of which more than 98 percent is ocean. The ocean is of major economic value for fisheries development, particularly because of the Exclusive Economic Zones (EEZs) and the sale of fishing rights to the Pacific tuna resource. Long coastlines relative to populations and unpolluted waters present vast untapped potentials for mariculture. The total population of the region was estimated in 2000 at 7.6 million of which PNG had 5 million or 66 percent, and the population is predominantly rural. The main crops of the sub-region are roots and tubers, coffee, cocoa and coconut (Quartermain, 2009).

1.3 The State of Agricultural Development in Asia-Pacific

Agricultural production index, using 1999-2001 as 100, in Asia-Pacific increased from 83.6 in 1995 to 115.3 in 2005, whereas for the world as a whole the corresponding figures were 87.6 and 111.3 (FAO, 2007). In the recent decade, the region's agricultural GDP has grown annually by about 2.5 to 3 percent against about 6.5 to 7 percent growth rate of the total GDP. Thus, while the share of agriculture in the region's total GDP has dropped to less than 20 percent, its share in the total workforce is around 55 percent, thus widening the income gap between agricultural non-agricultural sectors (World Bank, 2008).

Production and yield trends of cereals are given in Table 2. During the decade ending 2006, cereal production increased from 990 million tons to 1049 million tons, registering a growth rate of 0.6 percent, exclusively due to yield increase of 1.0 percent per annum, whereas the area under cereals had decreased annually by 0.4 percent. Among cereal, maize yield had increased by 1.3 percent, followed by 0.8 percent in rice and 0.5 percent in wheat. Among other major cop groups, fruits (excluding melons) production in the region increased from 152 million tons in 199 to over 210 million tons in 2006, at 3.3 percent per annum, while in the rest of the world, the production fell from 276 to 267 million tons, annually by 0.3 percent (Table 3). Total vegetables production in the region showed still better performance increasing from 362 million tons to nearly 600 million tons in 2005-06, registering a high growth rate of about 5 percent (Table 4).

Table 2. Cereals production and yield

Geographic Entity	Production (000 MT)			Yield (Kg/ha)		
	1996	2006	GR%	1996	2006	GR%
China	453665.4	429374.5	-0.5	4897	5231	0.7
India	218750.4	239130.0	0.9	2181	2474	1.3
Asia-Pacific	989981	1049224	0.6	3068	3373	1.0
Rest of World	1081169	1108269	0.2	2837	3266	1.4
World	2071149	2157494	0.4	2943	3317	1.2

Source: FAO, 2007

Table 3. Fruit total (excluding melons) production (000 MT)

Geographic Entity	1996	2005	2006	GR%
India	38185.9	43034.7	43034.7	1.2
China	48778.0	89123.3	89123.3	6.2
Asia-Pacific	152309.5	216593.1	210107.0	3.3
Rest of World	275726.9	294370.6	266554.7	-0.3
World	428036.4	510963.7	476661.7	1.1

Source: FAO, 2007

Table 4. Vegetable total (including melons) production (000 MT)

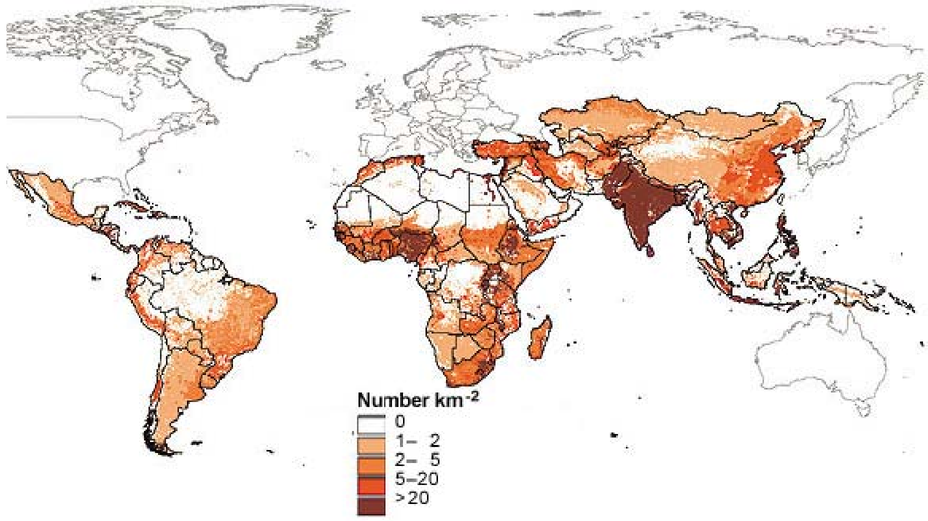
Geographic Entity	1996	2005	2006	GR%
India	56645.9	85401.9	85401.9	4.2
China	226363.1	434920.7	434920.7	6.7
Asia-Pacific	362402.9	614720.2	583873.4	4.9
Rest of World	235649.6	279057.4	244637.3	0.4
World	598052.5	893777.5	828510.7	3.3

Source: FAO, 2007

Livestock distribution in the region is much more egalitarian than the ownership of land. Three hundred million poor people in Asia depend to considerable extent on livestock for their livelihoods, some 200 million in South Asia and another 100 million in South-East Asia and China (Figure 3). There has been a dramatic shift in the Asia-Pacific region from vegetable-based diets to diets containing more animal protein. This has resulted in an ongoing transformation of the livestock sectors in the region, with subsequent implications for feed resources and other inputs. These shifts raise a number of new and evolving concerns, particularly regarding environmental issues, the provision of marketing opportunities and the need to balance feed production with demand. There is a trend away from horizontal to vertical integration, often discouraging traditional subsistence-oriented livestock farming. Judging from the past trend, industrial production of pigs and poultry is expected to further increase particularly in Southeast Asia and in

China relative to production from grazing and mixed farming systems involving ruminants. Milk production has grown more rapidly in Asia than anywhere else in the world, particularly in India, other South Asian countries and China (Table 5).

Figure 3. The distribution of poor livestock keepers



Source: Thornton et al., 2008

Table 5. Meat and milk production

Geographical Entity	Meat Production (000 MT)			Milk Production (000 MT)		
	1996	2006	GR%	1996	2006	GR%
China	47734.9	87133.3	6.2	10191.4	32179.5	12.2
India	4651.5	6053.0	2.7	68355.0	95675.0	3.4
Asia-Pacific	76681.8	12460.4	5.0	152313.3	221913.0	3.8
Rest of World	130659.1	153657.7	1.6	393046.4	419680.6	0.7
World	207340.9	278118.1	3.0	545359.7	641593.6	1.6

Source: FAO, 2007

The Asia-Pacific region continues to be the world's largest producer of fish. Both capture fisheries and aquaculture sectors continue to be of fundamental importance to the Asia-Pacific region in terms of food and nutritional security, revenue generation and employment. In many of the countries, particularly in the Pacific sub-region, catching or farming aquatic resources forms a vital part of rural people’s livelihoods, but the role has often been under estimated in the past. The Asia-pacific region accounts for 100 out of 130 million tons total fish production. The region also accounts for 95 percent of aquaculture production and 94 percent of the fish farmers in the world (Table 6). Aquaculture production in the region had doubled from 21.5 million tons in 1995 to 43 million tons in 2005 (FAO, 2007). Fish provides livelihood for more than 400 million people across the world, most in Asia-Pacific. Fish is also the main source of animal protein to the poor, meeting 16 percent of their animal protein requirement and in case of low income food deficit countries (LIFDCs) this is more than 18 percent. Asia-Pacific accounts for the bulk of fish trade in the world. The main exporters of fish from the region are China (US$ 8,968 million), Thailand (US$ 5,236 million) and Vietnam (US$ 3,350 million).

Table 6. Fisheries status of Asia-Pacific region

	Capture fisheries Production (in million t)		Aquaculture production (in million t)	People involved (in millions)	
	Marine	Inland		Fish farmers	Fishers
Asia-Pacific	58.2 (77%)	5.7(57%)	43.4 (95%)	8.1 (94%)	29.2 (84%)
World	75.2	10.0	45.6	8.7	34.8

Source: FAO: The State of Fisheries and Aquaculture, 2008.

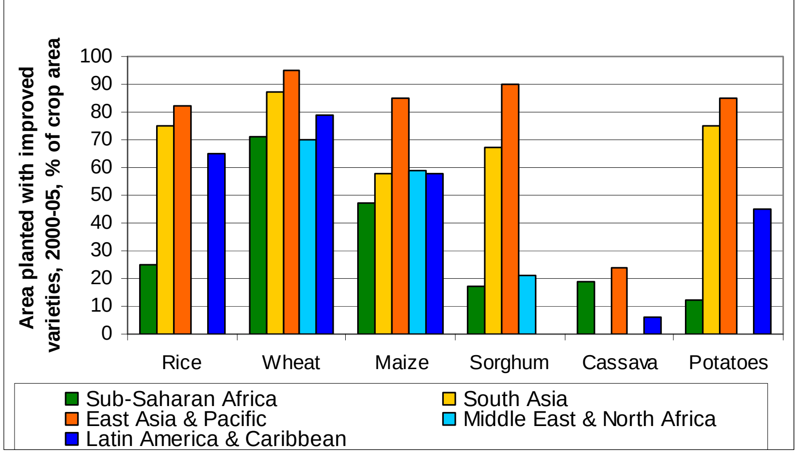
In the Pacific, fisheries are extremely important to the livelihoods with very large EEZs and long coastlines. In some countries the total population is coastal and dependant on seafood for protein (perhaps 80% of dietary protein) while in others it may be only half the population. But there may be a crisis in supply of fish in the region within a decade with supplies not meeting demand by 2020. There is over-fishing due to poor management and governance, and a growing demand for inshore resources such as beche de mer, shark fins, live reef fish and trochus. The likely effects of climate change are unknown but there will be a necessity to build resilience and capacity for collective action. Aquaculture will be part of the answer but not enough and other concerns are raised about how to feed stocks in aquaculture.

The role of forests in Asia and the Pacific is being increasingly recognized, especially in the face of emerging important new issues, including mitigation of climate change, demand for bio-energy, water issues, natural disasters, the contributions of forests in poverty reduction, and the potential role of coastal forests in mitigating the impacts of tsunami events. In the region as a whole there has been a net increase in forest area of about 633 000 ha annually between 2000 and 2005, in contrast to the region’s net loss of forest cover during the 1990s (FAO, 2009a). The improvement was largely the result of an increase of more than 4 million ha per year in China, as well as the efforts of other countries such as Bhutan, India and Vietnam, which have all been investing in afforestation and rehabilitation in recent years. However, many other countries experienced a net loss. As a sub-region, Southeast Asia experienced the largest decline in forest area, with an annual net loss of more than 2.8 million ha per year, about the same rate registered during the 1990s. The greatest forest loss occurred in Indonesia, almost 1.9 million ha per year, followed by Myanmar, Cambodia, the Philippines, Malaysia and the Democratic People’s Republic of Korea.

1.4 The Green Revolution

The Green Revolution, a science-led synergism among enhanced genetic potential (spread of improved seeds, Figure 4), irrigation, fertilizer, appropriate policies and farmers’ enthusiasm, launched in the late-1960s, brought an unprecedented transformation in food and agricultural production, food security, and rural development in the region (Singh, 1996; Swaminathan, 2000). During 1969-1999, Asian cereal production more than doubled – reaching nearly 1 billion tons recording an annual growth rate of 3 percent during the period. And four-fifth of the growth had accrued through yield and productivity growth – a clear impact of the sector’s research on agricultural production.

Figure 4. Adoption of improved varieties



Source: ASTI, 2008

Notwithstanding the addition of 1.3 billion people to the region's population during the 30 years, average per caput food availability increased by 25 percent. For the major food staples - rice and wheat - prices halved in real terms as productivity increased, making these staples more affordable, thereby resulting in halving the percentage of hungry people. Increased agricultural productivity, rapid industrial growth in many countries, and expansion of the non-formal rural economy resulted in almost quadrupling the per caput GDP, thus halving also the level of poverty.

Scientific and technological advancement in agriculture have greatly contributed to the outstanding achievements of China in achieving food security and alleviating poverty. Super rice, hybrid maize, transgenic cotton, hybrid rape, etc have covered about 95 percent of the respective cropped area (Yinlong, 2009). Covering plastic film technique is also a major break-through. Improvement of livestock breeds, prevention of major animal diseases and aquaculture advances have revolutionized the corresponding industries and today China ranks first in the world in the output of meat, eggs and aquatic products. Technological advancements in agricultural mechanization, 38 percent of all agricultural operations done by machines, has greatly enhanced land and agricultural labour productivity.

The post revolution reforms in China in research and technological development has resulted in 10 major scientific and technological achievements by 1996, namely, high yielding, high quality multi resistant crop varieties, the Super Rice, transgenic insect resistant cotton, large scale adoption of high-yield integrated crop technologies, energy saving solar greenhouses for vegetables, fruits and flower production, management of migratory bollworm, brown plant hopper and pest forecast, livestock and poultry breeding and disease management, new feeds and additives, information and communication development technology and efficient use of water and fertilizer resource resulting in water-saving and large-scale application of regulation technology in fertilizer application (Yinlong, 2009).

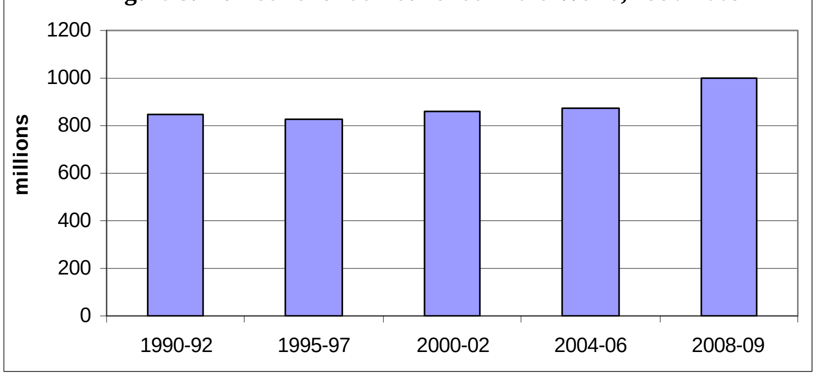
2. EXISTING AGRICULTURAL DEVELOPMENT NEEDS, PATTERNS AND RESEARCH PRIORITIES

2.1 Priority Development Needs and Challenges Linked with the State of Agricultural Development

2.1.1 Priority Development Needs: Alleviation of Hunger and Poverty

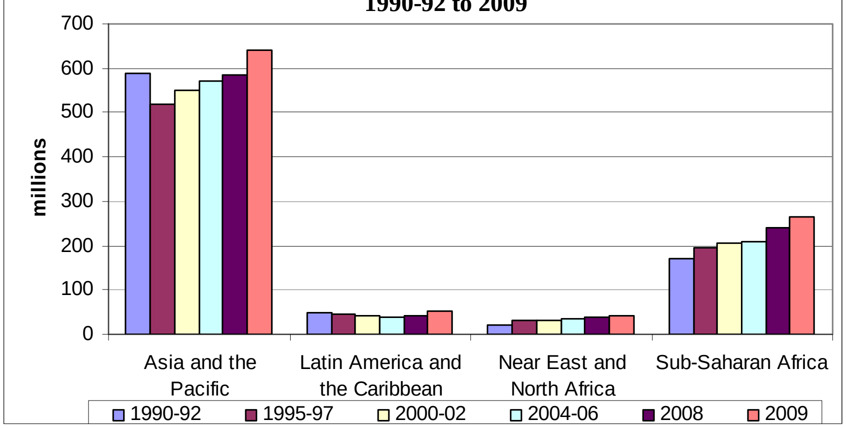
The number of undernourished people in the world had been increasing for a decade or so (Figure 5) and the number of hungry for the first time has crossed the 1 billion mark in 2008—09 (FAO, 2009b). The gains made in the 1980s and early 1990s in reducing chronic hunger have been lost and the hunger reduction targets of the first Millennium Development Goal (MDG) as well as of the WFS remain illusive. The soaring food prices of 2007-08 had drawn the poor farther from food, resulting in the unusual increase in the number and even proportion of undernourished. Despite the fall in international food and fuel prices starting in the late 2008, the prices in domestic markets remained 15 to 25 percent higher in real terms than the trend level – continuing the distress for the poor. Unfortunately, the Asia-Pacific region had the highest contribution to the rise in the number of undernourished people in the world (Figure 6).

Figure 5. Number of undernourished in the World, 1990-2009



Source: FAO, 2009b

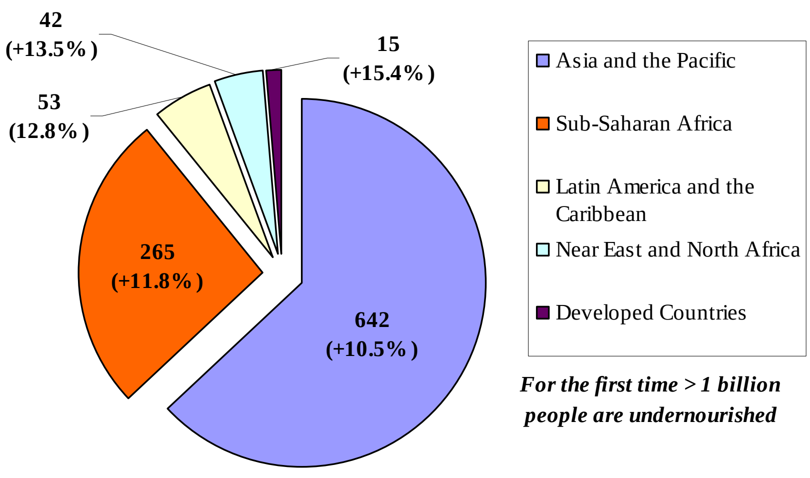
Figure 6. Number of undernourished in selected regions, 1990-92 to 2009



Source: FAO, 2009b

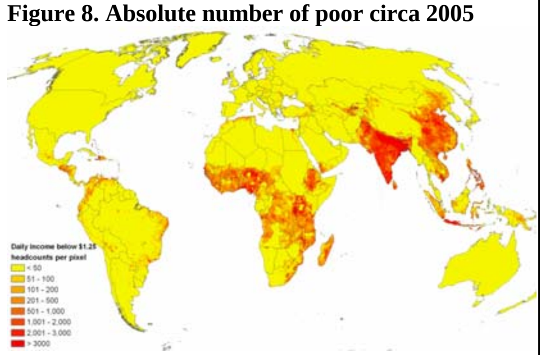
Alleviation of the twin scourges of hunger and poverty is the foremost development priority in the Asia-Pacific region - the larger half of the world. Almost two-third of the world's hungry, 642 million (Figure 7), and 67 percent of the world's poor have their homes in the region (Figures 8, 9 and 10). The Asian children are born underweight (von Braun, 2009a) and most of them remain so during the most critical first five years of growth and brain development (Figure 11). The region is home to 70 percent of the world's undernourished children and women. These numbers have remained stubbornly high and even increased lately (von Braun, *et. al.*, 2008). During the past one year, the number of hungry in the region has increased by 10.5 percent (FAO, 2009b). Thus, drawing the region farther from meeting the Millennium Development Goals, especially Goal 1, to halve poverty and hunger by 2015.

Figure 7. Estimated regional distribution of hunger in 2009 (in mil.) and increase from 2008 levels (in %)



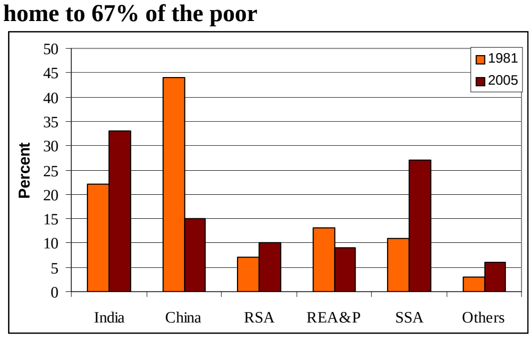
Source: FAO, 2009b

Figure 8. Absolute number of poor circa 2005



Source: von Braun, 2009a

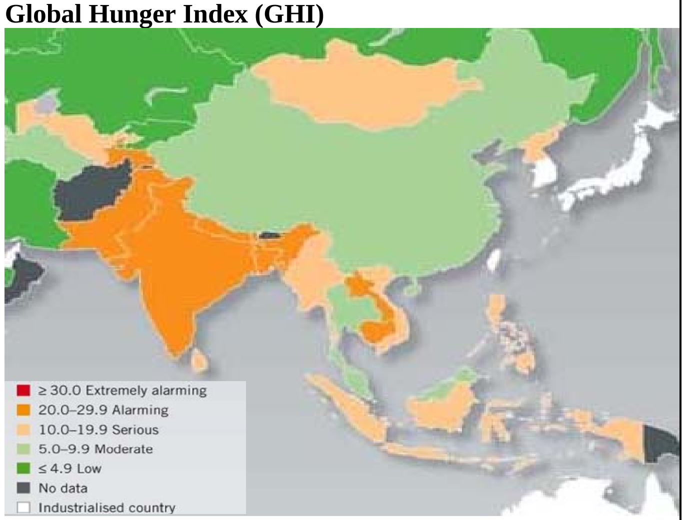
Figure 9. Global poverty scenario: Asia now home to 67% of the poor



Source: von Braun, 2009a

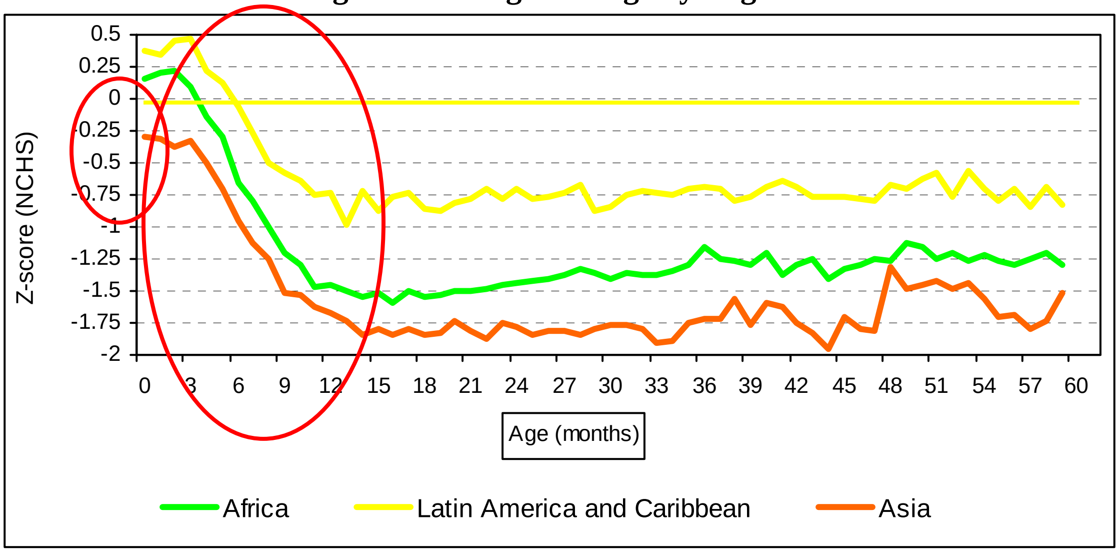
The Green Revolution in the Asia-Pacific has waned. Despite huge yield gaps, rates of growth in yields of foodgrain crops and in total factor productivity (TFP) have steadily declined and, as mentioned earlier, cereals production grew only by 0.6 percent per annum against the population growth rate of nearly 1.2 percent during 1996-2006. Thus per caput cereal availability has slightly declined from the peak level of 1990-92 (Figure 12). Region's food security is heavily dependent on cereal self-sufficiency, therefore, the declining trend in cereal production must be reversed by further increasing the yield levels, which call for newer technologies and efficient management of resources. The "Trickle Down" and "Market Magic" have failed the poor, whose ranks are swelling even in the urban areas and the veritable divides are widening. Income disparity between farmers and non-farmers had doubled from 1:2 to 1:4 during the last 20 years.

Figure 10. Hunger alarming in parts of Asia: 2008 Global Hunger Index (GHI)



Source: von Braun, 2009a

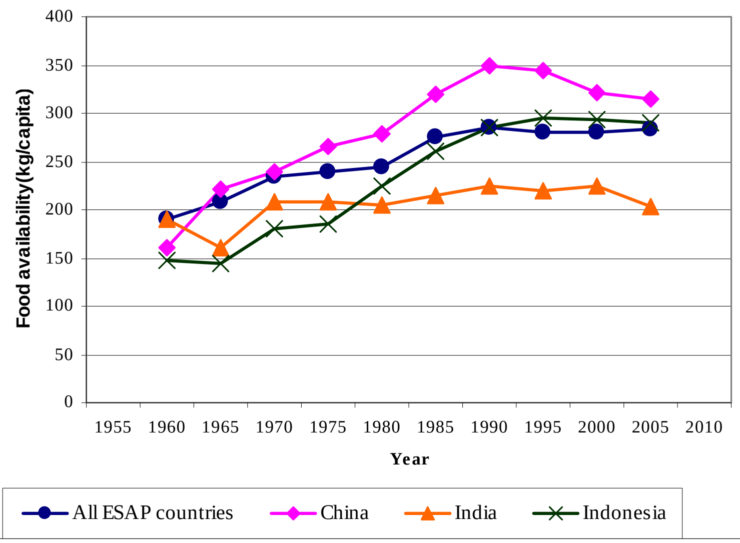
Figure 11. Weight for age by Region



Source: Shrimpton et. al. 2001(cited in von Braun, 2009a)

Various analyses in the region have reiterated that there is no greater engine for driving growth and thereby reducing poverty and hunger than investing in agriculture (Table 7), complemented by programmes that assure people to claim their entitlements. For China, aggregate growth originating in agriculture is estimated to have been 3.5 times more effective in reducing poverty than growth outside agriculture. Rapid agricultural growth in China, India, and Vietnam was also the precursor to the rise of industry (World Bank, 2008). Improved agriculture in this context, it is important to note that despite the high (about 40%) internal rate of return on investment in agricultural research, investment in agriculture and in agricultural research, education, and extension (REE) has declined, except in China and in India, thus compounding the problems.

Figure 12. Cereal availability (Kg/capita)



Source: ASTI, 2008

Table 7. Poverty reduction elasticities of agricultural growth

Low Income Countries	
SSA	-1.83
South Asia	-1.73
East Asia and Pacific	-1.44
Easter and Central Europe	-1.57
Latin America	-1.11
Middle East and North Africa	-0.92
All Low Income Countries	-1.6

Source: Christaensen et. al. 2005 (cited by von Braun, 2009a).

2.1.2 Main Challenges

2.1.2.1 Degrading Natural Resource

The fight against hunger and poverty is exacerbated by the fast declining and degrading land, water, biodiversity and other natural resources which in the Asia-Pacific region are three to five times more stressed due to population, economic and political pressures than in the rest of the world. The region has already reached the limits of land available for agriculture. Inefficient use and mismanagement of production resources, especially land, water, energy and agro-chemicals has vastly reduced fertility and damaged physical, chemical and biological properties of soil. Severely low soil carbon content, deficiency of macro and micro nutrients and high toxicity are widespread.

World's two-thirds irrigated land is in Asia-Pacific region. This asset, created by huge investment, must be utilized and sustained judiciously. Mining of underground water and misuse and pollution of surface water and water bodies, compounded with growing regional water scarcity and competition for water, represent major threats to future advances in food security and poverty alleviation. Per caput water availability in South Asia halved between 1967 and 1997 (Mruthyunjaya and Kumar, 2009). While agriculture is under severe scrutiny to account for the water it uses, per caput water availability in most countries of the region has either reached or shall soon be reaching the critical level.

2.1.2.2 Expanding Environmental Footprint of Agriculture

While maintaining a steady pace of development, the region will also have to reduce the agriculture's large environmental footprint and to overcome the challenge of climate change, notably higher temperatures (30 percent of greenhouse gas emission is attributed to agriculture), greater rainfall variability and more frequent extreme weather events, including floods and droughts. The reduction in water availability and increase in animal and plant diseases will primarily affect poor countries and the small island states that have reduced capacity of response to adapt and remedy against the negative impacts. Good agricultural practices such as conservation agriculture would contribute considerably to climate change adaptation and mitigation. These issues must be operationalised in global context at the ongoing Copenhagen Climate Change Summit (Rabbinge, 2009). Regrettably, man-made disasters may in some countries exacerbate the natural ones.

2.1.2.3 Intensifying Population and Economic Pressures Seeking Yield Enhancement

More people with higher incomes are exerting greater pressure than before on the natural resource base, and nearly 45 million people are being added every year to the region's population. The UN medium variant projection is that the Asian population will continue to increase further until at least 2050, when it will exceed 5.25 billion people. Towards 2030, the region will need to increase its cereal production by nearly 50 percent and meat production by 85 percent. And, all of this increase must accrue from increases in yields and cropping and farming intensity. This will certainly be an uphill task as the rates of growth in yields of the major cereal and other foodgrain crops have been declining and the natural resources have been degrading fast and the input use efficiencies have been extremely low. Further, being the largest supplier of agricultural products to the world, the Asia-Pacific will be required to meet the target to maintain the balance of world's food supply and the state of agriculture. The research, technology and innovation systems, both at national and international levels should be suitably empowered and positioned to help overcome these challenges.

2.1.2.4 Decreasing Net Trade

Agricultural trade in the Asia-Pacific has increased more quickly than in the rest of the developing world, and will further intensify. But, increasingly, Asia-Pacific agriculture is impacted generally adversely by progressions in globalization and in world trade (and in their regulation) for agricultural products and services. Although the overall trade has expanded fast, net trade of the developing Asia-Pacific has decreased (Annexure V) and at times jeopardized smallholder production. Asia-Pacific nations, and particularly the smaller among them, shall need continuing assistance to achieve optimal benefits from post-WTO liberalization and globalization. These developments have technological, environmental, socio-economic, and trade implications: overall agricultural production (and productivity) shall need to increase substantially, livestock activity shall become a larger component of farm enterprises, and shall increase substantially the per-person requirement for water for food and feed; Asia-Pacific agricultural-free-trade groupings are likely to be augmented; but for low-income food-deficit countries, food and nutritional security shall depend on international food supplies at affordable prices.

2.1.2.5 Effecting Necessary Policy Shifts

Ultimately, it is in the agricultural sector that problems such as non-sustainable production, low and stagnating productivity, widening rural–urban and farmer–non-farmer divides, stubbornly high hunger and poverty and natural resource depletion must be addressed. In order to face the challenge of food security, inclusiveness and climate change, Governments will need to seek agreements and plan adjustments to policies, institutions, investments and infrastructure which correctly value the services provided by the sector. The true value of the role of agriculture and rural development in poverty alleviation and provision of environmental services needs to be duly recognized and agricultural R&D should forward informed coherent policy options and actions for governments to adopt and implement in synergistic partnership of other concerned sectors, departments and stakeholders. Agriculture should lead integrated policy and planning, linking micro-planning with macro-planning between line ministries and the private sector. This will allow the definition of appropriate policy objectives within the agricultural sector, based on negotiated strategic actions, including legal structures and resource allocation.

2.2 Existing Research Priorities in Agriculture and Food

Through various exercises, starting from 1996, APAARI has identified regional and sub-regional priority research areas (Ghodake, 2006), as listed below:

Asia-Pacific

- Integrated natural resource management (NRM), integrated pest management (IPM), integrated crop management (ICM) and agro-ecology, including policy issues;
- Germplasm collection, conservation and use of crop biodiversity;
- Identification of new sources of resistance to biotic and abiotic stresses for individual species/systems, and germplasm enhancement and augmentation through genetic improvement;
- Integrated crop production technologies, and agro-forestry and community forestry systems;
- Up-scaling the use of integrated pest, disease and crop management;
- Improvement of high value, low volume and low weight locally produced horticultural, food and medicinal plants and of commodity value chains in hills/mountains;
- Value addition to and profitability, food safety and quality of agriculture, fisheries and forest products through processing and other means;
- Monitoring and socio-economic impact assessment of technology transfer/adoption;

- Markets, marketing systems and enterprise development in both domestic and international markets; and
- Information, communication technology, knowledge management and exchange; and development of new information and communication tools/techniques.

South Asia
- Management of soil degradation in irrigated ecosystems;
- Assessment of watershed as functional unit in hills and mountains, and harvesting of surface runoff on a watershed basis in rainfed/arid ecosystems;
- Improvement (breeding) of commercially important and under-utilized crops; and
- Alternative livelihood opportunities and safetynet mechanisms in rainfed/arid ecosystems.

Southeast Asia
- Conservation and use of animal biodiversity;
- Supply chain analysis (improving market access); and
- Entrepreneurial development of farmers and fisher-folk.

The Pacific
- Atoll resources management;
- Crop management and organic production system; and
- Pest and disease surveillance, monitoring and border control.

Regional research priorities embedded in development programmes were also identified, as below:

In short to medium terms
1. Integrated natural resources management and related policy issues for increased agricultural/systems productivity, quality, efficiency, profitability and sustainability;
2. Conservation, management and utilization of genetic resources/ agro-biodiversity (plants, fish, animal, micro-organisms, etc.) for evolving high performing varieties and breeds;
3. Value addition through post-harvest management and processing; markets and marketing and enterprise development; and linking farmers to markets (commodity and value chains) including related policy issues with respect to agriculture, fisheries and forest products for increased income;
4. Socio-economics, policy, impact assessment, technology transfer, innovations and adaptation, including participatory approaches (farmers, youth, women, NGOs, the private sector);
5. Information communication technology, knowledge management and exchange, development of information, communication tools and techniques;
6. Production and use of bio-fuel from agriculture; and
7. Capacity building in R&D.

Anticipatory, in long term
1. Studying impact of climate changes, and evolving strategies to mitigate them to develop environmental sustainability; and

2. Risk assessment and management in agriculture arising from natural disasters and climatic variations.

SAARC Vision 2020, prepared in 2008, had identified country-specific agricultural research and development priorities, highlighting the need for accelerating agricultural output growth; strengthening agricultural research, education and extension system; supplying adequate quality seeds and other inputs; increasing production of foodgrains while promoting diversification; promoting sustainable use of natural resources; and addressing needs of smallholders through creating suitable jobs in non-agriculture sector. Other research areas and processes suggested were: contract farming; co-operative farming; adaptation to climate change through innovations in technology, institutions and policies; suitable policies to address energy crisis by developing strategies to harness potential of bio-energy crops and tree species and development of technologies for use of agricultural waste and surplus for generating energy; favourable food price policy, food safety and food standards; public-private sector partnership (PPP); intellectual property right (IPR) management, biosafety and biosecurity; rural infrastructure; and regional collaboration.

The thematic classification of national agricultural research as collected for the year 2002-03 by the ASTI survey is presented in Table 8 (Raitzer *et. al*, 2009). The major research themes identified were genetic improvement, pest and disease control, natural resources, and post-harvest technologies. Upon regrouping, share of crops, livestock and natural resources was 39, 14.1 and 16.3 percent, respectively. The thematic orientation of the research activity by the CGIAR (Table 9), however, did not agree with the one prepared by the national programmer although both gave prominence to genetic resources and natural resource management.

Table 8. Thematic focus of national agricultural research in Southeast Asia, 2002/2003

Thematic focus	Share (%)
Crop genetic improvement	14.6
Crop pest and disease control	9.8
Other crop	14.6
Livestock genetic improvement	4.4
Livestock pest and disease control	2.7
Other livestock	7.0
Soil	5.6
Water	4.5
Other natural resources	6.2
Post-harvest technologies	4.7
Other*	25.9
Total	100.0

Source: ASTI survey results (cited in Raitzer et al, 2009)

** This other category comprises forestry and fisheries research that is not included under the NRM and post-harvest research themes as well as unspecified research themes in general (such as socio-economic and market research, agricultural engineering, and farming systems).*

During the past few years, APAARI had identified the following themes for regional level discussions: AR4D (2001), Post-harvest processing and value addition (2004), Biotechnology (2005), Linking farmers to markets (2007), Bio-fuels (2007), Climate Change (2009a), and Bio-pesticides and bio-fertilizers (2009b).

Table 9. Thematic focus of the CGIAR activities targeting Southeast Asia, 2008

Thematic focus	Share (%)
Sustaining biodiversity	8.3
Genetic improvement	18.6
Diversification & high value commodities	13.7
Integrated NR management	28.6
Policies & institutional innovations	22.8
Other	8.0
Total	100

Source: ASTI survey results (cited in Raitzer et al, 2009)

In order to widen participation of various stakeholders in priority setting, APAARI, in collaboration with ANGOC and GFAR, organised an Asia-Pacific regional workshop on agricultural research for development in 2008 and established the NGO Association for Agricultural Research in Asia-Pacific (NAARAP) which noted the need for changes in the current nature of AR4D, towards one that is :

- Farmer-driven and in partnership with NGOs and Agri Research Systems (ARS) at national, regional and international levels;
- Directed at the needs of the poor/vulnerable small farm holders;
- Intimately linked to farmer-to-farmer learning;
- Focused on the most prominent (successful) farming system of each area and that facilitates replication of successful experiences by farmers of the area;
- Based on identification and promotion of agro-technologies that are environmentally benign and which can reverse the negative fallouts of conventional agriculture, re-empower farmers, and ensure quality and sustainable levels of yields;
- Based on agro-ecology as a scientific basis, with traditional knowledge as a starting point;
- Fully inclusive of women, indigenous peoples and other under-represented groups;
- Producing outputs that are not privatized and that remain in the public domain;
- Embedded in a larger context of policy development that emphasizes poverty reduction, especially in rural areas;
- Scaled up to bring large numbers of farmers back into the fold of low cost farming systems of the area, producing inputs on farm. This would require policy and developmental support from governments and multilateral institutions;
- Directed at nutrition, health and food security, especially in marginal/vulnerable environments where the poor live, and guided by concerns of national food sovereignty, right to nutrition, health, food and equity;

- Based on full and real participation of small farm holders and CSOs in priority-setting, agenda formulation, research collaboration, governance and decision-making in partnership with ARS; and
- Focused on issues of resource access for poor people, e.g., land, water, genetic resources.

2.3 Summaries of Recent Global Agricultural Development/ Agricultural Research Reviews

Agriculture for Development Report (The World Bank, 2008) provides detailed account of efforts made by countries towards agricultural development, including the role of science and technology innovations. In Asia, overcoming widespread poverty requires confronting widening rural-urban income inequalities, has emphasised the Report. Asia's fast growing economies remain home to two-third of world's people living in extreme poverty, and despite massive rural-urban migration, rural poverty will remain dominant for several more decades. For addressing this, generating rural jobs by diversifying into labour intensive, high value agriculture linked to a dynamic rural non-farm sector is important. With rising land and water scarcity and the added pressures of a globalizing world, the future of Asian agriculture is intrinsically tied to better stewardship of natural resources. The World Bank Report underlines that with the right incentives and investment, agriculture can be made environmentally friendly. Rapidly expanding domestic and global markets, institutional innovations in markets, finance, and collective action and revolutions in biotechnology, information technology, and nano-technology all offer exciting opportunities to be used in agriculture for development. But, seizing these opportunities requires the political will and reforms in governance in agriculture. The role of the international community is to level the playing field in international trade, provide technologies for food staples, help developing countries address climate change, and overcome looming health pandemics for plants, animals and humans. The governments and donors have to reverse years of policy neglect and remedy underinvestment/ misinvestment in agriculture. The assets of the poor households (land, water and human capital) have to be increased to make small holder's agriculture more productive and create more job and income opportunities in the rural non-farm economy.

It is estimated that to meet the projected food demand in Asia-Pacific, cereal production will have to increase by nearly 50 percent and meat production by 85% from 2000 to 2030. To make small farmers agriculture productive, the TFP growth rate in South Asia will need to be increased from current level of 1 percent to 2.1 percent. In addition, throughout the region, improving price incentives and increasing the quality and quantity of public investment, making product markets work better, improving access to financial services and reducing exposure to uninsured risks, enhancing the performance of producer organizations, promoting innovation through science and technology and making agriculture more sustainable and a provider of environmental services become important.

To create a dynamic rural economy and upgrade skills to participate in it requires rapidly growing agriculture and a good investment climate, linking the local economy to broader markets by reducing transaction costs, investing in infrastructure and providing business services and market intelligence, education, skills and entrepreneurship. Providing safety nets and social assistance to the chronic and transitory poor can increase both efficiency and welfare. Agriculture-for-development agenda includes managing the political economy of agricultural policies to overcome policy biases, underinvestment and misinvestment and strengthening governance for the implementation of agricultural policies which gets low scores. The quality of implementation is critical and has to be improved enormously. Often, as in India, because of the reducing weight of agriculture in national economies, the investment needs of agriculture sector are generally ignored, despite the continuing dependence of majority of the people on agriculture for their livelihoods.

In the document, "Transforming the Rural Asian Economy: The Unfinished Revolution", Rosegrant & Hazell (2000), have examined the efforts made by Asian countries to transform rural economies and suggested road map for accelerating the transformation. They observed that both Asia and the world should be able to meet projected food demand at least in the aggregate. There should be steady progress by governments and the international community in devising and carrying out policies which should include investment in agricultural research, extension, irrigation and water development, human capital and rural infrastructure. Besides, continued efforts towards market orientation and involvement of private sector, governance – transparency, responsiveness and eradication of corruption, are keys to sustained growth. Governments have to increase the level of productive investment made in rural infrastructure, agricultural research and extension, education and health as well as expand the reach of the social safetynet programmes. They further observed that while conditions are not there, widespread poverty and malnutrition still co-exist with great wealth, and underpinned "completion of the rural revolution, radical reduction in poverty and improvement in food security in Asia hang in the balance" and they are attainable, if complacency is resisted.

CGIAR had used congruence analysis with an optimum budget allocation derived from allocation of a normative formula embodying a number of criteria meant to achieve CGIAR objectives. Optimum resource allocation was established across commodities, sectors and regions for 19 crops plus livestock, forestry and fisheries and 5 geographical regions. Optimum budget allocations were determined on the basis of (a) the share of the activity and region in the total value of output (VOP) and (b) modifiers to these shares to account for considerations of poverty, participation of women, new scientific opportunities, alternative sources of research and probability of success. But, overtime this approach has become increasingly incomplete owing to the growing diversities of activities of CGIAR such as basic science, natural resource management (NRM), socio-economics and policy, research management, training etc. Clearly, budget allocation based on production value does not work well when priorities increasingly address issues that do not involve production of goods and services valued in the market place.

The CGIAR's Science Council (CGIAR, 2003) had listed 10 systems priorities with the intention of developing a more cohesive and better focused research programme. These were: (i) Conservation and characterization of genetic resources, (ii) Genetic improvement of specific traits, (iii) Improved water management and use in agriculture, (iv) Better management and use of forests and forest landscapes, (v) Better soil and land management and use, (vi) Improved production and processing systems for high value commodities, (vii) Enhancing resource efficient and equitable forms of livestock sector growth, (viii) Improved management and use of aquatic resources, (ix) Policy and institutional innovation to reduce poverty and hunger and to enhance competitiveness of smallholders, and (x) Strengthening national and regional capacities for agricultural research and rural institutions.

The approach followed for the 2003 prioritization and strategy (P&S) exercise complemented the traditional congruence analysis with a broad consultation on priorities with stakeholders and scientists. This consultation finally suggested CGIAR research resources allocation of 30% to germplasm and genetic improvement, 30% to sustainable systems and NRM and 40% to policy and institutions. Emphasising the need for reorienting research agenda for development, now CGIAR is particularly focusing on the needs, demands and realities of the poor. One of the steps towards this was organizing five regional panels stakeholders consultations in phases. Some results of the Asia Panel include enhancing germplasm through conventional approaches and biotechnology (20%), sustainable production systems (16%), strengthening of NARS and other rural institutions (12%), germplasm collection and conservation (8%) and improving policies (7%). The top priority of the Asia Panel was to operationalise an explicit poverty focus for the CGIAR which should look for research priorities that may bear simultaneously on several dimensions of poverty, thus, requiring to look at rural development as a whole instead of only agricultural development. This is a major redirection of the CGIARs traditional research focus that should guide priority setting.

The other thrust areas identified by the Asian Panel were productivity enhancement, NRM, risk management, sustainability, competitiveness and institutional sustainability of innovation systems. It suggested that novel international mechanisms should be developed for engaging the stronger NARIs in such works.

The global panel recommendations include conservation and utilization of knowledge (16%), raising the productivity and resilience of farming systems (15.5%), germplasm improvement through biotechnology and traditional methods (14.5%), developing research priority setting methods, maintaining and improving the efficiency of natural resources (11.5%), enhancing knowledge management and the capacity of NARS (9.5%), and projecting the impact of resource and climate change on agro-ecosystems and wild resource systems over the next 25 years. Thus the stakeholders consultation demanded research on improvement of germplasm, work on collection and maintenance of genetic resources, research on improving the efficiency, resilience and sustainability of small holder farming systems and more research on policies, institutions and markets.

The discussion on the recommendations of the global panel suggested that the CGIAR should assess its readiness and ability to adopt a pro-poor agenda as its main objective, restructuring the CGIAR into three areas, (a) strategic research (b) methodology development and (c) capacity building as follows: Germplasm (40%), Resources (40%) and Policy (20%). The Asian priorities recommended by the panel are annexed (Annexure VI) The panel had felt that the CGIAR has a key role to play in achievements of the ambitious MDGs. The panel considered poverty, productivity, sustainability, institutional strengthening, and international competitiveness as priority themes.

The draft Strategy and Results Framework (CGIAR, 2009) for the overall CGIAR system builds on the three objectives of the system, namely:

1. Create and accelerate sustainable increases in the productivity and production of healthy food by and for the poor. ("Food for People");
2. Conserve, enhance, and sustainably use natural resources and biodiversity to improve the livelihoods of the poor in response to climate change and other factors. ("Environment for People"); and
3. Promote policy and institutional change that will stimulate agricultural growth and equity to benefit the poor, especially rural women and other disadvantaged groups. ("Policy for People").

The SRF suggests the following indicators at the system level:

a) Lift annual agricultural productivity by an additional 0.5 percentage point to meet the food needs of a future world population and to help to reduce poverty by 15 percent by 2020;
b) Contribute to reduction of hunger and improved nutrition in line with Millennium Development Goal 1 (MDG 1) targets, cutting in half by 2015 the number of rural poor who are undernourished, with a focus on child undernutrition; and
c) Deliver these outcomes in more sustainable ways by using less water (through greater water productivity), halting or reducing the rate of further deforestation and soil degradation (through improved land management practices) and contributing to climate change mitigation and adaptation.

The building blocks of the SRF are a set of 7 interlinked mega-programmes (MPs) and two platforms, gender and capacity-strengthening, that serves cross-cutting purposes for all seven MPs. The MPs include (i) crop germplasm conservation, enhancement and use, (ii) diets, agriculture, nutrition and health, (iii) institutional innovations, ICTs and markets, (iv) climate change and agriculture, (v) agricultural systems for the poor and vulnerable, (vi) water, soils and ecosystems, and (vii) forests and biomass. To deliver these, CGIAR would aim at US$ 1.4 billion, about tripling its current size.

While the CGIAR system is formulating its SRF, its individual International Agricultural Research Centers (IARCs) are refining their priorities and seeking necessary additional funding support to implement their research agendas. For instance, the International Rice Research Institute (IRRI) has recently (2008) prepared a plan entitled "Responding to the Rice Crisis", and come-up with a nine-point programme:

1. Bring about an agronomic revolution in Asian rice production to reduce existing yield gaps;
2. Accelerate the delivery of new post-harvest technologies to reduce losses;
3. Accelerate the introduction and adoption of higher-yielding rice varieties and hybrids with broader adaptation to biotic and abiotic stresses;
4. Strengthen and upgrade the rice breeding and research pipelines;
5. Accelerate research on the world's thousands of rice varieties so scientists can use efficiently the vast reservoir of untapped genetic knowledge they harbor;
6. Develop a new generation of rice scientists and researchers for the public and private sector;
7. Increase public investment in agricultural infrastructure;

8. Reform policy to improve the efficiency of marketing systems for both inputs and outputs; and
9. Strengthen the food safetynet for the poor.

As regards the Pacific countries, the SPC works with many donor and collaborating partners to allocate resources to the member countries and to specific programmes. For instance, GTZ, Taiwan/Republic of China, ACIAR, CTA, FAO, Republic of Korea, IFAD, University of the South Pacific, ADAP, Biosecurity Australia, AQIS, CABI, Australia DAFF, Queensland DPI, NZ Ministry of Agriculture, NZ Pacific Security Fund, Land care NZ, SPREP, USDA, Conservation International, The Nature Conservancy and World Organisation for Animal Health (Quartermain, 2009).

Major recent or continuing donors in the Pacific have been Australia through AusAID and ACIAR, New Zealand through NZAID, FAO, EU, France to its own territories and the United States to American Micronesia. CTA has also been active in training and awareness raising with respect to farmer innovation, innovation systems and most recently tertiary education in ACP (Africa-Caribbean-Pacific) countries.

The Australian Centre for International Agricultural Research (ACIAR) provides 20.4% of total funding going to the Pacific with 9.9% to PNG alone. The PNG portfolio has five sub-programs as follows (with number of current projects in parentheses):

1. Addressing social, cultural and policy constraints to the adoption of agricultural technologies (5);
2. Enhancement of smallholder incomes from horticulture and root crops (7);
3. Improving smallholder returns from export tree crop production and marketing (2 cocoa and oil palm; 2 coffee);
4. New livelihoods from smallholder fisheries, aquaculture and forestry (5 fisheries; 8 forestry); and
5. Agricultural biosecurity and sustainable management of forestry and fisheries resources (13).

The Pacific Island portfolio has three sub-programs:

1. Improving food and nutritional security (15);
2. Integrated and sustainable agriculture, fisheries and forestry resource management and development (6 fisheries; 5 forestry); and
3. Improved bio-security and increased trade in agriculture, fisheries and forestry products (4).

2.4 Coherence and Gaps in Current and Projected Research Priorities, and New Needs

2.4.1 Gaps in Current Research Priorities

The following key feedbacks were received through the E and F2F Consultations:

- Needs of the resource-poor smallholders not well addressed (except generally in case of rice) by the AR4D agenda in the past;

- Inability of majority of resource-poor farmers to adopt high-input-cost and high-risk technologies, and this fact not internalized in the past research agendas;
- Underinvestment in Agriculture & AR4D, particularly in horticulture, livestock and fisheries, rainfed areas, socio-economic and NRM research, maintenance research and human capital formation;
- Climate change adaptation, uncertainty and vulnerability, scarcity and declining quality of water, declining soil fertility, agro-biodiversity erosion, increasing biotic stresses, increasing threats of bio-insecurity, market volatility and income divides are frontline issues, but have so far not received due attention; and
- Besides fighting stubbornly high hunger and poverty, synergizing productivity, sustainability and inclusiveness, closing technology transfer gaps at various levels, and strengthening linkage of farmers with markets and value chain were identified as other key gaps and should be main drivers for AR4D.

The prevalent research and technology development processes are generally mono-disciplinary, dominated by researchers themselves, non-participatory, fragmented and poorly coordinated, hence the innovation gaps. There is serious gap in investment and availability of critical mass of human resources (especially in the Pacific island countries). Other gaps include, the lack of prioritization of the drivers and challenges and inability to translate them into action research. A long term vision and strategic designing of research agenda, internalizing the following aspects, is thus needed.

2.4.2 Projected AR4D Priorities: South Asia

Based on the sources of literature review, analysis of evidences, the E Consultation and the F2F Consultation, the following priority research needs were identified by the South Asian Group (Mruthyunjaya and Kumar, 2009):

1. Commodity-based:
    - Rice;
    - Wheat;
    - Local staple cereals;
    - Pulses;
    - Livestock;
    - Horticulture (Fruit and Vegetables); and
    - Fisheries.
2. Overarching research areas:
    - Climate change management;
    - Natural Resource Management (NRM);
    - Integrated Farming System;
    - Socio-economics, policy and value chain management;
    - Germplasm conservation and improvement;

- Post-harvest management, agro-processing and value addition;
- Quality improvement and safety; and
- Rural non-farm employment and income generation.

The Group had also suggested complementary approaches and policies (reflected in the regional scenario) and specifically suggested three to four times increase in funding support to agricultural research, extension and education in South Asia from US$1.6 billion in 2002 to US$4.6 billion in 2020 (at current price) towards attaining food and nutritional security, poverty alleviation and social empowerment. It had observed that prioritization exercises need to explicitly target poor as otherwise their needs are under-funded.

2.4.3 Projected AR4D priorities: Southeast Asia

The Southeast Asian sub-regional study (Raitzer, et. al., 2009) quantified expected and historical levels of benefits for the poor and the environment from different areas of research and contrasted relative expected impact potential with current relative allocations across research areas. The analysis found key gaps between current investments and expected impacts for productivity enhancing research on rice, vegetables, fruit and aquaculture, with the rice gap the most pronounced. The following were identified as priority research needs for Southeast Asia:

1. In terms of target agricultural products, productivity enhancing research for:
    - Rice;
    - Vegetables;
    - Fruit; and
    - Aquaculture.

2. In terms of research activities:
    - Crop genetic enhancement; and
    - Post-harvest processing, particularly for quality.

As an additional issue raised in the consultations and review of changes in the context for agricultural research, integration among disciplines in research organization and conduct was identified as important to the effectiveness of future research efforts.

2.4.4 Projected AR4D Priorities: The Pacific

Over 80 percent of the island populations are directly dependent on the sustainable use of renewable natural resources for sustenance, health and prosperity. Although the 22 island countries differ widely in ecology, demography, economy and culture, the development emphasis in all the countries is on combating hunger, malnutrition, poverty and environmental degradation.

The Pacific sub-region had highlighted (Quartermain, 2009) the following challenges: (i) small population and economies, (ii) inappropriate policies and weak institutional capacity in both public and private sector, (iii) remoteness from and low competitiveness in international markets – high costs of transportation and labour, (iv) susceptibility to natural disasters and climate change, (v) fragility of land and marine ecosystems, (vi) limited fertile soil and fresh water supply, (vii) high import dependency, (viii) non-adoption of technologies from research, (ix) vulnerability to exogenous shocks, and (x) special problems of atolls.

The continuing research priorities were crop production and improvement, livestock, forestry, fisheries, natural resource management, biosecurity and income growth. In addition, the following priorities were identified for greater attention:

- Value-adding (inclusive) for niche markets (domestic and export) to be considered within a value chain approach, and alleviation of non-communicable diseases (NCDs);
- Crop improvement, especially horticultural crops to support value-adding and climate change readiness and also for nutritional security;
- Climate change management through mitigation and adaptation (modeling sadly lacking);
- Community-based systems for managing all natural resources, integrated farming system, forest retention, coastal or reef fisheries, including stocks assessment;
- Bio-security and trade facilitation – market access and farmer-market linkage; and
- Sustaining livelihoods in atolls.

Supportive policy actions and approaches were also suggested and have been internalized in the regional scenario (Annexure X).

2.4.5 Pressing Needs and New Challenges in the Asia-Pacific as a Whole

The following continuing and new and emerging challenges deserve high attention:

- *Continuing Challenges*
    - Limited resource base, particularly land (cultivates only 38% of global arable land) and water (scarce both in terms of quantity and quality);
    - Fast declining water and agro-biodiversity resources with environmental footprint of agriculture intensifying;
    - Majority of producers are small and marginal farmers who cultivate on the average about 0.3 ha per person (versus average of 1.4 ha per person with the rest of the world);
    - There are fairly good number of NARES, despite dwindling resources received, and there are emerging NARES in India and China that can and have started playing lead roles in the region; and

  - Continuing challenges that need to be addressed head on are: (i) more than 60% of hungry and extremely poor are in Asia and Pacific, (ii) the undernourished in the region is the highest globally and is still rising, and (iiii) the number of poor is highest and rising too in South Asia.

- *New Challenges*
  - Food and nutritional insecurity;
  - Global economic downturn and market volatility;
  - Climate change with projected intense and more frequent extreme weather resulting in increased risks, bio-insecurity and vulnerability; and
  - Competing land use: Food versus Fuel versus Feed.

2.4.6 Priority Criteria for AR4D in Asia-Pacific Based on the Feedback from the E and F2F Consultations:

- Focus on development needs of the resource-poor smallholder farmers;
- Synergize productivity, sustainability and inclusiveness (pro-poor and gender inclusive): these in turn are the drivers for sustained structural transformation and industrialization;
- Promote demand-driven and market-based AR4D; AR4D should ensure that it particularly addresses the food and agri- and food and nutrition-based needs of the poor and especially the extremely poor (hungry) consumers, women and children; AR4D should aim for Food and Nutritional Security
- Multi-stakeholder led AR4D; need for ownership of those who will directly contribute to the value chain; and
- Maximize use of partnerships for science, technology/innovations, ICT; as well as ensure wide outreach among smallholders.

2.4.7 Thematic Research Priorities for Asia-Pacific

With the above backdrop and keeping in view the sub-regional priorities, the thematic research priorities for the Asia-Pacific region are listed below:

- Sustained productivity enhancement particularly in food staples and those that will diversify incomes at the farm sector, with special reference to smallholder farmers, and yield improvement through use of science and technology;
- Improve value chain development and management, weakest links in the chain are infrastructure that link farmers to markets and should be strengthened, market outreach should be augmented through building networks and partnerships;
- Increase resilience in two major areas: climate change, and those resulting from economic shocks;
- The above AR4D agenda has spatial dimensions:

	South Asia	Southeast Asia	Pacific
Sustained and Increased Productivity			
Food Staples	Rice, wheat, local staple cereals, pulses	Rice	Local roots and tubers, bananas, sago and nuts
Diversified crops/livestock	Horticulture, fisheries, livestock	Vegetable, fruit, aquaculture	That ensure inclusive value adding for niche markets: Vegetables, fruits, fisheries and livestock
Integrated farming system research	Cereals-pulses-horticulture-agroforestry-livestock-aquaculture integrated farming	-	Root crops-livestock-fisheries integrated farming
Through science and technology	Germplasm conservation & improvement	Genetic improvement utilizing the potentials of genomics and bioinformatics	For nutritional security, value-adding Sustaining atoll livelihoods
Improved Value Chain Development (Weak links in the chain)			
Infrastructure: farmer-market links	Post-harvest, agro-processing, management ICT Safety & Quality	Post-harvest, particularly for quality	Post-harvest Transport ICT Safety & Quality
Markets & networks/partnerships	Public-private-partnerships (PPPs) South-south cooperation	–	Niche markets (domestic, foreign) Trade facilitation
Increased Resilience			
Climate change management	Adaptation & mitigation	Averted agricultural expansion through productivity improvement; germplasm adaptation	Adaptation & mitigation Need for increased capacity on modeling/forecasting
Economic Shocks	Rural & non-farm jobs Risk management	Food affordability/ agricultural productivity	Special concerns of atolls

- The other priority research agendas are:
  - Integrated farm and natural resources (land, water, livestock, agro-biodiversity) management and enhanced sustainability, including those of homesteads/farmsteads, special focus needed on land degradation and water erosion and scarcity;
  - Innovative institutional and financing arrangements for revitalizing innovation sharing and extension systems to enhance access of research outcomes by small and resource poor farmers, and that strengthen NARS in frontier areas of agriculture science and links with extension services; and
  - Those that will stimulate or spin-off to off-farm and non-farm employments.

For all AR4D: cross-cutting themes are good governance and gender sensitivity.

The main themes in the Asia-Pacific context have been elaborated below:

2.4.7.1 Focus on the Agricultural System of the Resource-poor Farmer

As the Asia-Pacific region accounts for over 80 percent of the world's smallholders, research technology and innovation systems should be focused on the needs and opportunities of these majority deprived people, which is not the case so far (Singh, *et.al.*, 2002). They should be linked with the entire production-consumption chain coupled with an enabling policy and institutional framework. The TFP of the small farms in South Asia should also be enhanced as done in East Asia, especially China as also at large farms in Latin America (Table 10). At production level, accelerated sustainable use of genetic resources, seed systems that cater to the needs of smallholders, eco-system management approach to crop, livestock and fisheries production, including conservation agriculture and integrated pest management will be needed. Even the known and proven technologies for smallholder systems have a weaker uptake, emphasising the need to strengthen the policies to facilitate access to goods, services and markets for bridging the uptake gap.

Table 10. Annual total factor productivity growth, 1992-2003

	%
East Asia	2.7
South Asia	1.0
East Africa	0.4
West Africa	1.6
Southern Africa	1.3
Latin America	2.7
North Africa & West Asia	1.4
All regions	2.1

Source: von Braun et. al, 2008

Generally, research agendas have not sufficiently addressed the needs of the small farmers. The inability of small resource-poor farmers to access knowledge, technologies and afford costly inputs as well as to take risks associated with new technologies has not been internalized adequately in respective research agendas. Often the agendas do not accommodate the views of farmers, priorities of states, status of input supply chains, market forces and edaphic factors. Care should also be taken of the change over from subsistence farming to commercial agriculture. Inadequate attention has been paid to horticulture, livestock and fisheries sub-sectors that are globally growing rapidly and have a lot of potential to reduce poverty, hunger and undernutrition/malnutrition through production and marketing of high value products and to enable economic empowerment.

Intensified research on rice, wheat and maize - the Green Revolution crops must continue as these are the foundation of food security and livelihoods (Chand, 2009a). In doing so, the pitfalls of the Green Revolution adversely affecting natural resources, such as loss of biodiversity, environmental pollution, land and water degradation and enhanced pestilence, often due to inappropriate/injudicious use of technology, should be avoided. The total factor productivity (TFP) growth rate in farming has continuously declined and the on-farm input-output ratio has become increasingly unfavourable for maintaining profitability and sustainability of farms, particularly of smallholders.

Within the Asia-Pacific food-production and rural-livelihoods-support systems, the *rice-based systems* have immense importance (Barker and Dawe, 2002). The Asia-Pacific region produces and consumes 90 percent of the world rice. They extend to an annual rice-harvest area of no less than 137 million hectares; they are tended by over 300 million persons, and support over 3 billion rice consumers: one-half of the world's population. For most of those 3 billion consumers, rice supplies one-third or more of the dietary energy and protein; for 0.3 billion of them: two-thirds or more. Indeed, within the major rice-growing countries, and in dietary terms, as in social, economic, and ecological terms, rice is dominant. Productivity enhancing research on rice is exceptionally pro poor. In the case of Southeast Asia nearly half of forecasted future agricultural research benefits to poor producers and consumers accrue via this crop, compared with the other top agricultural products (Raitzer et al, 2009).

In fisheries, other than tuna, most past efforts have not been as successful or had limited impact due to the lack of personnel, commitment and social obligations. The fishers, like the pastorals, are generally excluded from the development streams. Commercial operations at government or village community level have been unsuccessful and there is need to work with the private sector to access global markets. Successes with giant clams, the aquarium trade and seaweed have so far been short-term. There needs to be an enabling environment for public-private partnerships in fisheries development.

2.4.7.2 Forging Coherence among Productivity, Sustainability and Biosecurity

Efforts must be made to synergise productivity enhancement, sustainability and biosecurity. The gaps are both in the desired priority of a given research area as well as in the process of technology development, transfer and adoption. Often the main drivers and challenges are not congrued into formulating research agendas for development. For instance, research priorities of both NARS and international systems in Asia-Pacific should be highly focused on alleviation of poverty, fighting hunger, accelerating productivity and enhancing income of smallholders. But, this has generally not happened. Gaps have arisen also due to social dynamics. Researchers have generally concentrated on productivity and intensification and given little consideration to sustainability issues in their research designs and agendas. The congruence of economic viability, practical feasibility and social acceptability of packages of technologies has often not been kept in mind, hence gaps in programmes and outcomes of research and technology activities. In this context, the South Asian Association for Regional Cooperation (SAARC) in collaboration with FAO (particularly the Regional Office for Asia and the Pacific) and ADB, through an exercise during 2007-08, had prioritized strategies, programmes and projects to coherently address productivity, sustainability and profitability leading to comprehensive food security in the sub-region (Table 11), which could easily be adopted by NARS and supported by donors and national and international development agencies/banks.

Table 11. Priority strategies, programmes and projects for food security in South Asia

Issues / Concerns *(in order of priority)*	**Prioritized Regional Strategies for FS**	**Prioritized Regional Programmes for FS**	**Possible Project(s)**
1. Low and stagnating production and productivity	Increasing Food Production, including nutrition supplementation through food-based interventions	Increasing food production through technology development and sharing in agricultural production and marketing	(a) Enhancing productivity of small farmers in marginal and unfavorable areas/regions; (b) Enhancing and sustaining production and productivity in irrigated and other favourable areas;
2. High pre- and post-harvest losses; low value addition	Development and transfer of improved technology and institutional support	Improvement of pre- and post-harvest handling, processing and value chain development	Prevention of pre- and post-harvest losses, through appropriate interventions, and value chain development at farm level, including production of seeds, biofertilizers and biopesticides and distribution of suitable irrigation and farming tools and implements;
3. Over exploitation and degradation of resource base (land, water, bio-diversity)	Preservation of Ecology and Biodiversity	Integrated management and utilization of land, water and bio-diversity resources, especially through farming system approach	(a) Technical and policy support towards conservation and efficient use of land, water and bio-diversity resources; (b) Promoting rational/ balanced use of agricultural inputs (fertilizer, agro-chemicals);
4. Lack of / inadequate Bio-security measures (*including Bio-Safety, Food Safety*)	Promotion of Food Quality/Safety Standards	Control of Trans-boundary plant and fish diseases; Food safety and quality measures	(a) Development/Updating of national SPS Standards in line with CODEX; (b) Development/up-gradation of a mutually recognized SAARC Accredited Laboratory System; c) Institutionalization of a SAARC mechanism/network on control of Trans-Boundary Plant and Fish Diseases;
5. Inadequate human resource capacity in the areas of food safety, quality and standards; and trade	Development of Human Resource	Training, Education and Awareness on food safety, quality and standards; and trade	(a) Support/assistance in capacity-building in the areas of food safety, quality and standards; (b) Support/assistance in capacity-building in trade policy analysis and formulation *vis-à-vis* ensuring food security;

Source: SAARC/FAO-RAP, 2008

2.4.7.3 Managing Climate Change

Climate change has emerged as a key driver for agriculture. The Asia-Pacific region, especially South Asia, is predicted to suffer the most due to the climate change. The Intergovernmental Panel on Climate Change (IPCC, 2007) has projected 1.56 to 5.44º C rise in temperature by 2080 in South Asia, reducing yields of major crops at least by 20 percent if no effective adaptation measures are taken. The region is also prone to high frequency of meteorological disasters such as droughts, floods and cyclones severely impacting quantity and stability of food production. Entire biodiversity will be affected, including fish breeding, migration and harvests and reduced milk and overall livestock production. Adaptation strategies including improved livestock breeds and balanced feeding can help minimize negative impacts, needing greater research, innovation, policy and financial support. In most Asia-Pacific countries little research is being done on carbon sequestration and carbon market and economy. In general, research on climate adaptation and mitigation is lacking or inadequate in most countries (see section 4.2.6 for further details).

2.4.7.4 Balancing Bioenergy and Food Needs

The growing importance of biofuels is a major challenge (as well as an opportunity) for the sector. Biofuels, mainly ethanol from sugarcane and corn, and to a lesser extent bio-diesel from oil-seed crops, represent a modest 1.5 percent of transport fuel use worldwide. Many national policies have ambitiously set targets of 20 to 30 percent of total energy demand to be met from bio-energy. This has enormous implications for the natural resource base and the natural environment of those countries. FAO (2009c) recently reviewed the situation of biofuel strategies for the Mekong delta region and found that if petroleum prices remain high and more ethanol plants are built, demand for sugar and maize will increase, leading to higher prices of these as well as other crops, with global impact. A study has estimated that a 20 percent increase in food prices would increase the number of undernourished in Asia by 158 million people; thus, the impact of biofuels demand is worrisome indeed let alone the environmental costs. Other than Brazil, only a few other developing countries are likely to be efficient producers with current technologies. Policy decisions on biofuels need to devise regulations or certification systems to mitigate the potentially large environmental footprint of biofuels production. Increased public and private investment in research is important to develop more efficient and sustainable production processes based on feed-stocks other than food staples.

2.4.7.5 Soaring Food Prices and Food Security

In recent years the food security situation has worsened due to soaring food prices, global economic meltdown, energy crisis and climate change – all being particularly hard on the poor (von Braun, 2008; FAO, 2009b). The 2009 domestic staple food prices were about 15 to 25 percent higher in real terms than two years earlier, and the worst affected are the resource-poor – especially rural landless and female headed households. The volatile food prices and the uncertainties of agricultural markets have become major concerns as they threaten not only food security but also social and political stability. On the other hand, the smallholder farmer is not benefiting in his net income from the price hike. To address these issues, governments, donors, financial institutions and world and regional organizations must take urgent and bold measures to unlock agricultural potential and rapidly boost production and farmers' income in the most affected countries, in order to increase food supplies as well as to facilitate the access of impoverished and vulnerable population groups to food. Some governments have initiated special food security programmes combining accelerated production, public distribution systems combining various safetynets such as mid-day meals to school children and employment guarantee schemes. Such experiences should be shared among countries.

2.4.7.6 Bridging Gaps among Political Economy, Policy Options and Actions

There are serious gaps also in policies and processes. In most countries, existing national institutions on agricultural education and research are inadequate to address the multiple roles and functions of agriculture. Social, economic, political and legal knowledge is generally missing or highly sub-optimal. Most of the programmes and institutional systems are linearly organised while today there is need for non-linear models for forging horizontal linkages to address the multiple factors impacting agriculture-led development. Also there is gap between knowledge and innovation due to non-involvement of concerned stakeholders along the research-innovation pathway.

If agriculture is given its due attention and support from the top levels of government, bureaucracy and policy, then all else in terms of social development will follow as farmers become more prosperous. Governments of the sub-region must be led to acknowledge two truths – that their countries have real issues of food security and poverty and that support for agricultural development offers the only pathway out of this situation. But, due to upsurge in non-agriculture sectors (industry and services), agriculture sector is often kept on the back burner and the political economy is generally indifferent to agricultural economy.

Dynamic new markets, far-reaching technological and institutional innovations, and new roles for the state, the private sector, and civil society have emerged and these together characterize the new context for agriculture. The new agriculture is led by private entrepreneurs in extensive value chains linking producers to consumers to which could be added many entrepreneurial smallholders if duly supported by appropriate policies, institutions and investments. For those who are not able to capture economies of scale in production and marketing, labor-intensive commercial farming can be a better form of production, and efficient and fair labor markets are the key instrument to reducing rural poverty. The other stakeholders should support the change process. The private sector should drive the organization of value chains that bring the market to smallholders and commercial farms. The state – through enhanced capacity and new forms of governance – should correct market failures, regulate competition, and engage strategically in public-private partnerships to promote competitiveness in the agribusiness sector and support the greater inclusion of smallholders and rural workers. In this emerging vision, agriculture assumes a prominent role in the development agenda.

The principal task over the next 20 years is to consolidate and extend the gains of Green Revolution years while meeting new challenges. The most pressing of these challenges are crop-soil-water imbalances, conservation and improvement of natural and other production resources and efficient use of energy while pursuing intensification, accelerating productivity growth, meeting the strong growth in demand for animal, horticultural, and other high-value commodities by diversification strategies, improving and harnessing the potential of rainfed and other unfavourable regimes (where many of the poor live, and which have been neglected in the past) and by meeting the opportunities and costs of globalization and of biotechnological and informatics revolutions (keeping in mind the welfare and livelihood security of the hungry and poor).

Policies for meeting these challenges will function and evolve within a number of dynamic technological, socio-economic and institutional constraints and settings. In brief, science will be required to play, as in the past, the central role in alleviating hunger and poverty in a sustainable manner. It will be called upon to benefit the poor more than in the past, and to enable much faster growth than in recent years, and to improve the environment. It must also improve productivity, profitability, competitiveness, and rural incomes, and increase the accessibility of the poor to adequate quantities of safe, good-quality food for a nutritionally adequate diet. However, science can meet its promises only when there is synergy among political economy, policies and action programmes.

2.4.7.7 Meeting Other Unmet or Partially-met Challenges

Most South and Southeast Asian countries, including China, have been updating their research agendas to deal with the continuing as well as with new and emerging challenges. However, the main challenges facing food, agriculture and rural development, namely, the large and increasing number of undernourished and poor in the region, the rising inequality and problems of access to food and livelihoods by the most vulnerable population, and the increased scarcity of natural resources exacerbated by climate change and diversion of food lands for bio-fuel production and other non-agricultural uses are not being addressed adequately. Other important inadequately addressed or neglected concerns include: challenges associated with the climate change, unlevelled playing field in international trade, barriers to market access and distorting domestic provisions, food safety and biosecurity issues including transboudary pests and diseases, stagnating productivity, increasing pressure on natural resources, such as, land, water, forests, aquatic resources and biodiversity, and continuing gender and social inequalities in access to productive resources and services. Agricultural research and technology generation and transfer must be tuned to meet the challenges by addressing nutrition, health and environment problems coupled with the rapid spread of affordable information and communication technologies, supporting pan Asia-Pacific sharing of information and knowledge, and increasing smallholder market access and know how.

3. CURRENT IMPLEMENTATION MECHANISMS

3.1 Institutional and Infrastructural Arrangements

The national agricultural research systems (NARS) in the Asia-Pacific region are dynamically heterogeneous and evolving. The four sub-regional reports, South Asia, Southeast Asia, China and the Pacific, give respective country-wise and sub-region-wise details. Upfront, it is important to emphasise that new technologies are becoming increasingly complex, knowledge-intensive and location-specific compared with those developed during the Green Revolution, thus necessitating more decentralized research and extension systems (Rosegrant and Hazell, 2000) and increased and well targeted investments in public and private agricultural R&D. Sustainable support for agricultural R&D, both financially and politically, is therefore crucial if important and emerging challenges are to be addressed (Hazell and Haddad, 2001; Ryan, 2002).

3.1.1 Agricultural Research Institutional Development

As analysed jointly by IFPRI, APAARI and ASTI (Beintema and Stads, 2008a and 2008b), since the 1960s, many Asian countries have been consolidating and reshaping their agricultural research operations and systems. In Bangladesh, India, Pakistan, and the Philippines (and more recently in Nepal, Sri Lanka, and Taiwan), this involved the establishment of an agricultural research council, which became responsible for the management and financing of agricultural research. Some councils also manage the operations of the agricultural research entities. In other countries, such as Indonesia, Malaysia, Papua New Guinea, and South Korea, all government agricultural research operations were merged to create a single national agricultural research institute, often with considerable operational autonomy. China's agricultural research infrastructure developed considerably during the 1950s and early 1960s, but faltered during the Cultural Revolution from 1966 to 1976. After 1979, many of the former research agencies in China were, however, revived and relocated back to the cities.

In most of the smaller countries, agricultural research is undertaken by a few government agencies and faculties of universities. In Nepal, local initiatives for Biodiversity Research and Development (LIBIRD), a non-profit institution, makes useful contribution. Likewise, in the Papua New Guinea, Cocoa and Coconut Research Institute (CCRI), Oil Palm Research Association (OPRA) and Coffee Research Institute (CRI), respectively, constitute 17, 12 and 7 percent of the fte (full time equivalent) of the public sector research staff. In the large countries like China, India, and the Philippines the systems are extremely complex (Table 12).

The Chinese agricultural research system involves a number of ministries and is highly decentralized. Agricultural research at the national level is primarily conducted by the Ministry of Agriculture's Chinese Academy of Agricultural Sciences (CAAS), Chinese Academy of Fishery Science and Chinese Academy of Forestry, along with their associated institutes. At the provincial level, agricultural research is carried out at academies and related government-sponsored agricultural research institutes, focusing on local issues and conditions. The agricultural research, extension, and education in China are undertaken by separate institutions (Fan, Qian, and Zhang, 2006), which often results in duplication and poor coordination.

Table 12. Institutional structure of agricultural research in 11 sample countries, 2002/03

Country	Main government agencies	Main universities
Bangladesh	10 institutes under the Bangladesh Agricultural Research Council (BARC) (74%); 2 institutes and 2 laboratories under the Ministry of Science, Information, and Communication Technology (9%)	Bangladesh Agricultural University (BAU) (17%)
India	93 institutes under the Indian Council for Agricultural Research (ICAR) (37%)	38 State Agricultural Universities (SAUs) (54%)
Nepal	Nepal Agricultural Research Council (NARC) (77%)	2 agencies under Tribhuvan University (14%)
Pakistan	Federal level: National Agricultural Research Center (NARC) (14%); 15 institutes and units under the Pakistan Agricultural Research Council (PARC) (7%) Punjab province: Ayub Agricultural Research Institute (AARI) (22%); 5 institutes and units under Livestock and Dairy Development Department (7%)	University of Agriculture, Faisalabad (3%)
Sri Lanka	8 institutes under the Ministry of Agriculture, Livestock, Land, and Irrigation (38%); 4 institutes under the Ministry of Plantation Industries (40%)	Faculty of Agriculture under the University of Peradeniya (5%)
Indonesia	9 institutes and centers under the Indonesian Agency for Agricultural Research and Development (IAARD) (49%); Indonesian Forest Research and Development Agency (FORDA) (11%); Indonesian Research Institute for Estate Crops (IRIEC) (5%)	Bogor Agricultural University (10%); 5 faculties under Udayana University (4%)
Laos	National Agriculture and Forestry Research Institute (NAFRI) (85%)	2 faculties under the National University of Laos (15%)
Malaysia	Malaysian Agricultural Research and Development Institute (MARDI) (37%); Malaysian Palm Oil Board (MPOB) (17%); Forest Research Institute Malaysia (FRIM) (12%); Fisheries Research Institute (FRI) (5%)	4 faculties under University Putra Malaysia (UPM) (7%)
The Philippines	14 Integrated Agricultural Research Centers (IARC) of the Department of Agriculture (15%); Philippine Rice Research Institute (PhilRice) (11%); 14 Ecosystems Research and Development Services (ERDS) of the Department of Environmental and Natural Resources (DENR) (5%)	26 units under the University of the Philippines, Los Baños (UPLB) (8%)
Vietnam	28 institutes and centers under Ministry of Agriculture and Rural Development (MARD) (71%); 4 institutes under the Ministry of Fisheries (7%)	Hanoi Agricultural University (4%); Water Resources University (4%); Agro-Forest University in Ho Chi Minh City (3%)
Papua New Guinea	National Agricultural Research Institute (NARI) (34%); Papua New Guinea Forestry Research Institute (PNGFRI) (26%)	2 departments under the PNG University of Technology (4%)

Note : The information is based on an ASTI survey; the figures in parenthesis represent proportion full time equivalent of the staff employed.
Source: Beintema and Stads, 2008a,b

The Philippine Council for Agriculture, Forestry and Natural Resources Research and Development (PCARRD) is the central coordinating body of agricultural R&D activities in the Philippines. It supports and manages the operations of a national network of government and higher education agencies involved in crop, livestock, forestry, fishery, soil and water, mineral resources, and socioeconomic research. PCARRD provides support to 132 implementing agencies, as well as to 14 regional consortia scattered across the archipelago.

In PNG, funding in 2002/03 was dominated almost equally by government and other sources (commodity levies) with only small amounts from donors and own income. Private sector expenditure was 8.7% of the total public + private expenditure. The Secretariat of the Pacific Community is the critical agency in coordination and support for assisting the Pacific community to improve food, nutritional and income security and manage agricultural and forest, marine and human resources in a productive yet sustainable way. The collective mission of its Land Resources, Marine Resources and Social Resources Divisions is "to help Pacific Island people position themselves to respond effectively to the challenges they face and make informed decisions about their future and the future they wish to leave for the generations that follow." Work programs developed through extensive consultation cover technical assistance, professional, scientific and research support, and planning and management capability building. The Land Resources Division has three key objectives in its current Strategic Plan 2009-2012:

1. Improved food and nutritional security;
2. Integrated and sustainable agricultural and forestry resource management and development; and
3. Improved bio-security and increased trade in agriculture and forestry products.

As regards institutional distribution, the government sector still dominates public agricultural research in most of the 11 countries included in the ASTI survey round. On an average, the government sector employed 62 percent of the public agricultural R&D staff in 2002/03, while the higher education sector accounted for 38 percent, and the nonprofit sector for just 0.2 percent.

The higher education sector has gained prominence in a few countries, but the individual capacity of many higher education agencies remains very small. India employed more agricultural researchers working in the higher education sector than in the government sector due to the land-grant system adopted by the country which closely links education, research and extension.

Several of the NARS are rather weak. Given high return on investment in research and technology development, such NARS must strive to establish and create enabling mechanisms for technology procurement, assessment and adoption. The concerned governments should ensure the necessary financial and human resources to enable their countries to access the globally available technologies and knowledge and to participate effectively in science-led growth and development. The CGIAR should pay greater attention to the needs of such countries and NARS and provide global public goods in the areas of agricultural research and innovation systems. Further, the Consultative Group should devolve some of its responsibilities to advanced developing countries, NARS viz. China, India and Malaysia. Further, south-south cooperation in research, education and extension should be strengthened and vigorously promoted. The donor community should also take note of these possibilities and development and extend desired support.

3.1.2 Human Resource in Agricultural Research

The overall trend of human resources revealed that in 2002, China employed more than 50,000 full-time equivalent (fte) researchers in the public agricultural sector, while India employed close to 17,000. Three other sample countries employed 3,000 or more fte's: Indonesia, Pakistan, and the Philippines. The small agricultural research systems of Laos and Papua New Guinea employed just over 100 fte researchers each. One-fifth of research workers in Asia-Pacific, were female, ranging from 6 percent in Pakistan to 40 percent in the Philippines. Barring Sri Lanka, South Asian countries had far lower proportion of female researchers as compared to that in Southeast Asia.

Average degree levels of agricultural research staff also diverged widely from one country to the other. India has the most qualified research staff. Nonetheless, all countries are experiencing improvements in qualification levels of agricultural scientists over the past decade, despite the challenges that certain countries face in rejuvenating their researcher pool.

Regarding research focus, in 2002, more than half of the nearly 36,000 fte researchers in the 11-country sample conducted crop research, while 13 percent undertook livestock research. Forestry and natural resources research accounted for 8 and 7 percent of total fte's, respectively, while the remaining 18 percent of the researchers focused on fisheries, post-harvest or other research areas. Large differences were observed in focus of agricultural research across countries. In India, nearly 35 percent of the resources were focused on germplsm, 26 percent on agrochemicals and 21 percent on soil and water research. More than 55 percent of the resources were devoted to raising the productivity of natural resources and less than 10 percent on socio-economic aspects (Jha and Kumar, 2006).

In the Pacific, there are a reasonable number of scientists working in the region but much of this resource is primarily engaged in tertiary teaching, administration or conduct of bio-security measures. Lack of research capacity is a very real constraint. The tertiary educational institutions with natural resource programmes vary in their abilities to attract and train research and development personnel. Agricultural science has always been an undervalued profession because its impact is not readily identified. Effective research requires a better understanding of the farmers and their systems, their traditional knowledge and capacity for innovation, and what they are willing and able to do. Then it is essential to include them and all other relevant actors in planning of the research right from inception and continuing their involvement. Uptake will then be likely to be more successful. Farmers are innovative if they are not desperate and can take risks, and good news spreads quickly in spite of poor communications (Quartermain, 2009).

3.1.3 Investment in Agricultural Research

3.1.3.1 Overall Trend

The research agenda of the developed countries is indifferent to the interests of the world's poorest people. The developing countries that have relied on technological spillovers from the North will no longer be able to do so. Rich-country support to productivity-enhancing technologies has reduced. Moreover, excepting a handful of countries, the gains of developing countries in scientific and technological capacities have slowed from the pace achieved in the 1960s, 1970s and into the 1980s, raising the prospect that a sizable number of developing countries may become "technological orphans". This trend must be reversed and developing countries will have to become more self-reliant in the development of applicable agricultural technologies (Alston, Pardey and Piggott, 2006).

3.1.3.2 Pubic Sector Investment

In 2002, the region (31 countries including 4 developed countries which together spent nearly $4 billion) spent a total of $9.6 billion on public agricultural R&D (in 2005 international dollar). The 27 developing countries spent about $5.7 billion. The size of agricultural R&D investments differed considerably across countries. China and Japan each spent more than one-quarter of the region's public agricultural R&D expenditures; 14 percent were spent in India (Table 13). These three countries together accounted for over 70 percent of the regional spending. The 11 low income countries (excluding India) accounted for only 5 percent of the region's public agricultural R&D expenditures. Other countries with significant spending on agricultural research were Malaysia, South Korea, Thailand, and Australia, with total expenditures ranging from $400 to $640 million each.

Table 13. National, regional and global trends in public agricultural R&D spending, 1981-2002, in 2005 international dollar

Region/ Country	Total spending				Regional shares			
	1981	1991	1996	2002	1981	1991	1996	2002
China	711	1174	1531	2574	14.4	17.5	19.5	26.8
India	396	746	861	1355	8.0	11.1	11.0	14.1
South Asia excluding India (5)	234	357	329	359	4.8	5.3	4.2	3.7
Southeast Asia (9)	598	967	1225	1355	12.1	14.4	15.6	14.1
The Pacific (11)	22	32	39	34	0.4	0.5	0.5	0.4
OECD countries (4)	2969	3443	3870	3945	60.2	51.2	49.3	41.0
Asia-Pacific total (31)	4930	6719	7856	9623	100	100	100	100
Global total (141)*	15513	20266	21395	22924	-	-	-	-

Note : in first column, the figures in parenthesis were number of countries;
The global figures were for the year 2000.
Source: Beintema and Stads, 2008a

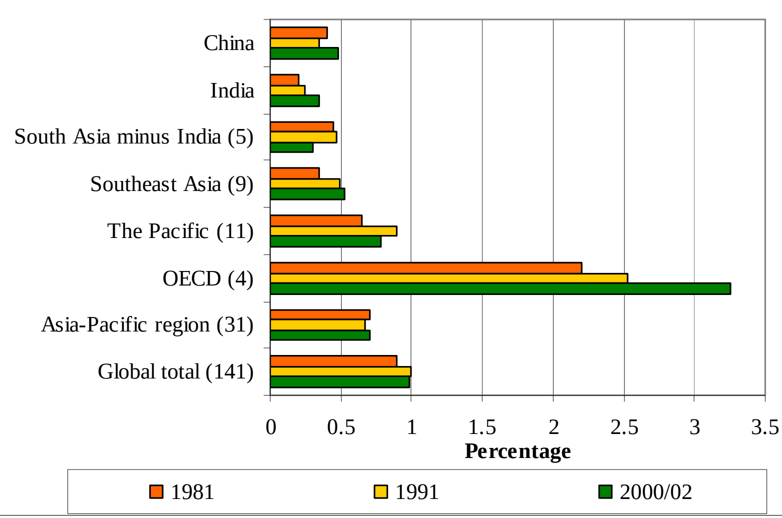
In 2000, the $8.7 billion of total agricultural R&D spending in the Asia-Pacific region accounted for 38 percent of the global total of $22.9 billion (Beintema and Stads, 2008a). This is a considerable increase from the corresponding ratio of 32 percent in 1981. The share of the developing countries of the region of the global total in 2000 was 21 percent.

During the 1981-2002 period, public agricultural R&D spending in Asia-Pacific region as a whole grew by an average of 3.4 percent per year. Most of this growth took place in China and India, where total public spending more than tripled over this period. Unfortunately, in most other countries there was little growth. In Japan and the remaining 28 countries combined the growth in agricultural R&D spending was much lower than in China and India.

The investment intensity as well as amount in agricultural research in China doubled between 1995 and 2003, increasing from 37.4 billion to 75.5 billion CNY. The public sector spending on agricultural research increased from 50 percent to 73 percent during the same period. In 2003 the crops sub-sector accounted for 55.1 percent of the total investment in agricultural research followed by 18.6 percent in agriculture services, 10.9 percent in forestry, 5.9 percent in livestock and 5.1 percent in fisheries. These investments have greatly impacted reduction in poverty and hunger. The focused attention of agricultural development for reduction of rural poverty had paid rich dividends, rural poverty dropping from 33 percent (250 million people) to 1.6 percent (15 million people) in 2007, an experience worth emulating by other relevant countries.

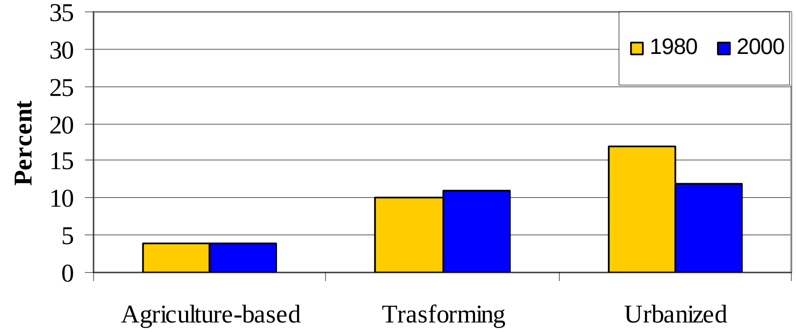
In 2002, the 31 Asia-Pacific countries had an intensity ratio of 0.7 percent which was slightly higher than the 1981 figure of 0.68 percent (Figure 13). Globally, it has been observed that developed countries have much higher intensity ratios than developing countries. In 2002, agricultural research intensity ratios for nearly all low- and middle-income countries in the Asia-Pacific region were under 0.50 percent, except for Malaysia and PNG which were 1.92 and 0.89, respectively. Among the developing countries, the agriculture-based countries spent only about 4 percent of their agricultural GDP against 10 to 11 percent in the transforming countries (Figure 14).

Figure 13. Regional and global intensity ratios, 1981-2002



Source: Beintema and Stads (2008a, b)

Figure 14. Public-spending on agriculture/agricultural GDP



Source: Beintema and Stads (2008a, b)

Government allocations represent the principal source of funding for public agricultural research in most countries of the region. In 6 of the ASTI sample countries, government contributions accounted for between two-thirds (Malaysia and Sri Lanka) and over 90 percent (India) of total agricultural research funding in 2002/03.

Public agricultural research in Laos and Nepal has traditionally been very donor-dependent, three-quarters of their funding derived from donor contributions. The World Bank was an important contributor to agricultural research activities in certain Asian countries through loan-supported projects in the 1990s and early 2000s. Bangladesh, India, Indonesia, Nepal, and Pakistan, in particular, received sizeable World Bank loans during the 1990s and early 2000s. In India, National Agricultural Technology Project (NATP) and National Agricultural Innovation Project (NAIP), operational over the past 10 years, are one of the largest agricultural research projects ever funded by World Bank, exceeding US$ 500 million. It will be useful to assess impact of this huge loan. Other important donors and multilateral development banks investing in the region's agricultural R&D include the Asian Development Bank (ADB), USAID, and the Australian government.

In recent years, funding sources and mechanisms have become more diversified in a number of Asian countries. New mechanisms of financing public agricultural R&D are gradually gaining ground. Internally generated resources, for example, have become an increasingly important component of funding agricultural R&D in China and Indonesia. Conducting contract research for public/private enterprises and the sale of plantation crops and technology inputs (such as seed stock) constituted the most important income sources during 1994-2003 for the Indonesian Research Institute for Estate Crops (IRIEC) – Indonesia's largest government agency in terms of R&D expenditures. In the Philippines, many of the regional agricultural research agencies are also generating their own resources.

Malaysia, Papua New Guinea and Sri Lanka have introduced commodity levies for export crops and a share of the resulting revenues is earmarked for research. Research in Malaysia (for oil palm and rubber), Papua New Guinea (for cocoa, coffee, and oil palm), and Sri Lanka (for tea, coconut, and rubber) is largely financed through export levies. In Indonesia, the deforestation fund works on the same line, whereby the Forestry Research and Development Agency (FORDA) receives a share of revenues raised through a per hectare levy on logged forest land.

In order to promote enhanced financial diversity and efficiency, various Asian countries such as India, Indonesia, Malaysia, and Sri Lanka have created competitive funding mechanisms as an alternative means of disbursing government funds to agricultural research. They are seen as an effective means of redirecting research priorities; increasing the involvement of universities and private companies in research; establishing stronger links among government, academic, and private research agencies; and increasing flexibility. Competitive grant systems could still be more effective if used as a complement to conventional block grants and up-front funding. NARS could generate additional research funds also by commercializing their research products, but such funds should not be diverted to other heads (Echeverría and Beintema, 2009).

3.1.3.3 Private Sector Investment

The role of the private sector in agricultural research in the developing world is still small and is likely to remain so given the weak funding incentives for private research. Nonetheless, involvement of the private sector in agricultural research is higher in Asia, at least in a number of countries, than in the rest of the developing world. In a few countries the share of agricultural research conducted by private firms has increased considerably and private-sector funding of public agricultural research has also increased in a number of countries. In some countries, private companies outsource their research needs to government agencies, while in other countries farmers pay levies on their production or exports of cash crops.

In Bangladesh, Laos, Nepal, and Sri Lanka, the private sector accounted for less than 1 percent and 3 percent in Vietnam, whereas it is 18 and 19 percent in the Philippines and Indonesia, respectively of total (public and private) spending in agricultural R&D. The private sector is responsible for the vast majority of scientific research conducted in Malaysia's manufacturing sector, but it undertakes only limited research in the agricultural sector (5 percent of total public and private spending in 2002). Most of these investments were in plantation crops (oil palm, coconut palm, sugarcane, and rubber), and nearly all the companies have government linkages. The current Malaysian government has identified agriculture as one of three engines for growth; it has therefore instituted a number of agricultural development policies and programs, including mechanisms to promote private sector involvement in agricultural research such as an investment tax allowance, tax exemptions, and financial and professional assistance for privately performed R&D.

Discussing the determinants of private sector investment in R&D in developing countries, Naseem *et. al*. (2006) had suggested to analyse the market and institutional constraints constraining private investment growth and the incentive mechanisms that can strengthen the investment – from both the supply and demand sides – particularly in relation to pro-poor growth.

In India, private sector contributes about 10 percent of the R&D investment, doubled during the last ten years. Private sector's support has increased particularly for biotechnology in India and in the Philippines. The National Commission on Farmers (NCF 2005), India, had made the following recommendations for increasing share of the private sector in AR4D: (i) provide tax incentives, including tax holidays, so as to increase private sector's contribution to R&D from 14% to 33%; (ii) strengthen national capacities in regulatory matters, especially IPR, SPS and quarantine facilities to promote technology acquisition as well as trade; (iii) encourage testing of new varieties bred by private sector and their other technological products in the public sector supported national technology testing programmes; and (iv) undertake joint research activities with clearly defined responsibility, accountability and profit sharing (NCF, 2006).

Private sector involvement in Chinese agricultural research has also risen. Fan, Zhang and Qian (2006) estimated that about one-fifth of these agribusinesses are involved in agricultural research, resulting in a private-sector share of total agricultural R&D spending of 9 percent in 2003. Most of these firms, however, were still at least partially state-owned. In recent years, a number of policies have been introduced by the Chinese government to promote private-sector involvement in agricultural research. These include value added tax exemptions or reductions, favourable loan for export-oriented products, and financial subsidies. The government has given up its monopolies on agricultural input distribution, although input markets are still regulated by the government through a legal framework. Fan, Qian, and Zhang (2006) argue that although the legal IPR framework is in place, stricter and more transparent enforcement is needed; restrictions on foreign investments need to be removed because they have hindered investment and technology transfer of the newest internationally developed seed varieties to Chinese farmers; and the procedures for obtaining tax exemptions, reductions, or loans for private companies are unduly complex.

3.1.4 Regional and International Collaboration

Regional and international partnerships in agricultural research have grown in recent decades and a large number of regional and global networks have been established. Among other advantages, the networks help capture technology spillovers across geographical and national boundaries. Some Asian countries already have well-developed national agricultural research programs and produce technologies and methods that are applicable to other countries in the Asia-Pacific region and other parts of the world. Multilateral organizations, such as the Consultative Group on International Agricultural Research (CGIAR), have also created networks in the region which have been addressing the issue of technology spillovers and provide global public goods to all countries.

The Asia-Pacific region has a wide number of networks related to agricultural research. Prime among these is the Asia-Pacific Association of Agricultural Research Institutions (APAARI), which was established in 1991 with the aim of promoting "the development of national agricultural research systems in the Asia-Pacific region through facilitation of intraregional, inter institutional, and international cooperation." APAARI works with over 20 member countries, as well as a number of CGIAR centers, regional organizations, and other organizations. The association promotes the exchange of scientific and technological knowledge; the improvement of research capacity; and strong linkages across national, regional, and international partners (Paroda, 2006). Another such regional network is the Asia-Pacific Association of Forestry Research Institutes (APAFRI). Both, APAARI and APAFRI, focus on collaboration and networking and do not undertake any research on their own. A large number of smaller regional networks, most of which appear to be managed by one or more CGIAR centers, focus on specialized research themes of relevance to the region (see Annexure VII).

The majority of the region's international research is carried out by the CGIAR. In 2008, 29 percent of the CGIAR's total expenditure of US$536 million (that is, US$155 million) was spent on activities specifically related to the Asia-Pacific region (CGIAR Secretariat 2009). Although this represents a slight increase in absolute terms over 2002 levels, the share declined from 33 percent. This amount also represents a 2 percent share of the $5.7 billion of total agricultural R&D spending by developing countries in the Asia-Pacific region in 2002 (calculated in 2005 international dollars). Of the current 15 CGIAR centers, 5 are headquartered in the region – IRRI located in the Philippines, the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) located in India, the World Fish Center located in Malaysia, the Center for International Forestry

Research (CIFOR) located in Indonesia, and the International Water Management Institute (IWMI) located in Sri Lanka—and the remaining 10 centers have offices and research programs in the region. All 15 CGIAR centers have formal links with China, for example, and 5 of them operate country-based offices. In addition to ICRISAT (with offices in Andhra Pradesh and New Delhi), 7 other CGIAR centers have offices in New Delhi.

Several other international and regional organizations have a presence and conduct or fund agricultural research in the Asia-Pacific region. The Australian Centre for International Agricultural Research (ACIAR), for example, does not conduct research in the region's developing countries itself but it does develop international agricultural research partnerships that focus on reducing poverty, improving food security, and sustaining natural resource management. ACIAR supports over 300 bilateral projects in developing countries, primarily in the Asia-Pacific region aiming to promote capacity building and knowledge and technology exchange. In 2007, ACIAR's budget totaled 60 million Australian dollars (about US$50 million), 75 percent of which was disbursed as grants to partnering research agencies, including the CGIAR centers (ACIAR 2007). The Japanese International Research Center for Agricultural Sciences (JIRCAS) conducts experimental research for the technological advancement of agriculture, forestry, fisheries, and related industries. Although JIRCAS's mandate includes all developing countries, most of its research is conducted in Asia. In 2007, JIRCAS employed 107 scientists, and its budget was 3.5 billion yen or close to US$30 million (JIRCAS 2008).

The Asian Vegetable Development Centre (AVRDC), particularly through its networks, such as the South Asia Vegetable Research Network (SAVERNET) has helped in germplasm exchange, development of elite varieties and hybrids, seed production technologies, IPM of diamondback moth, year round safe vegetable production, vegetables – and mungbean – based cropping systems, trainings and promotion of nutrition gardens for nutritional adequacy.

Pardey *et al* (2006), highlighting the growing global investment divide in agricultural research, had shown that throughout the 20th century, improvements in agricultural productivity have considerably alleviated poverty and starvation and fueled economic progress. Further, a large body of evidence closely links productivity improvements to investments in agricultural research and development (R&D). In the past several decades, however, many countries have made major changes in the way they fund and organize public agricultural R&D and the incentives affecting private R&D, said the authors, raising questions about the prospects for sustaining productivity growth over the next several decades and beyond.

3.2 Main Research Uptake and Innovation

Yield and productivity in rainfed areas, covering about two-third of the region's agricultural land, especially drylands and flood-prone areas, have been one-half or one-third of those in water-assured areas. Thus a major challenge is to narrow the income and productivity gaps between favored and less-favored regions. Better technologies for soil, water, and livestock management and more sustainable and resilient agricultural systems, including varieties more tolerant of pests, diseases, and drought, are needed for the latter regions. Approaches that exploit biological and ecological processes can minimize the use of external inputs, especially agricultural chemicals. Examples include improved fallows, green manure cover crops, soil conservation, and integrated pest management. Since most of these technologies are location-specific, their development and adoption requires more decentralized and participatory approaches, combined with collective action by farmers and communities. Better technologies and better ways of managing modern farm inputs can also make rainfed farming more sustainable. One of agriculture's major success stories in the past two decades is conservation (or zero) tillage. This approach has worked among smallholders in South Asia's rice-wheat systems. In less-favored regions, community-based approaches to natural resource management, such as the watershed management offer significant promise. Women's active engagement in community organizations improves the effectiveness of natural resources management and the ability to resolve conflicts. Towards improving research uptake and effective adoption of innovations, the following five management strategies/approaches are essential.

3.2.1 Investment Management

While the intensity of investment is important, equally important, if not more, is the quality of the investment (where and how) and the environment in which it is being made. Technologies can not work in a vacuum and a vacuum can not create technologies and innovations. As the outcome (yield) = G (research product) + E (environment – policy, institutions and services) + G x E, maximization of the interaction effect, which greatly enhances cost-effectiveness, must be the foremost strategy of AR4D programme.

The enhanced investment in agriculture research in India, unlike in China has not proportionately impacted productivity growth. For instance, average yield of major crops in India is around half to one third of that in China (Table 14) and has been growing only slowly or stagnating. And, this is attributed mostly to inadequate implementation of agricultural and other related policies such as the India's National Policy for Farmers (NPF, 2007) and to declining investment in agriculture. Thus, adequate investment with a human face concurrently both in agriculture and rural development and in agricultural research is essential and the two have to be strongly synergistic to each other.

Table 14. Yield of selected crops in India, China, Asia-Pacific and World, 2004-06 (Kg/ha)

Crop	India	China	Asia-Pacific	World
Paddy	3104	6275	4156	4108
Wheat	2681	4267	2627	2874
Maize	1901	5233	4139	4936
Groundnut (in shell)	998	3059	2200	1749

Source: FAO/RAP, 2007

Chand (2009b) has analyzed "agricultural development policies and the growth of Indian agriculture" and concluded that underinvestment in agriculture is at the core of the problem of declining productivity in agriculture. He observed that, nonetheless, the active role played by government and supportive policies for technology had played vital role in addressing many formidable challenges in agriculture and food sectors in India.

However, in the post economic reforms era, several adverse trends have emerged in Indian agriculture – the growth rate of GDP agriculture has decelerated sharply whereas population dependent on agriculture continues to be high, terms of trade for agriculture have turned adverse, slowdown in growth of fertilizer use, irrigation and energy (electric power) and increasing strain on natural resources like land and water. These challenges can be faced by the agriculture sector by stepping up investments and putting in place suitable institutional mechanisms to exploit irrigation potential that exists in most of the states; increasing power supply to the sector; promoting fertilizer use by expanding the distribution network and improving credit facilities for farmers; establishing competitive seed markets and ensuring attractive prices for seeds; improvement in terms of trade for agriculture; clear policy on new technology; and by promoting competitive markets for agricultural produce. Similar situation prevails in most developing Asia-Pacific countries.

Conventional research has been badly affected by preferential investment in new and emerging areas, including biotechnology, and this asymmetry should be corrected by mainstreaming the basic science faculties with applied research. There is underinvestment in socio-economic and natural resources management (NRM) research, thus adversely affecting the development of more effective policies, the functioning of institutions, capacity building and the decisions on investments with focus on the poor and inclusiveness, and the development of rainfed dry-lands and other less-favoured areas. More recently, nonetheless, in some countries there has been some shift in emphasis on research on resource conservation technologies for resource-poor farmers in disadvantaged eco-regions such as rainfed, upland, hilly, arid, and semi-arid areas. But their visible and significant impacts are neither widely demonstrated nor up-scaled. A balanced investment is thus called for (i) catering to the needs of maintenance research, (ii) extending research benefits to dry lands, hills and mountains, small island countries and coastal eco-regions and (iii) attaining higher economic gains and new yield potentials.

Research expenditures will have to increase much more in some countries than in others. Where research expenditure are already high, the focus on the poor as well as the quality of research and relevance will have to increase, thus calling for substantial reorientation of research. Investments in agricultural and the rural sector, in addition to those in agricultural research, would be essential to achieve agricultural development. As well documented, attention to policy, institutional development, investment in roads and transport, infrastructure, seed, finance, extension are all essential without which incomes and productivity of the poor will not increase. Additional attention must be given to quality of agricultural education, staff incentives and information and communication systems.

Research institutions are generally willing to be development friendly and even entrepreneurial, but are not able to meet their commitments due to shortage of funds. There needs to be a better balance between a) long-term funding to ensure continuity and the ability to undertake long-term research and b) competitive short-term funding to allow fast response to emerging research challenges and to ensure quality and relevance. Donor agencies must be willing to fund the more downstream efforts of R&D institutions. But, research grants should be linked to involvement of stakeholders in defining the research agenda and the target beneficiaries. Risks, accountability and benefits of research must be clearly defined and dispassionately analysed. Innovative and progressive farmers should be trained to record data and maintain documentation so that their experiment, experience and learning are available to the research system, professionals and other farmers.

3.2.2 Research Management

Research management should encourage processes which are necessary for implementation of the strategy to meet research goals. These processes may relate with identification and prioritization of research programmes in changing context, management of knowledge and technologies in the IPR regime, fostering partnerships, and technology transfer, including linkages with stakeholders. Some of these processes are fairly understood but need to be made effective. The IPR policy and institutional mechanism to implement are often in place but their implications are yet to be understood by researchers. This is an instrument of public policy to provide incentives to innovators in the form of appropriation of part of research benefits. But the public system should use this mechanism for realization of larger research objective of sustainable agricultural development. The Chinese experience has shown that excess focus on commercialization for resource generation could be counter-productive, and may even restrict flow of technologies to resource-poor farmers (Pal, 2008).

Strengthening capacity in cutting-edge science is essential to face emerging research challenges, and to play a global leadership role. Some degree of decentralization and devolution of administrative and financial powers may be required for developing research leadership at both the institute and national levels and for increasing research efficiency. Therefore, the process of decentralization should be seen as a strategy to strengthen system and empowerment of scientists.

Besides, many public research organizations face serious leadership, management, and financial constraints that require urgent attention. But higher-value markets open new opportunities for the private sector to foster innovation along the value chain. Efficacy of the wider range of institutional options now available should be evaluated to identify the most appropriate option for a given situation. The role of professionals in governance and regulation of agricultural R&D is absolutely vital and should increase significantly.

Responsiveness and efficiency of the research system can only be sustained in the long-run when there is an inclusive blend of basic, strategic, applied and anticipatory researches. This requires commitment of a large proportion of manpower and other resources, dynamism in identification, design and implementation of research programs and continuity of research efforts. This will essentially pave the way for development of productivity-enhancing technologies, and thereby making it possible to release some area for agricultural diversification. Immediate constraint to address this issue is the availability of quality scientific personnel, which may even become more severe in future because of changing incentive structure in the economy.

Finally, a balance of policy, institutions and technology will continue to remain critical for science-based and technology-led equitable agricultural development. However, nature and degree of their interactions are changing rapidly because of institutional and technological innovations. The policy-makers should understand and monitor these developments and should use policy and regulatory mechanisms to maintain a harmony among these pillars of agricultural development.

3.2.3 Research-Extension-Farmer Linkage Management

Often, a good number of new technologies are not adopted. Reasons for the increased adoption gaps are :

- (i) low profitability and low income;
- (ii) inappropriateness of the technology *per se;*
- (iii) knowledge and information gap;
- (iv) investment, input and infrastructural gap;
- (v) non-availability of market for the intended products; and
- (vi) policy and institutional gaps, including non-assessment of the needs and readiness of target farmer groups.

"Generally, the high-cost-input based technologies are not sufficiently adapted to the conditions of small and marginal farmers and their ability to take risks. The farmer will surely adopt an income yielding technology", voiced many at the E Consultation. Research institutions need to work more closely with development agencies and policy makers so that appropriate action research is pursued at the farm/micro level and also the needs of landless farmers, pastorals, small fishers and tribals are addressed adequately.

Extension/technology/knowledge transfer systems have weakened (during the E Consultation some voiced that the extension systems are "dead"). These must be revitalized and strengthened and rendered more relevant, dynamic, farmer-centric and development oriented. Common weaknesses include: (i) lack of connection between teaching, research and extension institutions and agencies, (ii) lack of cooperation between government, NGO, private sector and farmer, and (iii) lack of integrated approaches along the whole value chain. Amidst the generally unsatisfactory situation of extension services, there are some good models of extension and support services by the private sector, farmers' cooperatives and NGOs, which should be supported by the public sector by establishing innovative public-private/NGO-market partnership. Village agriclinics, training, especially of youth and women, and market-led extension have proved extremely helpful in technology transfer.

Economic viability and ecological compatibility of promising alternative farming systems for different farm sizes should be demonstrated through participatory modes at farmers' fields to build the confidence of the farmers in the R&D process and to identify the best mix of technology components and the processes for wide adoption of the selected technology packages. Suitable awareness enhancement on the benefits of technologies to consuming communities also needs to be a research priority so as to enhance acceptability of the commodities farmed out of such technologies.

Revolutionary advances in biotechnology offer potentially large benefits to poor producers and poor consumers. But today's investments in biotechnology, concentrated in the private sector and driven by commercial interests, have had limited impacts on smallholder productivity in the developing world – the exception is Bt cotton in China and India. Slow progress in regulating possible environmental and food safety risks and lack of IPR has restrained the development of genetically modified organisms (GMOs) that could help the poor. Each research centre should have a strong outreach programme and a window of agribusiness. Effective SPS and quarantine facilities are essential for facilitating safe sharing of technologies and planting materials. The potential benefits of these technologies should not be missed.

Lack of support services and of timely availability of quality inputs (such as limited flow of quality seed from breeders' plots to farmers' fields would delay variety replacement) discourage continued adoption of new agricultural technologies. Deception of faith leads to technology-aversion. The need for strong research-extension-farmer linkage involving farmers cooperative federations, SHGs, CSOs and other farmers' organizations can hardly be over-emphasised. Necessary infrastructure and other support should be provided for strengthening the linkages and communications.

We need to look at all research projects and proposals through the eyes of the farmers. How will the results contribute to development, to poverty alleviation or to help both producers and consumers? For instance, participatory approaches for agriculture` and forestry development fit well, in general, with most aspects of Pacific social systems built on cohesiveness, sharing and democratic decision making. Farmers will access information if they can and turn it into knowledge. However, this is difficult if they are illiterate. The mobile phone phenomenon is a great new thing that has the power to transform the lives of many rural people.

Farm schools established at farms of lead farmers have proved to be highly effective particularly for transfer of complex messages and technologies such as those related to integrated farming, integrated pest management, integrated plant nutrient management and integrated crop care, and the approach should be vigorously promoted.

The recent development in ICT, village knowledge centres, visual and radio networks should be used for sharing knowledge and information and to bridge extension centers to markets – a market-led extension. Several studies have revealed the efficacy of mobile phones in message sharing particularly for market information.

3.2.4 Empower the Women Farmers

With the increasing feminization of agriculture, women-friendly technologies and tools should be promoted and women training for skill, agribusiness and entrepreneurship development should become regular features.

Countries with lower achievement in the Human Development Index and Gender Development[3] Index have a larger percentage of their economically active population (both male and female) employed in the agriculture industry. Second, these same countries have a higher proportion of economically active women involved in agricultural

[3] Human Development Index (HDI) is based on three indicators; longevity, as measured by life expectancy at birth; educational attainment as measured by combination of adult literacy (two thirds weight) and combined primary, secondary and tertiary enrolment ratios (one third weight); and standard of living, as measured by real GDP per capita. Gender Development Index (GDI) uses the same variables as HDI. The difference is that GDI adjusts the average achievement of each country's life expectancy, educational attainment and income in accordance with the disparity in achievement between women and men.

activities relative to men. The disparities are likely to increase as rural to urban migration continues to change the composition of rural areas putting even greater responsibilities for the growth of the agricultural sector on women than they already have. In aggregate, women in rural areas in the poorer countries will be impacted most heavily as the agriculture population shifts over time. Agricultural technologies specifically designed to improve the efficiency and productivity of a female labour force will thus greatly improve overall agricultural productivity.

The Asian rural scenario is marked by shifting population trends and demographic phenomenon, such as migration, female labour arrangements for agriculture and rural production, rural women's lack of tenure to land, and uneven access to support systems to ensure productivity and welfare. Lack of analytical understanding leads to a failure of articulation and advocacy of the strategic gender aspect of demographic transition. There is a lack of organized empirical evidence and of key information on the negative impact of the gender bias – as of unpaid work of rural women within the family, child labour, inadequate nutrition for mothers and children, inequitable access to credit and support services and to health and education facilities. This lack contributes to the continuing inability to influence those agricultural policies, programmes, and policy makers that affect rural women.

The vision to empower rural women must move beyond rhetoric and must cease to be an unreachable aspiration. Social research must provide analytical information on rural women that can feed into policy formulation, and that can help articulate the demands of rural women to break the shackles of poverty, and pave the way to empowerment. Thus, the insecurity-poverty nexus, and its gender dimension, should be fully researched, understood, documented, and publicized. Science must help gender mainstreaming to fully realize this huge human capital wherewith to combat hunger and poverty. Women's education and status have overwhelming impact on child malnutrition (Smith and Haddad, 2000).

A comprehensive poverty-alleviation and food-security strategy must be anchored on the acceleration of food and agricultural production, improved access to clean drinking water, primary health care, hygiene and sanitation and to production resources, including land as well as the sustained expansion of employment opportunities for both men and women - both on-farm and non-farm. Agricultural policies and strategies gloss over the fundamental role of gender to sustained food security. Rural women, in those A-P countries in which agriculture dominates the national economies, contribute to food security, but they face problems of food insecurity and unstable livelihood. Hence, by assisting women to improve their access and use of productive resources (including technologies and effective use of their own time), one could move closer to achieving the goal of food for all.

3.2.5 Public-Private Partnership

The presence and role of private sector in the agricultural R&D is likely to see further expansion in years to come, both because of increasing market opportunities and strong incentives under the new IPR regime. This should be encouraged to increase resources for R&D and make research more demand-driven. The public sector should foster partnership with private sector to accelerate flow of technologies. At the same time, the public system should be vigilant about developments in the private sector, and emergence of monopoly tendencies should be addressed through appropriate measure. Also, private sector is vulnerable to economic crisis like current economic slowdown, which may affect supply of technology-embedded modern inputs and services to farmers, affecting food and livelihood security. Therefore, a strong public research system and responsive governance is a must.

Lack of incentives and contractual mechanism may discourage the partnership, but still both the sectors can assume complementary roles. For instance, public sector can share responsibility of basic research, applied crop and resource management research, training of manpower and enforcement of regulatory policies. Some of the applied and adaptive researches could be in the private sector. In this task there may not be any formal partnership, but the roles are complementary to each other. Converting basic research into commercial technologies involves a number of processes, interfacing both the sectors at different stages. This interface can be operationalized in consultative, contractual, collaborative, or supervisory modes.

Instead of trying to find common ground and exploiting their different strengths, public and private organizations involved in grassroot-level delivery of information and technologies tend to ignore each other and competitively push their own interests. Farmers are bombarded with confusing information from different sources and at the end they become indifferent even to good messages. Complementary action plans towards common goals of knowledge bridging and dissemination should be increasingly patronized. Several of the small countries lack adequate scientific research capacity to address the veritable problems. The "soft skills" such as research planning, priority setting, impact assessment, innovative resource mobilization etc. are usually missing among scientists and hence, should be enabled.

The International Agricultural Research Centres (IARCs) of the CGIAR have long been interacting with the private sector, and mutually benefiting thereby. Some of the centers have formalized their collaborations through agreements. So far, the CGIAR system has been able to share its technologies and products as international public goods. But, there has been pressure on the system from the collaborating private companies to institute appropriate intellectual protection on technologies and products arising from the use of their protected materials. The private sector has generally been willing to license proprietary technologies to CGIAR but only on a negotiated basis. The CGIAR must maintain a system which will allow a continuation of the free flow of technologies to the poor, without jeopardizing their partnership with the private sector; that sector will also expect to make appropriate adjustments (Spielman, *et. al.*, 2006). Financial and other support should be extended to the CGIAR system to enable it to pursue frontline research and generate highly competitive technologies, which, along with the genetic resources held by the IARCs, could constitute bargaining chips in negotiations with private and other public system institutions. Furthermore, more linkages should be established among IARCs to build complementary centres of excellence and avoid duplication of efforts. Under the SRF, the centres must be undertaking considerable structural and management changes to promote effective collaboration among the centres.

3.3 Agricultural Education and Human Resource Management

Agricultural education is generally missing the spark and is not able to promote excellence in science and to make agriculture more meaningful and attractive to graduates and scientists and to render them more entrepreneurial.

Efforts should be undertaken to provide basic systematic agricultural knowledge to a much wider audience, preferably all stakeholders. Ideally, this could be achieved through collaborating with professional educational management institutions to develop agricultural modules for rural primary and secondary schools and agriculture, natural resource management and livelihood security should be made a compulsory subject in all schools as launched in PNG. College/University curricula should include also traditional integrated agriculture systems. Desired infrastructure/labs and competitive salary/service structures and incentives are needed and should be duly reflected in budget provisions.

Effort should be enhanced to keep creating good plant breeders, entomologists, pathologists, agronomists, crop physiologists and experts in other traditional agricultural disciplines, as their members have been dwindling. Having an increased supply of biotechnologists is not an adequate substitution for such disciplines, which need currency of knowledge load.

Since the job-market determines inflow of students in a given discipline, it is imperative that course designing shall be an ongoing marketing strategy of universities. New areas such as intellectual property management, molecular technology and adoption, marketability of knowledge and products are to be cared for – an approach which is common in industries but rare in agriculture.

In the Pacific, the major constraints to implementation of research and the dissemination of knowledge are the low capacity generally in trained and experienced human resources, motivation and incentives. Better use can be made of the universities and the private sector although there have been significant improvements over recent years. But only one university outside of PNG serves most of the Pacific and research capacity is extremely limited. Scholarships are needed to encourage the best graduates to stay on and work at home but there is limited capacity to supervise the good post-graduate students. Universities and Institutes must play their parts in making the work environment attractive and conducive. Agricultural science has always been an undervalued profession because it is not perceived as having immediate impact and lives are not immediately dependent on the results (Quartermain, 2009).

There are unique inputs of agriculture and natural resource management into all levels of the PNG education system both rural and urban. We still need to improve the living conditions in rural areas to attract many educated youth into farming. Flexible and distance learning is likely to become more and more useful with improvements to communications and the para-veterinary training which was developed by SPC and partners is a good example of a modular home-based approach to solve a particular human resource shortfall. A regional e-training module for plant breeders is being developed by Bioversity International. Comparative systems studies carried out on farmer fields can be particularly instructive for students and staff alike.

The demand for skilled and well-trained human resources in agriculture is likely to escalate. The agricultural education system should be able to encourage cross-fertilization of ideas among disciplines and cater to meet rising demand for manpower from diverse sectors, including private R&D organisations. In the context of the global competitiveness of our agricultural education system:

- Farm graduates should be well-trained in principles of ecology, gender and social equity, economics and employment generation, sand should achieve computer, trade and patent literacy;
- Home Science education should be restructured for enhanced technological and skill empowerment of women in market-driven technological enterprises and sustainable management of natural resources;
- Integrated development of crops, livestock, fisheries and forestry should be strengthened and we need to stop fragmentation of farm education in narrow domains and establish viable linkages among institutions/universities; and
- A variety of non-degree training programmes based on both market preferences and specific needs of educational/research/extension departments should be instituted.

It is also time that our institutions dealing with agricultural education extend beyond formal schools of learning and develop outreach programmes that can be of considerable value to the ultimate stakeholders of agricultural education, the farmers. Revolution in information technology is already galvanizing process of knowledge communication. Each village should become a knowledge centre.

Interestingly, agricultural schools for higher learning in China have already been developing from colleges toward being multidisciplinary universities, which are termed as ‘Comprehensive Universities’, since the sixties. An excellent example of this reform is the new Zhejiang University, now the largest university with most diversified scientific and technical disciplines in China, created by combining Zhejiang University, Hangzhou University, Zhejiang Agricultural University, and Zhejiang Medical University. This has allowed attention to all disciplines, especially biotechnology, information technology, and materials science, and improved the basic level of agricultural specialties in China (Yinlong, 2009).

4. ADDRESSING THE NEEDS OF THE POOR, HUNGRY AND MALNOURISHED

4.1 Key Areas for Addressing the Needs of the Poor

4.1.1 Investing in the Poor and Resource-poor Farmer

Investing in the poor and resource-poor farmer is the foremost need of the day. Innovation through science and technology must be the main driver of pro-poor development. However, the knowledge divide between industrial and developing countries and between haves and have-nots is widening. Including both public and private sources, developing countries invest only a ninth of what industrial countries put into agricultural R&D (largely from private sector) as a share of agricultural GDP. The declining investment in agriculture amounts to utter negligence of and indifference to the needs of the poor, especially the resource-poor farmer. To narrow this divide, sharply increased investments in agriculture and agricultural R&D must be at the top of the policy agendas. It is well known that investments in agricultural R&D and agriculture have paid off handsomely, with an average internal rate of return of about 40 percent and have been highly pro-poor. While investment in agricultural R&D tripled in China and in India over the past 20 years, it increased only slowly in most other countries. For these countries, sharply increased investment and regional cooperation in R&D are urgent to bridge productivity, income and development gaps.

Byerlee and Alex (2003) had demonstrated that a broad-based approach to promoting agricultural growth can have substantial impacts on poverty reduction where: (a) agriculture is important to the incomes of rural poor; (b) the agro-ecological base allows significant potential for productivity growth; (c) land distribution is relatively equitable; and (d) the poor consume non-tradable food staples. Without these preconditions for win-win productivity growth and poverty reduction, agricultural research may still have strong poverty reduction impacts, but must be carefully targeted on poor producers and consumers.

According to an analysis by the International Food Policy Research Institute (IFPRI), doubling spending on public agricultural research over five years would significantly raise agricultural output and reduce poverty. But targeting different regions would yield different benefits. Allocating more investment to East and Southeast Asia would raise agricultural output growth the most and reduce the number of people living on less than US$1 a day by 204 million by 2020. Spending more in Sub-Saharan Africa and South Asia would have less impact on agricultural growth, but would lift more people—about 282 million out of poverty by 2020 (Table 15). Two overwhelming conclusions are obvious: (i) enhanced investment in agricultural research will yield the highest returns to the humanity (human welfare) and (ii) South Asia should be the foremost region with world to realise this investment.

But not all agricultural research investments are equally effective in combating hunger and poverty. Scientists and researchers from the CGIAR have produced a list of fourteen "best bets" that would reap the greatest benefits and get the most "bang for the buck". These investments fall into three broad categories: (a) Food for People, Environment for People and Policy for People as mentioned earlier. *"If the potential of these "Best bets" research programs were unleashed, they could benefit billions of people over the next five years. While the investments required might seem large by the standards of agricultural research, they are small compared with other general development expenditures. In terms of the number of people reached and the potential returns to investment – improved health and well-being for billions of people – doubling spending on CGIAR research is more than a wise business investment; it's a moral imperative"* (von Braun, 2008).

Table 15. R&D investment and its impact on poverty and output growth under output maximization and poverty minimization

Region/ Country	**Allocation of R&D investment (million 2005 US$)**		**Output maximization**		**Poverty minimization**	
			Change in the number of poor (Millions)	Agricultural output growth rate (%)	Change in the number of poor (Millions)	Agricultural output growth rate (%)
	2008	**2013**	**2008-2020**	**2008-2020**	**2008-2020**	**2008-2020**
Sub-Saharan Africa	608	933	-67.2	1.14	-143.8	2.75
South Asia	908	2131	-95.4	1.78	-124.6	2.40
India	707	1638	-71.3	1.76	-92.7	2.35
Southeast/ east Asia	1956	5268	-41.0	2.26	-13.5	0.69
China	1457	4247	-29.4	2.37	-8.9	0.69
Latin America	957	1004	-0.2	0.08	0.2	0.07
Total Developing	4975	9951	-203.8	1.55	-282.1	1.11

Source: von Braun et. al., 2008

In South Asia, the current resource allocation is not in favour of the poor (Mruthyunjaya and Kumar, 2009). Based on the analysis for India it emerged that the priority index is the highest for very poor households (1.81) followed by poor (1.54), and non-poor low income group (1.25), suggesting that 81 % additional income is required to the very poor households to meet the objective of nutritional security and social empowerment. In order to make South Asia food secured, using TFP information and the elasticity of research investment for raising output of all commodities, the investment required is projected at current annual growth rate of 2.14 percent of food supply and target growth rate of 4 percent to meet the challenges of both hunger and poverty. In the sub-region, if the current growth rate in food supply is to be maintained, the resource allocation has to be increased to US$ 2390 million from the current US$ 1590 million per year by 2020. Targeting 4% growth rate, the investment (at current price) has to be raised to US$ 4590 million per year (Table 16).

In India, the distribution of undernourished and poor is closely linked with the farm size (Table 17), nearly 60 percent and 55 of the marginal farmers were respectively poor and undernourished against the corresponding figures of only 2 and 5 percent of the large farmers. The main drivers for reduction of undernourished population in rural India were education, rice-wheat cropping system, irrigation, livestock and aquaculture (Singh et. al., 2002), suggesting that these sub-sectors need to be accorded high priority with multiple objective of diversifying agriculture, raising income levels and meeting the nutritional security of the resource-poor households in rural India.

The current national and international investments in rice are not commensurate with rice facts. The Southeast Asian analysis (Table 18) has shown that if a 5 percent improvement in productivity is assumed as the result of research for all major food items, rice (43.7%) and vegetables (19.8%), fruits (8.2%) and aquaculture (6.2%) will give highest percentage of benefits to the poor from top 11 foods (Raitzer, et. al., 2009). The analysis further suggest that the higher value commodities such as vegetable and meat will gain importance, but that continued productivity improvement for rice is necessary to underpin this diversification, and current investment in rice is not congruent with its historical or expected benefits – either in national or international systems. This is a key gap to address.

Table 16. Required investment in agricultural R&D to attain food security and to reduce poverty and hunger in South Asia

(Current price in million US$)

Country	2002	2010	2015	2020	2025
Scenario 1	**2.14% agricultural growth (to attain national food security)**				
Bangladesh	101.2	143.0	177.5	220.3	273.5
India	1258.3	1778.0	2206.9	2739.3	3400.0
Nepal	24.1	34.2	42.4	52.6	65.2
Pakistan	158.8	224.4	278.5	345.7	429.2
Sri Lanka	47.4	66.9	83.1	103.1	128.0
South Asia	1589.8	2246.4	2788.3	3461.0	4295.8
Scenario 2	**4% agricultural growth (to attain household food security and alleviation of poverty and hunger**				
Bangladesh	101.2	162.1	217.6	292.3	392.3
India	1258.3	2015.6	2705.8	3632.6	4876.5
Nepal	24.1	38.7	52.0	69.7	93.6
Pakistan	158.8	254.3	341.5	458.4	615.5
Sri Lanka	47.4	75.9	101.9	136.7	183.5
South Asia	1589.8	2546.7	3418.8	4589.7	6161.4

Source: Mruthyunjaya and Kumar, 2009

Table 17. Proportion of poor and of undernourished persons in different farm-size groups, rural India, 1999-00

	Agricultural labour households	Marginal farms (< 1 ha)	Small farms (1-2 ha)	Medium farms (2-4 ha)	Large farms (>4 ha)	Total persons (million)
% share of each group in total poor persons	22.8	59.6	10.3	5.3	2.0	159.8
% share of each group in total under-nourished persons	19.1	54.6	12.9	8.4	4.9	223.2

Source: Computed from 55th NSS rounds on consumer household expenditure survey, New Delhi, India: Government of India.

More than 0.2 billion of Asia's rural poor (of whom more than 0.1 billion abjectly poor), a good number of them pastorals, depend on livestock, and increased livestock production constitutes one of the few opportunities to enhance their livelihoods. However, livestock production is much constrained by infectious and parasitic diseases – including diseases that affect reproductive performance and/or nutritional balance – and which bring considerable losses to production and to stock, and restrict exports; moreover, disease control consumes financial resources, and drugs are encountering resistance because of inappropriate use.

Table 18. Annual benefits to Southeast Asian consumers with incomes below a $1.25/day PPP poverty line from a 5% average improvement in productivity for specific agricultural products, considering reduced food expenditure as income, and adjusted for expected changes to dietary composition in 2020

Commodities	No. of people lifted out of poverty (million)	Annual benefits to poor (US$ million)	Percentage of benefits to the poor from top 11 foods
Rice	8.14	315.97	43.7%
Vegetables	3.68	143.08	19.8%
Fruit	1.53	59.30	8.2%
Aquaculture	1.15	44.67	6.2%
Poultry	0.78	30.35	4.2%
Sugar	0.78	30.15	4.2%
Pork	0.70	27.10	3.8%
Palm oil	0.69	26.70	3.7%
Eggs	0.53	20.65	2.9%
Beef	0.11	4.38	0.6%
Lamb, mutton, goat and other meats	0.02	0.74	0.1%

Source: Raitzer et. al., 2009

In terms of research activities generating impacts, benefits documented to date for the Southeast Asian sub-region are largely the result of crop genetic improvement. The analysis suggests that advances in genomics will continue the impact potential of this area, and that this is essential in the context of climate change. Yet, only 15% of NARS expenditures in the region are in this area, and IARCs have a similar share. This is an essential gap to rectify. Other somewhat less striking gaps where shares of past known impacts exceed current relative investment shares include post-harvest work and aquaculture improvement.

There are wide differences among the developing regions and sub-regions in their spending on per agricultural worker, being the lowest in South Asia, which was much lower than that in the second lowest region – Sub-Saharan Africa (Table 19). As mentioned, South Asia has the highest concentration of malnourished and poor people. The inverse relationship between prevalence of undernourishment and government expenditure is apparent. The average expenditure per agricultural worker in the highest undernourishment category is at least 30 times lower than that of the category with the lowest prevalence.

Table 19. Expenditure per agricultural worker (developing region 1990-1998)

Region	1990	1991	1992	1993	1994	1995	1996	1997	1998
L. America and Caribbean	667	709	623	415	493	958	397	503	677
Near East and N. Africa	1598	533	1101	1062	1133	1473	1132	863	388
Africa South of the Sahara	103	103	59	59	65	200	239	297	n/a
East and SE Asia*	244	250	259	286	414	463	482	540	n/a
South Asia	32	58	76	97	97	151	73	29	25

Source: IMF, Government Financial Statistics Yearbook, 2000
** Singapore not included (expenditure per agricultural worker in the range of 8000 $)*

It is a matter of great concern that aid to agriculture had steadily declined. Real disbursement of net aid to agriculture in the late 1990s was one-third the level in the late 1980s, which was itself down from the late 1970s. Despite the fact that agricultural growth is a prerequisite for economic development in general and rural development in particular, and that it must be pro-poor for improving quality of life in rural areas, direct lending and technical assistance to agriculture by ADB had sharply declined, from US $ 1,242 million in 1990 to only US $ 433 million in 1999 (FAO, 2001). The World Bank/IDA halved their lendings for agriculture from 18 percent in 1990 to 9 percent in 1999. Fortunately, of late, the global aid system has realised the gap and is giving a fresh look to the issue (World Bank, 2008). Likewise, ADB has also been giving greater importance to agricultural research for development (ADB, 2000, 2004, 2006 and its leadership in the present study).

The waning trend must be a matter of still greater concern as the agriculture sector is facing unprecedented challenges of food insecurity, sustainability, productivity of small farms, increasing competition and knowledge and income divides that are quite complex and increasingly crucial. Accelerated investment is needed to facilitate agricultural and rural development through:

- strengthening of research, education and technology development capacities leading to enhanced productivity and sustainability,
- adaptation to and mitigation of climate change,
- energy crunch and high food prices,
- reliable and timely availability of quality inputs at reasonable prices, institutional and credit supports, especially for small and resource-poor farmers, and support to land and water resources development,
- improved rural employment opportunities, including those through creating agricultural clinics, seed and grain banks, agriculture-based rural agro-processing and agro-industries, gender equity, improved rural infrastructures, including access to information, and effective markets, farm to market roads and related infrastructure, and
- primary education, health care, clean drinking water, safe sanitation, adequate nutrition particularly for children and women. These investments will need to be supported through policies that do not discriminate against agriculture and the rural poor. Given the crucial role of agriculture in development and increasing role of small farmers in food security and poverty alleviation, development efforts must be geared to meet the needs and potential of the

sector and smallholders through their active participation in the growth process (Pinstrup -Andersen, 2000).

In the above context, appropriate policies and concerted advocacy at national and international levels are called for. The World Bank's Poverty Reduction Strategy Paper (PRSP) offered an opportunity to analyze the trend, but unfortunately, PRSPs elaborated were also short on agriculture and rural sectors. Further, the available limited resources should be deployed judiciously to yield wholesome outcome. There is evidence (Table 20) from a study on India to suggest that investment in less-favoured areas can yield relatively high rates of economic return and also significantly lessen poverty and environmental and resource degradation (Fan, Hazell and Thorat, 1999). Further, such investment does not imply any slackening in improving efficiency of irrigated production systems. On the contrary, high priority should be given to the development of technologies and knowledge which will enhance efficiencies of land, water, and fertilizer use for improving both economic and environmental proficiency.

Table 20. Incremental effects of government spending on poverty, India

Investment in:	Decrease in number of poor, per million Rupees spent	Rank
Research and Development	91.4	2
Irrigation	7.4	5
Roads	165	1
Education	31.7	3
Power	2.9	7
Soil and Water	6.7	6
Rural Development	27.8	4
Health	4	8

Source: Fan, Hazell and Thorat, 1999

Notwithstanding the urgency of substantially enhancing investment in AR4D, in order to realise the "bang of the bucks" (B), the environment (E) around the (B) has to be congenial to maximize the P (productivity, profitability, progress) of the resource-poor farmer and other poors through not only the best direct effects of B and E but also, and much more important, the synergistic interaction effect of BxE. The latter will call for conducive policy and institutional changes, as described later under section 4.3.

4.1.2 Improving Entitlement of the Poor

Rendering research poor-friendly requires increasing farmers' income and access to assets, making smallholder farming more competitive and sustainable, and diversifying income sources from off-farm and non-farm rural opportunities. Three core assets, namely, land, water, and human capital are required for AR4D focused on resource-poor farmers. Enhancing assets requires significant public investments in irrigation, health, and education. Institutional development, such as enhancing equity, the security of property rights and the quality of land administration are equally important (Sen, 1999).

Land reform can promote smallholder entry into the market, reduce inequalities in land distribution, increase efficiency, and should be organized in ways that recognize women's rights. Redistributing underutilized large estates or chunks of reclaimed land to settle smallholders can work if complemented by transfer of appropriate technologies and reforms to secure the competitiveness of the beneficiaries. Targeted subsidies to facilitate market-based land reform have proved helpful and need to be critically examined and scaled up.

Access to water and irrigation is a major determinant of land productivity and the stability of yields. Irrigated land productivity is more than double that of rainfed land. With climate change leading to rising uncertainties in rainfed agriculture, investment in water storage and conservation will be increasingly critical. Revamping existing irrigation schemes, expanding small-scale schemes and water harvesting, and enhancing on-farm water use efficiency are essential for increasing productivity of small farms. National policies on water should declare natural water as common property and promote community-based management of water and institutionalise role of Water User Associations.

Ultimately, it is the human capital which matters the most. Thus, increasingly it is the quality of rural education that requires the most improvement, with education conceived broadly to include vocational training that can provide technical and business skills that are useful in the new agriculture and the rural non-farm economy.

4.1.3 Enhancing Income of Farmers

Synergy of improved productivity, profitability, and sustainability of smallholder farming is the main pathway of AR4D, and can be achieved by improving price incentives and increasing the quality and quantity of public investment, making product markets work better, improving access to financial services and reducing exposure to uninsured risks, enhancing the performance of producer organizations, promoting innovation through science and technology, and making agriculture more sustainable and a provider of environmental services.

While price incentive should be rationally improved, the response to this incentive depends on public investments in market infrastructure, institutions, and support services. But the quality of public spending is often low and needs improvement. For instance, in some countries, non-strategic subsidies amount to as much as half of the public budget for agriculture. Implications of such budget allocations should be analysed and the results widely shared. Needless to emphasise, at times, subsidies are essential, but, these must be targetted and result-oriented, as these have high opportunity costs for productive public goods and social expenditures. Nonetheless, through judicious use of subsidies, it is possible to avoid risk aversion in adoption of new technologies. Subsidies need to be part of a comprehensive strategy to improve productivity and must have credible exit options.

Producers' companies or organizations can reduce transaction costs in markets, achieve some market power, and increase representation in national and international policy forums. For smallholders, producer organizations are essential to achieve competitiveness. The Indian Dairy Cooperatives Network has 12.3 million individual members, many of them landless and women, and they produce 22 percent of India's total milk supply – the largest in the world. Such experiences should be strengthened by governmental, financial, legal and training supports and shared by others.

In the Pacific, one of the key areas needing attention is the alleviation of the multiple problems of atolls. These ecosystems are not rich in diversity and genetic resources, although they have distinct cultivars of some crops, there is a shortage of land and fertile soil, and they are extremely vulnerable to natural disasters. At the same time they are almost totally lacking in research and development capacity. Given the proposition that work to be of real value in such systems must be done in-situ, a concerted effort must be made to create the means by which this can be done. Sea level rise is of particular concern in the atolls and some monitoring is being or can be done through remote sensing by organisations such as the Pacific Islands Applied Geoscience Commission (SOPAC).

Recognizing that the relative income of farmers has been sliding down consistently, the focus of research must shift from only production to the whole value chain. Production, processing and distribution of high value crops and commodities should be encouraged. Based on comparative advantages, new agro-industries for new markets should be developed to enable farmers to rise out of poverty and contribute to national development. The development of indigenous nut production in Melanesia is a case in point.

Off-farm rural employment and essential facilities and infrastructure for primary health and education should be created with due emphasis on streamlining of input-output markets, agro-processing and value addition, particularly in horticulture and livestock sub-sectors, and services geared towards the resource-poor farmers, including the landless and women. Research should lead to high-value labour-intensive employment opportunities.

A multi-pronged approach should be adopted to increase income of farmers through policy, social, infrastructure, technology and market development, with emphasis on productivity and inclusiveness. In case, despite all efforts, the farming households whose land and other farming endowments are not able to provide the minimal livelihood, they should be given informed guidance for facilitating them to exit farming with promising livelihood alternatives. National research priorities for enhanced agricultural growth shall not be in conflict with the existence and sustenance of such rural livelihood-oriented farming systems.

4.1.4 Linking Farmers with Market and Value Chain

Farmers must be linked with markets and positioned along the value-chain to be enabled to capture most of the price paid by the consumer through promoting Producer Companies, Small Farmers Estates, Nucleus Estate System, Cooperatives and SHGs (Singh, 2006). They should be duly trained and incentivised to innovate and become change agent so as to be a part of the change that he/she aspires for. The linkages should be further strengthened through contract, corporate and group farming, marketing cooperatives for farm inputs and outputs, introduction of agriculture commodity exchange and futures market for food, fodder/feed and other agricultural products.

Policies aimed at private sector-led development of value and supply chains for high value agriculture will further strengthen the linkages. Developing off-farm agro-based livelihood activities and agri-business enterprises will greatly complement the effort.

The concept of Producer Company (PC) Intervention for Sustainable Rural Development and Livelihood Improvement should be pursued vigorously. PC is an enterprise that is community-based, community-paced and community-owned. By its very design and intent, PC can give the poor and the marginal farmers: (i) a sense of self worth and identity (ii) capability to harness their wisdom in agriculture and allied activities, (iii) brands to their produce, (iv) empowerment to create local capacity and exercise their rights, (v) equity to their production and commercial relationships, and (vi) dignity to their labour and lives. The fundamentals of such a PC rest on 'Economies of Scope', optimal scale/size, appropriate technology to the marginal producers, 'Ownership Control' by the producers but staffed and managed by professionals.

The Producer Company approach ensures that arranging finance, procuring quality inputs, crop insurance, cultivation, harvesting, storage, value addition, packaging and marketing are all done professionally. The profits generated from the value additions would go back to the farmers as dividends and bonus. The Producer Company in its own interest would take care of extension, technology packaging, sustainability and environmental aspects in association with relevant stakeholders, in addition to finance, value addition, marketing, etc. The PCs should work for the poor and the marginal producers. Towards achieving this objective and sustainability of marginal producers, careful and serious intervention from the Government, successful farmers, consultants and the CSO/NGOs is the need of the hour. The efforts of the Government will be to give effective support by providing the required seed capital to be used as margin money demanded by financial institutions/banks for sanctioning the capital and working capital requirements, basic assistance for infrastructure, funding for professional managers, social communication and organization experts.

Research should be carried out to ensure that the markets (domestic and international) are serviced effectively and there are minimal market risks and farmers are advised accordingly for production planning. This should be complemented by providing appropriate technologies, timely credit, business support services etc. Efficacies of different agri-business models should be researched to provide effective guidance for their adoption.

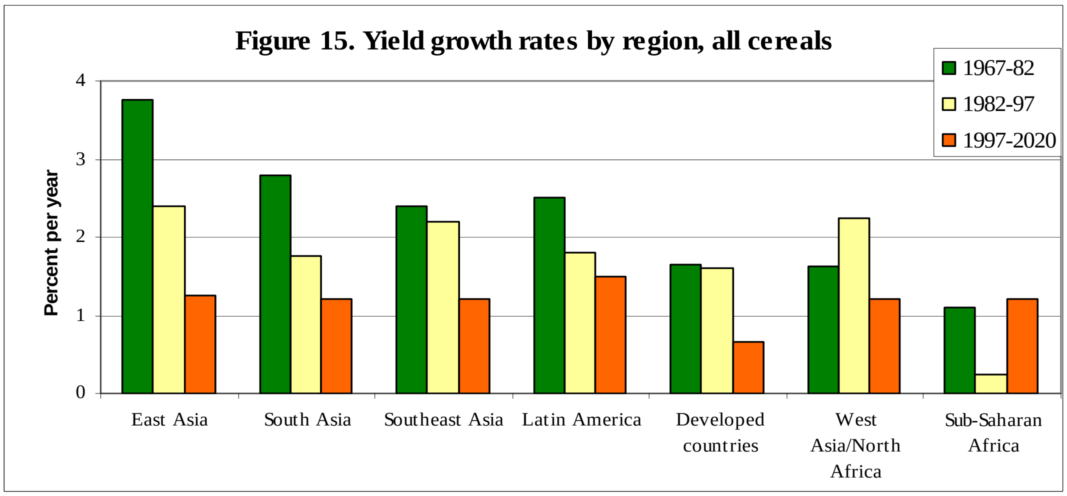
New policy is needed for handling commodities (both perishable and non-perishable) on an order-based production mode (a type of contract farming; Minimum Support Price does not ensure such contract) wherein governments should secure public interest. The worthiness of a suitable design shall be through both backward and forward linkages.

Competitiveness of farmers in developing countries is adversely affected by non-tariff barriers in the globalised world. Increased awareness-emphasis in all communities is required on biosecurity, gene literacy and food and health safety. Research is needed for undertaking comprehensive risk analysis and management along assigned and perceived value chains.

4.2 Key Areas Where Agricultural Research is Being Proposed Explicitly to Improve the Livelihood of the Poorest Farmers and Others

4.2.1 Productivity Enhancement

Barring China, average yields of most food and agricultural crops and commodities in the region are low and even declining. On the other hand, the projected yield growth rate of about 1.3 percent to meet the demand towards 2030, depicted in Figure 15, is the highest in the Asia-Pacific region among the regions of the world. Given the little scope for area expansion, the target must be attained for meeting out food demand.



Source: ASTI, 2008

The national and international agricultural research systems, especially the CGIAR, made an important contribution to the Green Revolution process in Asia during the 1960s and 1970s, developing new varieties of rice, maize, wheat, pearl millet, sorghum, potato, and a good number of vegetables that helped transform agricultural production and income generation. The needs of Asia-Pacific countries for agricultural technologies (like other regions and countries) have changed, and the research focus has shifted away from cereals toward other crop commodities, farming systems, livestock, (agro) forestry, aquaculture, and irrigation (Alston, Dehmer, and Pardey, 2006). While we must capture the new opportunities, we must not lose sight of the centrality of cereal crops in food security.

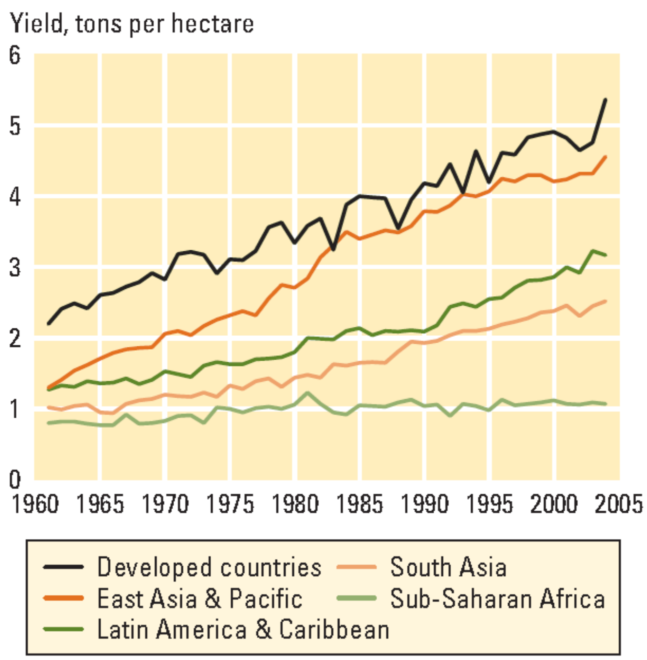
Large and economically exploitable yield gaps remain among regions (Figure 16) and should be abridged. In order to achieve the yield levels required for satisfying future food demands, a three-pronged approach is called for: first, elevate the yield ceilings, second, bridge the yield gaps at various levels, and third, maintain and protect the high yields already being obtained throughout some countries and in specific zones in other countries. As seen from Table 21, it is encouraging that wheat and rice yields in Asia have continued to increase during the past 40 years; they are projected to increase towards 2030, albeit at a decelerating rate, but nonetheless implying a continued need for developing the technologies wherewith to achieve increased yields. In terms of the crucial statistic of production per day - which quantifies the efficiency of using natural, human, and purchased resources - rice yields increased by about 15 percent between 1970 and 1990 and were expected to increase by 20 percent between 1990 and 2010 (Table 22). As cropping intensity becomes increasingly important, the features of crop duration and high per day productivity become preferred attributes.

Table 21. Yield increases (kg/ha.ann): wheat (South Asia) and rice (Southeast Asia)

Period	Wheat, South Asia	Rice, Southeast Asia
1960s	45	40
1970s	35	45
1980s	55	65
1990-1997	53	35
1997-2030	39	29

Source: Agriculture: Towards 2015/2030, FAO, 2006b

Figure 16. The yield gap for cereals among regions



Source: FAOSTAT, 2006b

Table 22. Yield potential: irrigated rice in tropical ecozones: 1970-1990-2010

Epoch	Cultivar	Seed-to-seed duration (days)	Yield potential (kg/ha)	Yield potential per day (kg/ha.day)
1970	IR8	150	10000	67
1990	Various indica	130	10000	77
2010	New plant type	130	12000	92

Source: calculated by the author based on various publications and reports

Major sources of yield growth are technology, level and quality of production inputs (irrigation, agrochemicals, machines and tools, labour skill), prices, and infrastructures. An analysis of sources of yield growth of rice and wheat in India during 1973-95 reveals that for rice the price was the most important determinant, accounting for 40 percent of the yield growth (Kumar, 2001). For rice, total factor productivity (TFP), which encompasses technological components, contributed only 24 percent, closely followed (20 percent) by access to electricity. Irrigation had rather a modest contribution of 8.4 percent. However, the situation was different for wheat: irrigation was the main source of yield growth (39 percent), followed by price (29 percent), and TFP (24 percent). During early stages of the Green Revolution, the contributions (to the output growth) were high for irrigation and electrification; subsequently, price and literacy increased in importance.

Technologies, both input-based and knowledge-based, particularly those impacting efficiency of input use, quality and market price of products (jointly contributing to cost effectiveness and competitiveness) greatly influence the level and rate of growth of total factor productivity (TFP). During the 1990s, the TFP growth rates both in rice and wheat have decelerated in several countries and under certain production regimes. This trend must be reversed, since the required increases in food production (the main pillar of food security in most developing countries) must accrue essentially through increasing yield per ha. Higher TFP growth rate means greater efficiency in the use of various inputs - especially fertilizer and water - to gain comparative advantage in production and in sustainability: a win- win situation.

As TFP increases, the cost of production decreases, and prices also decrease and stabilize. The International Model for Policy Analysis of Commodities and Trade (IMPACT) developed by the International Food Policy Research Institute (IFPRI) forecasted a declining real world food price between 1995 and 2020. While the low grain prices were extremely helpful until 2006 in improving poor persons' access to food, the farmers, especially those with marketable surpluses, suffered. The events in recent years, especially climate change, increased fuel prices and accent on bio-fuel production and overall economic downturn, had caused food price hike since 2007. But, this was accompanied with soaring prices of inputs. Thus, while the consumers suffered, the farmers failed to benefit, highlighting the importance of managing the market volatility and rendering it farmer-friendly. Further, the high economic growth and urbanization in the region and the accompanied increased demand for livestock products and other high-value commodities call for balanced system intensification, especially crop-livestock integrated farming (Singh and Velayutham, 2001; Birthal *et.al.*, 2007), diversification, and enhanced TFP growth.

Following steps are recommended for enhancing yield as well as for removing yield gaps (Singh, 2002):

- Development of more location specific technologies for crop management is required. The sharing, testing and utilization of technology and knowledge across the national boundaries has to be facilitated by regional and international bodies through various networks.
- The Integrated Crop Management approach can expedite the bridging of yield gaps and thus increase production. Location specific packages of technologies should be made available and popularized.
- The yield deceleration, stagnation and decline observed in high- yielding environments must be arrested, first by systematic studies to understand the

causes and then by the development of new varieties and crop management practices.

- Technical knowledge is an important factor in determining the adoption of improved crop management practices. New paradigms for technology transfer are required for seed and knowledge based technologies.
- Yield variability must be confronted. The diversion of resources towards risk reduction is a trade off in yield performance. The trade off between high yield and yield stability may be considered, particularly with the increasing climate change induced vulnerability.
- The efforts to break the rice and wheat yield ceilings (new plant type, hybrids, and agronomic manipulation) need to be geared-up to attain higher yields.
- Technologies to decrease the cost of production and increase profitability must be considered. Issues in poverty alleviation, social justice and diversification in agriculture are inter-linked.
- The trade globalization provided by GATT/WTO, and geographic comparative advantages can provide major incentives for farmers to bridge the yield gap.

Many of the underutilized species of the Pacific can grow under marginal conditions and withstand climatic extremes. The necessity is to create awareness and to promote and expand the use of genetic diversity. The Pacific countries are rich in plant and animal genetic resources on land and sea. It is essential to recognize, study and prospect the potentials of species with traditional uses as non-timber forest products and to provide the customary owners of the forests with alternative sources of income to counter deforestation. Bio-prospecting or bio-discovery and assessment of products for nutritional and pharmaceutical properties is an essential component of the search for sustainable forest management strategies. There are success stories with breeding or selection of taro, sweet potato and potato as well as oil palm, coffee, cocoa, rubber and sugarcane. Capacity must be increased however if these approaches are to be expanded to cover other crops.

Productivity of crops and livestock should be enhanced through genetic improvement to increase their adaptation to heat, water, biotic stresses, besides being high in nutritional qualities and yield. Research should be intensified to enhance conservation and sustainable use of natural resources particularly land, water and natural ecosystems resulting in the reversal of the decline of the total factor productivity growth rate, more efficient and remunerative use of resources, enhanced resilience and improved competitiveness of the farmers, particularly in face of the climate change and economic vulnerabilities. Prevention of post-harvest losses and efficient agro-processing interventions should be emphasised so as to add value and create attractiveness to the products that are grown/raised locally and link them with both domestic and international markets.

The accelerated growth of livestock sub-sector is expected to be more pro-poor. But, with the intensified accent on industrial and vertically integrated livestock production and distribution, the vast, small scale livestock production is losing ground as also the environmental pollution is accentuating. Critical analysis of existing small-scale production systems, as intended for local community consumption through shanties and markets, to operationalise suitable research on local breeds of animals is imperative. Can research and innovations save the small scale livestock production?

The threat from transboundary animal diseases and epizoonotics has increased. Research emphasis should be on developing crop-livestock-farming systems based on integrated food-fodder-feed-breed-health and bio-security management. Socio-economic and environmental implications of these developments should be critically analysed to provide policy guidance and to create regional institutions and mechanisms to meet the bio-security challenges. As in the case of prioritized human health policies for research, priority investment in public research and development towards surveillance and mitigation of contagious animal diseases in small-holdings is the call of the day in many developing Asia-Pacific nations.

The Asia-Pacific region is world leader in aquaculture and small-scale fisheries. Promoting an ecosystem approach to fisheries and aquaculture, research in this sub-sector should emphasise adaptation to the changes due to climate change, diversification of aquaculture through breeding, feeding and seed technology, improving water productivity in aquaculture, developing Best Management Practices in Aquaculture, biosafe and quality production and inshore marine fish management through stock assessment and regulated fishing. Enhanced R&D attention for fish processing and cold-chain based marketing infrastructure would enhance sustained profitability of this region.

4.2.2 Sustainability – Integrated Natural Resource Management

The declining availability and productivity of land, water and other production resources will need to be reversed through balanced intensification and enhanced resource use efficiency. The gaps in know how, do how and innovative farming methods should be filled to produce more food and agricultural products from limited and declining resources in a more sustainable way. Integrated food-energy systems would need to be put in place. New technologies and innovations for livestock production and aquaculture will be required to reduce pressure on natural resources and environment and for ensuring control and management of animal and zoonotic diseases, as mentioned earlier.

With rising resource scarcity, climate change, and concern about environmental costs, the farming systems of the rural poor should be rendered less vulnerable to natural disasters. More sustainable production methods connecting agriculture, natural resources and environment, must be devised so that the negative impacts are minimized. Agriculture can in fact play an important role in reversing the trends, for example by storing carbon in soils, enhancing the infiltration of water, and preserving rural landscapes and biodiversity.

In the Pacific, the lack of land or limited land areas, sea level rise, and rapid population increases notwithstanding, limited and high cost labour, access, communications, infrastructure, health and education are equally or more important constraints. The real challenge is to find ways around all of them. The Pacific farmers are innovative and not risk averse. But the R&D innovations often do not offer what farmers really want. We must understand the farmer and the systems and involve farmers in the research from the start. There appear to be three major knowledge gaps – (i) labour requirements for different crops or production systems, (ii) genotype x environment interactions or which crops, varieties or livestock breeds are best suited to be produced where, and (iii) the comparative nutritional values of crops, varieties and various food products.

Both intensive and extensive agriculture face environmental problems – but of different kinds. Agricultural intensification has generated environmental problems from reduced biodiversity, mismanaged irrigation water, agrochemical pollution, and health costs and deaths from pesticide poisoning. The livestock revolution has its own costs, especially in densely populated and peri-urban areas, through animal waste and the spread of animal diseases such as avian influenza. Many less-favored areas suffer from deforestation, soil erosion, desertification, and degradation of pastures and watersheds. The environmental footprint of agriculture has become large. It does not mean that agricultural development should slow down. Instead, more sustainable production systems should be sought. Water management strategies in irrigated areas must improve water productivity, meeting demands of all users (including the environment), and reduce water pollution and the unsustainable mining of groundwater (IWMI, 2007). These strategies depend on removing incentives for wasteful water usage, devolving water management to local user groups, investing in better technologies, and regulating externalities more effectively (FAO, 2009c).

The outstanding progress in science-led development of agriculture had its own environmental cost even in China. Economic losses caused by agricultural environmental degradation were 139-266 billion US$ each year during the 1990s, being about 3.8 to 7.3 percent of GDP (Yinlong, 2009). The country is facing increased shortage of cultivated land and water resources and enhanced ecological destruction and environmental pollution. The country is therefore, with its continued emphasis on poverty reduction, has set the following agricultural research, technology and innovation priorities for meeting the development challenges: (i) adjustment of agricultural structure, (ii) water-saving agricultural technologies, (iii) exploring seed resources and breeding of new varieties, (iv) creating environmental protective fertilizer and pesticide and ecological agriculture, (v) intensifying agricultural processing, transformation, storage and transportation technologies, (vi) comprehensive development and use of biomass energy and wind energy, (vii) ecologically safe agro-forestry and modern forestry, (viii) multi-functional agriculture equipments and instruments, (ix) precision farming and sharing of agricultural information, (x) restoring ecological systems in ecologically vulnerable areas, (xi) establishing modern milk industry, (xii) promoting rural hydro-projects, (xiii) institutionalizing agricultural insurance, and (xiv) promoting agricultural industrialization.

Agriculture and deforestation contribute an estimated 22 percent of total greenhouse gas emissions. Carbon-trading schemes – especially if their coverage is extended to provide financing for avoided deforestation and soil carbon sequestration (for example, conservation tillage) – offer significant untapped potential to reduce emissions from land-use change in agriculture. Some improvements in land and livestock management practices (for example, conservation tillage and agroforestry) are often win-win situations. Climate change induced suffering of the already poor and vulnerable has exacerbated. Based on the polluter-pays principle, it is the responsibility of the richer countries to compensate the poor for costs of adaptation. So far, global commitments to existing adaptation funds have been grossly inadequate. It is hoped that the Copenhagen

Conference will agree on implementable action plan and financial and technology sharing obligations.

While agricultural and natural resource conservation and management research is undertaken to meet the perceived challenges, the different objectives pertaining to relevant ecologies require different research approaches towards common goals. Although not mutually exclusive, there is hardly any periodic analysis undertaken to set balanced allocation of resources across these different objectives. This research gap should be abridged urgently so that the limited resources could be judiciously and effectively deployed.

Widespread adoption of more sustainable approaches is often hindered by inappropriate pricing and subsidy policies and the failure to manage externalities. Strengthening property rights and providing long term incentives for natural resource management with off-farm benefits (such as matching grants for soil conservation) are necessary in both intensive and extensive farming areas. Inappropriate incentives that encourage mining resources – such as subsidies to water intensive crops and to electricity/energy that cause groundwater over pumping – must be reduced. In fact, the water-wasters should be levied. On the other hand, providers of environmental services should be compensated through payments from beneficiaries of these services. Further, better water management through technology (remote sensing), better quality of irrigation services, and greater accountability to water should be strengthened. Policy instruments such as improved access to credit and crop and livestock insurance should be introduced to reduce on-farm risks. Farmer-friendly technologies, such as low to no external input requiring, labour productivity enhancing, conferring high acceptability of products in local market, promoting local value addition, possessing desired nutrition, taste and cooking quality and reducing risks both in market and monsoon, will readily be adopted.

4.2.3 Fighting Undernutrition

Undernutrition exacts its highest toll in Asia, especially South Asia. Micronutrient deficiency is widespread and causing both death and disability. Agricultural research can help to address these problems by improving the accessibility of micronutrients. A chief strategy to do so is through bio-fortification to improve the nutrient content of foods consumed. This can take place through changes in crop genetics, change in crop nutrient management or through the addition of nutrients at milling. The improvement of the availability and affordability of other micronutrient rich foods, such as vegetables can also help to address micronutrient deficiency. Many of the currently available data on micronutrient deficiency are in terms of prevalence. As highlighted in the Southeast Sub-regional Report, Disability Affect Life Years (DALY) lost from specific micronutrient deficiencies have been calculated by the WHO for vitamin A deficiency, iron deficiency anemia and iodine deficiency. These help to put the costs of micronutrient deficiency into perspective. For Southeast Asia, 1.75 million DALYs are lost per year as a result of Iodine, Vitamin A and iron deficiencies, valued at $1.75 billion in economic costs per year. A 5% reduction in these micronutrient deficiencies through research equate to $87.5 million in annual benefits under DALY value assumption (Raitzer *et. al.*, 2009). Asia-Pacific developing countries are paying not only the colossal economic, social and ethical costs, but also creating intergenerational gaps in development, hence nothing is more important for South Asia than to alleviate the child undernutrition.

Identifying vulnerable and disaster-prone peoples through a venture like FAO-led Food Insecurity and Vulnerability Information and Mapping Systems (FIVIMS) which is based on latest developments in GIS, space technology-based resource mapping, informatics, statistics, and understanding of socio-economic profiles, should be used by all nations and regions – an excellent example of AR4D. Status and efficacy of crops and other commodities especially designed to bridge nutritional gaps, such as "Golden Rice", canola varieties having a healthy-fatty acid composition and high lysine, and high tryptophane maize varieties (QPM) should be critically assessed and, based on merit, should be promoted through wise policies and production and distribution systems. We must take lesson from the undue delay in the adoption of "Golden Rice" – what and where is the hitch. An innovative participatory approach involving communities in the identification, design, implementation, and monitoring of development impact is essential. Local capacity building and supporting local initiatives and institutions for implementing food and nutrition programmes - including training in participatory appraisal and planning methods, expanding and diversifying food production, improving food preservation and storage and water supplies, expanding and diversifying income - generating activities and skills for small-scale businesses, providing basic education to women, and nutrition education and better access to basic health care services – social mobilization are strategically important for adoption of technologies and products.

A range of food groups is essential in providing food and nutrition security; this range is specific to the locality and to the resources and means of the people. Thus fish and legumes, particularly pulses, having high nutritional value, greatly supplement nutritional requirements of all people, especially children. The research and development needs of fisheries, livestock, and horticultural crops deserve greater attention; but efforts must continue for cereals, oilseeds, roots and tubers. Similarly, indigenous food crops and other food sources deserve special attention - not only to enrich nutrition and food options, but also to ensure their conservation as invaluable genetic resources for sustained livelihoods, particularly important for the Pacific. Education (particularly of women) and health care (Smith and Haddad, 2000) each help alleviate malnutrition - in adults and in children.

4.2.4 Harnessing Biotechnology for Enhanced Food Security

Biotechnology offers tremendous opportunities for application in agriculture sector. Genetic engineering is allowing identification and transfer of useful genes from across the species barrier making the entire biosphere a single gene pool. Biotechnology is already being used for improvement of crops and in several other areas of agriculture, food and nutrition, animal husbandry, fisheries, bio-security, medicine and bio-energy. Biotechnological interventions that have already made global impact and offer scope for revolutionizing the agricultural production and farmer's income include: (i) micro-propagation of elite planting material, (ii) molecular breeding for accelerated improvement of specific traits by pyramiding of genes available in the species gene pool, (iii) molecular diagnostics and vaccines for effective control of livestock diseases, and (iv) genetically modified organisms (GMO) incorporating foreign genes of interest into target crops and animals.

In 2008, 13.3 million farmers, including 12.3 million small and resource-poor farmers, in 25 countries planted biotech crops in 125 million ha. The global value of the biotech crop market in 2008 was US$7.5 billion with an accumulated value of US$ 50 billion for the period 1996 to 2008 (James, ISAAA, 2008). Among the 14 mega-biotech countries growing 50,000 ha or more of biotech crops, 4 belonged to the Asia-Pacific Region, namely, India (7.6 m. ha); China (3.8 m. ha), Philippines (0.4 m. ha) and Australia (0.2 m. ha); India being the fourth largest in the world, following USA (62.5 m. ha), Argentina (21 m. ha) and Brazil (15.8 m. ha).

In India, in 2008, 5 million small farmers planted and benefited from 7.6 million ha of Bt cotton, equivalent to 82 percent of the 9.3 million ha national cotton crop, the largest in the world. In the short span of 7 years, 2002 to 2008, of adoption of Bt cotton, India's cotton yield and production had doubled, resulting in an additional economic benefit of over US$ 4 billion annually and transforming the country from a cotton importer to a major exporter, the current net trade being over 8 million bales. At the same time, the insecticide requirements had halved. Thus, the technology has delivered significant and multiple agronomic, economic, environmental and welfare benefits to the farmers, especially small farmers, and has enabled the country to overtake the USA to become the second largest cotton producing country in the world, after China.

China's cotton economy has also benefited significantly from Bt cotton. In 2008, 7.1 million small farmers in China had planted 3.8 million ha of Bt cotton which was 68 percent of the national cotton crop of 5.7 million ha, thus further enhancing (by 10 percent or so) the yield, and reducing the pesticide use and generating additional income of US$ 1 billion per year. The ten-fold decrease in bollworm infestation in the Bt cotton areas had benefited 10 million non-cotton farmers cultivating 22 million ha of crops other than cotton, which also host cotton bollworm (James, ISAAA, 2008).

As regards food crops, in India, no transgenic has been commercialized, although several have been under field tests for several years and one was even approved for general cultivation. The Bt brinjal, a common vegetable food crop, despite having been cleared by the national Genetic Engineering Approval Committee (an inter-ministerial apex decision-making committee comprising representatives of Ministries of Agriculture, Science and Technology, Health and Environment and Forests), hosted by the Ministry of Environment and Forest, in the same manner as Bt cotton, has run into public debates and its commercialization has been kept on hold.

Recently, the concerned Indian Minister held a series of public consultation meetings in different parts of the country and found serious divides among scientists, farmers, consumers and policy makers on this issue and underpinned the need to strike a balance between science and society, producer and consumer and the Centre and the States. The public perception was that Monsanto was monopolizing the seed market and disregarding health issues and the Minister felt that the safety standards for food should be stricter than those for drugs, and issues of chronic toxicity should also be kept in mind. Towards this, the Minister suggested a network of independent testing laboratories and procedures and guidelines to have full confidence of the public through proper protocols and transparency, and there should be clear rules over conflict of interest. He has pledged to establish an independent and autonomous National Biotechnology Regulatory Authority, including the concerned elements of Seeds Bill, Food Safety, Labeling etc. Prime

Minister Dr. Manmohan Singh has recently (January, 2010) stated that, “the technology of genetic modification is also being extended to food crops, though this raises legitimate questions of safety. These must be given full weight, with appropriate regulator control based on strictly scientific criteria. Subject to these caveats, we should pursue all possible leads that biotechnology provides that might increase our food security as we go through climate related stress.”

In China, however, unlike in India, in addition to Bt cotton, following the necessary protocols, several transgenics of food crops also, such as tomato (1998), sweet pepper (1998) and papaya (2006), each occupying a few thousand hectare have been commercialized. Very recently, transgenic rice and maize hybrids have also been approved for commercial production – marking a much-needed step-up phase of the green revolution. In particular, the developments in rice have great implications for the Asia Pacific as it produces and consumes 90 percent of world’s rice and the crop is the pillar of food security and economy in the region, especially of smallholder farmers. Premier Wen Jiabao, recently addressing the Chinese Academy of Science had stated that, “to solve the food problem, we have to rely on big science and technology measures, rely on biotechnology, rely on GM”, and announced US$ 3.5 billion R&D initiative for biotech crops.

China has also been importing huge quantities of GM Roundup Ready (RR) Soybean (valued at US$ 4 billion in 2007) and is in process of commercializing its own biotech soybean. Biotech wheat, potato, cabbage, peanut, melon, chili, rapeseed and tobacco transgenics are also being field-tested. Bt poplars are also popular in China for their enhanced resistance to biotic stresses, and more recently biotech poplars are available with modified lignin and greater tolerance to abiotic stresses. China’s thrust on commercialization of biotech rice, maize and soybean varieties will have a tremendous impact on food security not only in the Asia-Pacific region but in the whole world, as also on the attitude towards transgenic crops.

Biotechnology is not limited to transgenics. Other biotechnological approaches, such as gene pyramiding through molecular aided selection (MAS), have proved extremely helpful in developing improved varieties. As no transgenics are involved in these processes, no special biosafety concerns are associated with such process and products derived from them. Through this approach, in India, durable resistance to bacterial leaf blight has been incorporated in aromatic rice Basmati varieties, such as Improved Pusa Basmati 1, which is instrumental in maintaining steady supply of the foremost grain export of the country. This approach is being successfully used also in China and other biotechnology countries in the region. Molecular breeding for the rapid transfer of genes for important traits to mega varieties is promising but new traits have to be discovered by evaluation of germplasm, and markers need to be developed and deployed very fast. This effort should be intensified in the public research system.

From the performance of the already commercialized biotech crops and of those in advanced trials it is revealed that biotech crops have the capability to contribute to (i) increasing crop productivity, (ii) conserving biodiversity, (iii) reducing the environmental footprint of agriculture, (iv) mitigating climate change and reducing greenhouse gases, (v) increasing stability of productivity and production, (vi) the improvement of economic, health and social benefits and (vii) the cost-effective production of renewable resource-based biofuels. Thus, these have potential to provide significant and important multiple and mutual benefits to producers, consumers and global society (James, ISAAA, 2008).

Genomics aided by bioinformatics is fast unravelling secrets of life processes at the molecular level, and is the knowledge engine for gene discovery needed for genetic engineering and molecular breeding. Biotechnology will further help to develop immunity against common diseases and GMO for complex traits like drought tolerance and genomics-assisted molecular breeding are already under extensive field-testing. The following future scope and distinct possibilities of biotechnological research and development exist in crops, livestock, fisheries and agriculturally important microbes:

Plant Biotechnology

1. Plant genomics and molecular breeding
    - Generation of genomic resources using high throughput systems
    - Expression profiling of transcriptome, proteome, metabolome and ionome
    - Construction of reference molecular maps and gene tagging
    - Discovery and cloning of novel genes and promoters
    - Basic understanding of biological processes and metabolic pathways
    - Development of molecular markers for foreground and background selections

2. Efficient characterization of genetic resources and search for novel alleles
    - High throughput molecular characterization of germplasm, coupled with phenotyping for key traits
    - Allele mining and association mapping for identification of novel genes/alleles

3. Climate change and adaptation strategies
    - Understanding molecular basis of plant adaptation response to climate change
    - Genomics and transgenic research on biotic and abiotic stress tolerance
    - Genomics and transgenic-based approaches for conversion of C_3 plants to C_4 plants with enhanced photosynthetic efficiency
    - Understanding molecular basis and enhancing nutrient and water use efficiency

4. Biotic stress tolerance
    - Understanding molecular basis for host- pathogen interaction
    - Understanding mechanism and utilization of non-host resistance
    - Genetic engineering for disease and insect-pest resistance

5. Specialty traits
    - Genomic research on Apomixes

- MAS and transgenic technologies for enhanced nutritional quality
- Bio fortification of macro and micronutrients

Animal Biotechnology

1. Animal genomics
    - Structural and functional genomics of buffalo, chicken and goat
    - Pharmacogenomics to identify specific drug susceptible groups
    - Bioinformatics studies on animal diseases and productivity

2. Molecular breeding
    - QTL analysis and MAS for enhanced productivity and disease resistance in cattle, buffalo, chicken, pig and goat

3. Animal cloning and transgenics
    - Cloning of large ruminants (cattle and buffalo)
    - Production of surrogate bulls for elite semen by stem cell approach
    - Transgenic chicken for pharmaceutical production
    - Designer eggs and meat

4. Molecular diagnostics
    - Novel immunogens/prophylactics against viral pathogens (e.g. recombinant and combinational vaccines)
    - Diagnostics for existing and emerging pathogens in livestock and poultry sectors (e.g. BVD, Caprine encephalitis, avian influenza)

5. Animal nutrition
    - Enhancing nutritional quality of crop straw and forage crops for animal feed
    - Enhancing nutritional quality of low quality roughages through *in vitro* microbial manipulation
    - Rumen micro flora management for enhanced conversion efficiency

Fish Biotechnology

1. Fish genomics
    - Generation of ESTs in Indian major carp (*Rohu*) and Tiger shrimp to gain genomic insights into aspects of growth, disease resistance and reproduction
    - Bio prospecting in seas and cold waters
    - Bioinformatics in fish studies

2. Fish molecular breeding
    - Population fingerprinting using microsatellite, SNP and mtDNA markers
    - Development of high density genetic and physical maps in *Rohu* using microsatellite and SNP markers

- Identification of disease resistance genes and molecular markers in shrimp for undertaking MAS

3. Transgenics
   - Autotransgenics in carp and catfish with growth hormone gene
   - RNAi for generating transgenic carp with disease resistance
   - Ornamental glow fish
   - Fish bioreactors (for pharmaceutical purpose)

4. Molecular diagnostics
   - Diagnosis of viral pathogens in fish and shrimp

5. Fish nutrition
   - Microbial processing of feed stuff
   - Probiotics in fish feed stuff

Microbial Biotechnology

1. Microbial genomics
   - Generation and utilization of genomic resources in microbes
   - Bio prospecting and allele mining in soil and water
   - DNA fingerprinting of microbial resources
   - Metagenomics of unculturable microbes

2. Transformation and strain improvement
   - Genetic engineering of microbes for bio-fertilizers and bio-pesticides
   - Bio-reactors for pharmaceuticals
   - Bio fuels from microbes
   - Microbial probiotics

Bio-safety and Bio-security

- Food and feed safety
- Environmental and ecological safety
- Post-release monitoring
- Surveillance and emergency planning
- Public education on bio-safety and bio-security

The patterns of generation, adoption and commercialization of biotech products would vary depending on national policies, strategies, institutions, regulatory and legislation mechanisms, economic prospects, consumers' attitude and awareness of the civil society. Notwithstanding the benefits of biotechnology, in particular, there are public concerns about food safety and human health, environmental impact, and ethics of biotechnology and of genetically modified foods (Singh, 2000 and 2008). Commercialization of GM crops will depend on public perception of their safety (both economical and biological), as amply demonstrated in case of Bt brinjal in India. The bio-safety evaluation should primarily be in the public domain and products should start coming from the public sector also to instil public confidence and to increase competition to the private sector for keeping the biotech seed prices within the reach of majority resource-poor farmers.

Efforts in science-based education and public awareness and gene literacy are needed to allay fears of the unintended effects of biotechnology, and to emphasize biotechnology's pro-poor actual and potential contributions. Correspondingly, there are needs to strengthen the linkages among the ongoing biotechnological programmes that hitherto have been country- and commodity-specific and to strengthen the inter-connections of biotechnology to programmes that ensure biosafety, food safety, health safety, environmental safety and conservation of biodiversity (and hence biosecurity). Much greater emphasis is needed on the development of quality trained human resource in the frontier areas of agricultural biotechnology. The human capital will further help faster assimilation and innovation of biotechnologies in a globally competitive and inclusive manner to address the problem of agriculture sector in the developing countries of Asia and the Pacific.

To help address the various challenges, necessary skills and resources have been or are being assembled in many Asia-Pacific countries. Governments in several fast transforming economies in the region, including China, India, Indonesia, Malaysia, Pakistan, Philippines, Thailand, and Vietnam are making major investments in biotechnology, as also are various regional and international programs and private-sector companies. These investments and programmes shall need to be directed at clearly defined needs of the poor, particularly food and nutrition security and poverty alleviation targets, and need to be complemented by appropriate policies and investments in science and technology and product development and delivery and by transparent and cogent regulatory and legislation frameworks that generate public and commercial confidence in the biotechnological products.

An unambiguously clear, well articulated and transparent policy for GM crops is fundamental to the effective harnessing of biotechnology. This need is amply underpinned by the situation in India. Despite a huge programme on biotechnology, the country is yet to declare a formal national policy on this extremely important but equally controversial subject. While commercialization of Bt cotton, a fiber cash crop, primarily promoted by the private sector, especially a multinational, has spread fast, commercialization of Bt brinjal, a food crop, although developed and cleared by the same route, has been kept on hold. This anomaly has arisen because India does not have a national policy on biotechnology and cogent legal and regulatory frameworks to inspire people's confidence. It is hightime that all countries should have their own national policies on biotechnology addressing risk, biosafety, value, farmers' income, equity, usefulness, appropriateness and other related aspects and streamline and harmonise their institutional, legal and regulatory frameworks.

A panel chaired by Prof. M.S. Swaminathan, June 2004, had prepared a draft National Biotechnology Policy document and suggested the establishment of an autonomous

National Biotechnology Regulatory Authority to oversee and harmonise biotechnological developments in field of agriculture and food, environment and medicine and pharmaceutics. The Department of Biotechnology, Ministry of Science and Technology, building on its Vision document, 2001, following a series of multistakeholder consultations, issued the National Biotechnology Development Strategy in 2007 which was approved by the Government of India. These documents contain the essential elements for creating realistic policy keeping in mind agricultural, environmental and livelihood priorities; institutional, regulatory and enforcement capacities; and broader economic and political contexts. These should be articulated into a National Policy on Biotechnology from which should flow necessary Acts, Regulations, Laws and Guidelines. Appropriate and effective institutional and financial mechanisms should be established for implementation of the various provisions under the policy.

The strategy document of the Department of Biotechnology highlights that :

- the Government recognizes that biotechnology needs focused attention;
- the strategy, while enabling the full utilization of currently available opportunities in manufacturing and services, will lay a strong foundation for discovery and innovation, effectively utilizing novel technology platforms with potential to contribute to long term benefits in agriculture, animal productivity, human health, environmental security and sustainable industrial growth;
- the cornerstone of the strategy is the focus on building coherence and connectivity between disciplines and to bring together variegated skills across sectors to enhance synergy;
- the strategy seeks to address number of challenges relating to the biotech sector in terms of R&D, creation of investment capital, technology transfer, absorption and diffusion, IPR, regulatory issues, building public confidence, and tailor made human capital for all these aspects;
- the stated vision of the strategy is responsible use of life sciences and biotechnology to promote balanced growth of all sections of the society; and
- the strategy towards reinforcing the regulatory framework stipulates to set up National Biotechnology Regulatory Authority as an independent, autonomous and professionally led body to provide a single window mechanism for biosafety clearance of genetically modified products and processes.

4.2.5 Scope of Nanotechnology for Alleviating Hunger

Nanotechnology which includes the study, design, creation, synthesis, manipulation and application of functional materials, devices and systems has several practical applications to food and agriculture, but these are still at early stages of development. Nanotechnology can complement biotechnological development. Potential applications are summarized in Table 23.

Nanotechnology is highly interdisciplinary by nature and requires close collaboration between biologists, physical scientists, and engineers. In agriculture it has several cutting-edge applications, such as nano-biotechnology, nano-diagnostics, vaccines and drug delivery, nano-biosensors for livestock, plants, fish and soil health, nano-delivery of fertilizers and pesticides for precision farming, and nano-processing.

Table 23. Application of nanotechnology most likely to contribute to agricultural development

Nanotechnologies	Examples	Potential application
Agricultural productivity enhancement	• Nanoporous zeolites for : slow-release and efficient delivery of water and fertilizers for plants; and nutrients and drugs (nano-vaccines) for livestock • Nanocapsules for herbicide delivery • Nanosensors for soil quality and plant health monitoring	More efficient and sustainable food production that requires fewer inputs
Food processing and storage	• Nanocomposites used in plastic film for food packaging • Antimicrobial nanoemulsions for decontamination of food • Nanotechnology-based antigen detection of contaminants	Cheaper, safer food products with longer storage life
Vector and pest detection and control	• Nanosensors for pest and pathogen detection • Nanoparticles for new pesticides, insecticides and insect repellents	More rapid deployment of safer control strategies with reduced losses

Source: Science Council (2005)

4.2.6 Internalizing and Enriching Traditional Technologies

Traditional knowledge is the cornerstone of a production system and should be conjured with modern knowledge and innovations. However, one must also acknowledge that the traditional knowledge and technologies must also evolve over time. Groundbreaking discoveries in science and technology are usually not made because of traditional knowledge alone, but they can certainly help creating a new stock of future traditional knowledge (Table 24).

Table 24. Examples of known indigenous agricultural practices emanating from traditional knowledge

Sector	Indigenous agricultural practice
Crops	Indigenous indicators to determine favorable times to prepare, plant, and harvest gardens; land preparation practices; indigenous ways to propagate plants; seed storage and processing (drying, threshing, cleaning, and grading); seed selection practices; indigenous methods of sowing (seed spacing and intercropping); seedling preparation and care; farming and cropping systems (for example complementary groupings); crop harvesting and storage; food processing and marketing; pest management systems and plant protection methods.
Livestock	Indigenous methods of animal breeding and production; traditional fodder and forage species and their specific uses; animal-disease classification; traditional ethno-veterinary medicine.
Forestry	Management of forest plots and their productivity; knowledge and use of forest plants and animals; understanding of the interrelationships between tree species, improved crop yields, and soil fertility.
Fisheries	Integrated aquaculture production into cropping systems such as the rice-fish systems; use of larva-eating fish.

4.2.7 Climate Change Management

Major uncertainties and likely impacts of climate change in the Asia-Pacific region are given in Table 25.

Table 25. Impact of climate change in Asia-Pacific

Key Uncertainties	Drivers of change directly affected	Implications for agriculture, food systems, products and services	Implications for development and sustainability goals in the Asia-Pacific region
Rise in sea level, temperature and precipitation (2015-2075)	Demographic changes Economic growth Agricultural growth Trade Investment	▪ Resurgence of tropical diseases ▪ High morbidity rates ▪ Reduced labor availability ▪ Unpredictable employment opportunities ▪ Factor productivity declines ▪ Food prices increase ▪ Unstable markets ▪ Declining crop productivity ▪ Cost of production increase ▪ Animal and crop diseases increase ▪ Preservation and storage crucial ▪ Deciduous forests incapable of regeneration ▪ Desertification increases ▪ Unpredictable production estimates, quality standards, etc. ▪ Futures markets collapse ▪ Higher market regulation with increasing loopholes ▪ Capital diverted to survival (food, health) ▪ Returns to investment decline	▪ Increase in poverty, ▪ hunger and malnutrition ▪ Inequality, civil strife increase ▪ Economic growth unsustainable ▪ Natural resource degradation ▪ S&T becomes emergency driven and legitimacy falls ▪ Governance and decision-making become more centralized ▪ End of capitalism

Source: IPCC, 2007

Studies from India (Aggarwal, 2009) have projected the following impacts:

(i) increase in CO_2 to above 500 ppm increases yields of rice, wheat, legumes and oilseeds by 10-20 percent;

(ii) a 1ºC increase in temperature may reduce yields of wheat, soybean, mustard, groundnut, and potato by 3.7 percent. Much higher losses at higher temperature;

(iii) productivity of most crops to decrease only marginally by 2020 but by 10-40 percent by 2100;

(iv) possibly some improvement in yields of chickpea, rabi maize, sorghum and millets and coconut in west coast;

(v) less loss in potato, mustard and vegetables in north-western India due to reduced frost damage;

(vi) increased droughts and floods are likely to increase production variability;

(vii) considerable effect on microbes, pathogens, and insects;

(viii) increasing sea and river water temperatures are likely to affect fish breeding, migration, and harvests;

(ix) increased water, shelter, and energy requirement for livestock;

(x) animal distress due to heat, effects on reproduction;

(xi) loss of 1.5 million tons of milk by 2020; and

(xii) imbalance in food trade due to positive impacts on Europe and N. America, and negative impacts on South Asia.

The necessary adaptation measures and agricultural knowledge and technology challenges are given in Table 26.

Table 26. Climate change and adaptation measures in agriculture

Sector	Adaptation Measures	Agrl. Knowledge and Technology Challenges
Agriculture cropping	*Choice of crop and cultivar:* Use of more heat/drought tolerant crop varieties in areas under water stress Use of more disease and pest tolerant crop varieties Use of salt-tolerant crop varieties Introduce higher yielding, earlier maturing crop varieties in cold regions *Farm management* Altered application of nutrients/fertilizer Altered application of insecticides/pesticides Change planting date to effectively use the prolonged growing season and irrigation Develop adaptive management strategy at farm level	▪ Identification of appropriate gene ▪ Lack of resources for the development of varieties ▪ Time-lag between development; field trial, acceptability of farmers and onset of climate change ▪ Onset of new pests and diseases ▪ Needs extensive research on nutrients and fertilizer requirements of new crop varieties ▪ Changing planting date could have effect on yield ▪ Resources and technology require at grass roots level
Livestock production	Breeding livestock for greater tolerance and productivity Increase stocks of forages for unfavorable time periods Improve pasture and grazing management including improved grasslands and pastures Improve management of stocking rates and rotation of pastures Increase the quantity of forages used to graze animals Plant native grassland species Increase plant coverage per hectare Provide local specific support in supplementary feed and veterinary service	▪ Breeding less climate sensitive livestock will be a formidable challenge ▪ Less climate sensitive grass and pasture varieties need to be developed ▪ Many native grassland species are not nutritious for animals ▪ Need resources, advanced technology for feed and veterinary service
Fishery	Breeding fish tolerant to high water temperature Improved fisheries management capabilities to tackle climate change	▪ Cross breeding with fishes from arid region is a possibility but its effects on local varieties will be unknown for long period ▪ Technology and resources will be major obstacle
Development of agricultural biotechnologies	Development and distribution of more drought, disease, pest and salt-tolerant crop varieties Develop improved processing and conservation technologies in livestock production Improve crossbreeds of high productivity animals	▪ Will emerge as technological challenge for poor countries ▪ Faster technological transfer is required ▪ A new nexus between technology owners may emerge to take advantage of climate change
Improvement of agricultural infrastructure	Improve pasture water supply Improve irrigation systems and their efficiency Improve use/store of rain and snow water Improve information exchange system on new technologies at national as well as regional and international level Improve sea defense and flood management Improve access of herders, fishers and farmers to timely weather forecasts	▪ Improved water store, supply and ▪ irrigation need new technologies and replacement of the old ▪ Dissemination of information on technology requires to build institutional capacity and educating farmers ▪ Improved sea defense and flood management have potentials but they have certain limits

Source: IPPC, 2007

4.2.8 Research Priorities for Commodities and NRM

Based on the various priority setting exercises done by national, regional and global institutions in the region or for the region, and arising from the critical analysis of important drivers, the following commodity and natural resource management research themes could be prioritized :

Crops and Horticulture

- Crop varieties for (a) tolerance to abiotic and biotic stresses, (b) raising crop yield ceilings particularly in irrigated areas, (c) better product quality, nutrition, value addition, shelf life and high suitability for processing, and (d) multipurpose use;
- Short duration, period-bound high yielding varieties of rice, wheat and maize to incorporate other crops, especially legumes and vegetables and flowers, in cropping systems to enhance cropping intensity and resource-productivity;
- Diversifying the production system consistent with land, water, social, economic regimes and market demand, particularly integrated management for off-season vegetables, flowers and peri-urban cultivation;
- Improving input use efficiency through ICM, IPM, INM, fertigation, precision farming etc., especially of fertilizers, nutrients, water and energy;
- Designing and improving cropping systems for higher yields, pest management, natural resource conservation, and integration with livestock and trees;
- Sustainable production and distribution of quality seed and planting materials and technology transfer system, including *in vitro* methods;
- Small farm mechanization and protected cultivation of vegetables and flowers;
- Post-harvest handling, value addition through processing and storage; and
- Crop and horticulture-based farming systems suited to distinct agro-eco-regions *viz.* arid, hill and mountain, coastal and hot-humid zones.

Livestock including poultry

- Improving nutrition through: quality of crops residues and removing anti-nutritional factors, strategic supplementation and improved varieties of fodder crops and feed balance and formulation, and reduction in methane emission;
- Animal health by enhanced science-based capacity in epidemiology and diagnosis of and vaccine production for major diseases, disease-nutrition interactions and genetic resistance to major diseases, and overall capacity in management of cross-border diseases and zoonotics;
- Characterization and improvement of local breeds through selective breeding, and evolving a science-led policy on cattle breeding;
- Market development, product processing and biosafety of products with focus on small holders; and
- Animal waste management and socio-economic and environmental impact of crop-livestock systems, including pastoral systems.

Fisheries Coastal

- Sustainable integrated management of coastal systems and marine protected areas, including mangroves;
- Sustainable management of marine shrimp farming (feed, nutrition, health and seed distribution), including effluent management; and
- Reef fishery systems management, crab culture and ornamental fishes.

Fisheries Inland/Aquaculture

- Genetic improvement for growth enhancement and disease resistance;
- Aquaculture systems management, including deepwater rice-fish/freshwater prawn, integrated fish farming, and open water culture-based fishery and cold water fish culture; and
- Fish health management, particularly for intensive culture of fish and crustaceans.

Forestry

- Management of felling-cutting cycles in natural forest, timber utilization, second-growth forests and forest health;
- Inventorying, evaluation and development of forest resources and biodiversity;
- Promotion and management of agro-forestry, landscape forestry, alley cropping, and carbon sequestration and trading; and
- Improvement of medicinal and aromatic plants and enhanced judicious extraction of non-timber and minor products and their marketing.

Natural Resources and Climate Change Management

- Conservation, characterization, evaluation and utilization of genetic (crop, livestock, fish, and tree) resources for food, agriculture, energy, adaptation to climate change and overall income and livelihood security;
- Knowledge-based integrated management of both supply and demand sides of water and other non-renewable resources in the regimes of increasing water crisis, declining natural resources and globalization;
- Improving efficiency in distribution and use of irrigation water, soil, nutrients/fertilizers (policy, technology and institutional issues) through enhancing crop-animal-water-nutrient-implement synergy;
- Technological, institutional and policy options for rainwater harvesting, acquifer recharge, water pricing, watershed management, reclamation of degraded/sodic lands, control/management of saline and arsenic contaminated water and conjoint and multiple uses of water;
- Sustainable integrated land use, organic recycling and soil fertility and water quantity and quality management to maintain crop-soil-water balance particularly under the changing climate regimes; and
- Developing drought, flood and good weather codes, contingency and compensatory farming systems and biotic stress management devices for adapting to abnormal meteorological (weather) and climate changes, duly supported by credible early warning and ICT systems.

4.3 Main Development Policy, Institutional and Governance Barriers and Ways to Overcome Them

4.3.1 Science-led Policy Advocacy and Formulation

Intensification of farming systems is essential if we are to meet the challenges of reducing poverty and feeding an increasing population, but this must be done in a way that is environmentally sustainable, socially equitable and economically viable. In most countries policies aiming to achieve this are very weak. Agricultural and natural resources research (ANRR) system has potentially a huge role to play in providing the robust evidence towards technological backstopping of such issues, based on which such policies can be developed.

Unfortunately the research institutions and community are not very effective at communicating with policy makers and ensuring that information and knowledge is delivered to the right people at the right time in the right format. There is a need to a) better understand the processes leading to agricultural development policies and the contribution provided by research outputs, b) undertake research on how to strengthen the research-policy-practice interfaces to increase the impact of research outputs and c) train researchers on how to communicate and interact with policy makers.

The policy formulation and advocacy systems to guide farmers on biotechnology products and bio-fuel crops should be science-based to allow a consistent and well-thought out long term policy. At present, it is primarily driven by commercial interests of multi-nationals. There is an urgent need to develop local capacity to address technological, food safety, social and environmental issues associated with these products. In the Asia-Pacific region utilization of agricultural land for non-food crops adds challenges and pressure to food production and food security. Misinformed or a "quick fix" diversification may cause damage in the long run.

Policy advocacy and actions are needed on the following aspects:

- Accelerated agricultural productivity and income growth to alleviate hunger, undernutrition and poverty;
- Research, technology and innovations for development with focus on the poor, especially the resource-poor farmers;
- Adequate public and private investment in agriculture as well as in agricultural research, education and extension (REE) and in participatory REE with focus on development;
- Institutional support for bridging yield, employment and income gaps, and for promoting inclusiveness and gender sensitivity;
- Integrated management of natural resources, biodiversity, inputs and biotic and abiotic stresses, including transboundary diseases, biosecurity;
- Informed diversification and promotion of bio-energy;
- Fair trade, input-output pricing, access to domestic and international markets and management of market volatility, linking farmers with markets, Producers' Company, and improving terms of trade for agriculture;
- Climate change management – adaptation and mitigation of crop-animal-soil-water cycle distortions;
- Enabling mechanisms, public-private partnership, knowledge pool and human resource capital (trained youth and women in agriculture); and
- Improve infrastructure, particularly transport and communications, and provide needed amenities in rural areas.

Institutional, human resource and policy supports must capture the positive effects and minimize the negative effects of globalization and liberalization and revolutions in biotechnology and information and communication technologies. Only a meaningful interaction between science and policy can bring the much- needed wholesome growth. Thus, it is not only biological and physical sciences, but also economics and social sciences, which must all interact dynamically to yield wholesome results.

Today's approach to poverty alleviation and food security in agricultural research agrees that while increased aggregate food supply alone is an important achievement, it is not enough to achieve food security at the household and individual level. There is a need to ensure that the food is accessible and affordable and that adequate quantities are consumed and absorbed. Proper nutrition includes health and sanitation - the prevention of diarrhea and other transmitted infections among children. Although agricultural research itself usually cannot address these issues, by being aware of their importance, scientists can more closely integrate with policy makers, so that their contribution to the policy debate is included and that the important outputs targeted at the poor - such as higher quality, more nutritious foods - actually are produced in greater quantities and do reach the poor.

Science should help in resolving the conflicting views on the efficacy of organic agriculture as well as of biotechnology in meeting the objectives of alleviating hunger and poverty. If there are economic and nutrition and biosecurity niches for profitable organic production, farmers should certainly adopt/adapt those. Where agro-technologies generated through the use of biotechnology, such as transgenic crop varieties and hybrids, have a proven advantage and the science is clear about their impact on (a) farmers' livelihoods, (b) human and animal health, (c) biodiversity and (d) the environment, commercial access of these to farmers should be enabled.

4.3.2 Bridging Awareness Gap

Knowledge gaps and lack of awareness have often caused development problems. For instance, in the Pacific, in recent years there has been an alarming increase in lifestyle-related diseases. These diseases of affluence are considered to be the result of an over-reliance on imported and nutritionally poor foods high in carbohydrates and fats. There is a seduction in fast foods. This, plus recognition of vitamin deficiency-related diseases in some parts of the Pacific, has prompted consideration of the contribution traditional food species can make to the nutritional security and well-being of local communities. Nutritional analysis of underutilized species and varieties within species is now being seen as an important component of PGR assessment. The interest is in quality of diet rather than in quantity of food. It is being increasingly recognised that dietary deficiencies create poverty. The genetic diversity that exists in the Pacific is highly significant and could be developed also to secure high-value niche markets.

Science has many roles including to (i) generate knowledge and make it accessible to all, (ii) identify issues - such as the causes and consequences of hunger, food insecurity and poverty, (iii) find facts to help resolve conflicts, and (iv) provide technical, physical and social solutions to problems and new options for human well-being. In the first stages of the fight against hunger, and especially in creating the green revolution, science has been used mainly in role (iv) It is now time to realize the other roles that science must play to aid the world and to meet new challenges.

Paradigm shifts are needed to ensure science-led accelerated and inclusive growth. The first shift relates to a shift in research approach from a single commodity based and monodisciplinary to a farming system based and multidisciplinary. The second shift demands a change from a top-down (training and visit system) extension approach to a participatory (effective research-extension-farmer-market interface) approach of technology assessment, refinement and transfer. The third shift seeks the integration of molecular biology, bio-technology and bio- information with conventional technology as well as with indigenous knowledge for speedy and more precise gains. The fourth shift seeks greater congruence between productivity and sustainability and creation of enabling mechanisms for adoption of new technologies. Cost-effectiveness of production, quality and safety in food and other products, and GMO biosafety and biosecurity, are important in the globalized and liberalized world.

4.3.3 Mutual Enrichment of Traditional and Modern Technologies

Further, it must be rooted in traditional wisdom and rendered increasingly relevant and efficient through blending with modern and dynamic knowledge and processes. Knowledge, old and new, is always a treasure. Generations after generations, farmers and other people have generated new knowledge to cope with their surroundings and environment. Converted into technologies, these are particularly valuable for ecological and social sustainability. On the other hand, science in its leaps and bounds is constantly generating new knowledge and modern technology. The frontiers of technology have been expanding fast. Traditional and modern technologies must be blended synergistically. Legal systems and formal sectors must therefore duly recognize the traditional wisdom and technologies so as to broaden and sustain the knowledge base.

4.3.4 Humanising Science

Technologies while promoting growth must also have a human face. The following features will humanize technologies for ensuring sustainable livelihood:

- Enhance capabilities for sustainable livelihood, and provide for new livelihood opportunities for the poor;
- Improve the productivity, profitability and sustainability of communities' assets, and establish effective linkages between community mobilization and the government and other service providers;
- Ensure the congruence and synergism among environmental, economic and social (gender and other equities) securities; and
- Empower communities, especially the vulnerable ones, to harness new and appropriate technologies and enable them to blend traditional local technologies with modern technologies. If such technologies are developed in close partnership with stakeholders, widespread adoption and further improvement will be assured.

4.3.5 Strengthening Enabling Mechanisms

The existence of an enabling environment to judiciously exploit scientific and technological developments is as important, if not more, as the technology itself. There must be policies, institutions and infrastructures to provide clearly defined and enforceable property rights, reduce transaction costs and encourage broad-based, decentralized development of activities in rural areas to enhance growth efforts. Along with the implementation of policies, there must be reforms that encourage private and public sector participation in economic activities in accord with the comparative advantages. Thus, the public sector should focus on addressing cases of market failure and thus enhance efficiency of private operations, should ensure competitiveness and quality of service, and should address the long-term social-welfare objectives of protecting environments and common-property resources, and of developing human resources. Overall, research in agricultural sciences for impact on food insecurity and poverty should also be strongly linked to strategic assessments of commodity and market trends as well as input supply and constraints of access: the information generated will help to inform/direct investment in science to the greater benefit of the poor and help in reducing the market volatilities, uncertainties and risks which hit the poor most severely. The various global conventions related to AR4D should be internalized in national enabling mechanisms and sub-regional and regional partnerships should be strengthened for faithful implementation of the conventions (Paroda, 2009).

4.3.6 Scientific and Rational Diversification

Diversification has always been an important strategy in agricultural production and distribution in the A-P Region, but sometimes it has not been effective, as conversion of rice fields into saline-water prawn-culture fields in Thailand. Diversification should be : (i) responsive to market changes and to socio-economic and agro-ecological settings, (ii) increase employment/income-generation opportunities and judicious use of land, water, labour, biodiversity and other resources, (iii) reduce the incidence and damage caused by pests and diseases and risk diffusive leading to higher and more stable production and income, and (iv) promote resource conservation through the adoption of integrated farming systems, (incorporating integrated pest management and integrated plant nutrient management), thereby exploiting synergism and lessening the requirements for increasingly scarce water, land, and other resources. To realize these possibilities, appropriate technologies shall need to be developed and disseminated.

Agricultural diversification and intensification must be complementary and not contradictory. This makes greater sense when one thinks in terms of congruence of productivity, sustainability, profitability, and equity. Moreover, diversification should not be seen as an end in itself, but, keeping in mind the needs and prospects at various levels, namely, household, community, village, sub-region, region and nation levels, it should be seen as a means to achieve targeted growth and development. For instance, for diversification out of and around rice, several countries have changed or plan to change their irrigation and water-use systems - which were designed primarily for rice cultivation. However, flexibility should be maintained in the production and processing systems to take advantage of new technologies and opportunities - consistent with long-term socio-economic, ecological, and environmental goals. Policies and institutional support, such as support prices, government procurement, public distribution systems, which are primarily directed to cereals production and distribution, will need to be reviewed.

With globalization and trade liberalization, regions, sub-regions, countries, and within-country ecozones (and depending on comparative advantages and compatibility with agro-ecological and socio-economic settings) are increasingly specializing. Overall, this may or may not lead to increased diversification at farm or/and country level. With the trustful adoption of the various provisions, such as phasing out of subsidies and the adoption of ‘polluter pays’, there shall be pressure to develop technologies and knowledge for improving input (land, water, fertilizer, labour) use efficiency and to minimize pollution. Inefficiency in irrigation (which is widespread) and in cropping and water management must be corrected so that systems become economically competitive and environmentally friendly.

The A-P Region is experiencing a livestock revolution. Since 1980, Asia’s livestock production has grown two to four times faster than the global average, and is forecast to maintain high growth until Year 2030. This will require diversification to forage and feed crops - especially maize. Mixed farming systems are dominant in developing Asia, and are likely to continue so because most of Asia’s livestock are owned by small-holder farmers (Singh and Kumar, 2001). Hopefully, this feature will promote gender equity, since many small-scale and poor Asian women derive proportionately more of their wealth from livestock than do the larger-scale farmers (Wright, 2009). Moreover, mixed crop- livestock farming systems are environment-friendly, are buffered against weather and socio -economic aberrations, and promote organic agriculture. Technologies suitable for mixed farming, especially for small-holdings, should have priority for development and diffusion. Moreover, these production systems should be linked to effective markets to increase farm income.

Technological transformations are intertwined with economic globalization and product diversification. Major political changes and the new tools of information and communication have rendered the world a global village. Liberalization has brought a focus on technology as a major factor in competitive marketing. These developments will promote vertical diversification. Thus, as trade shifts from primary products towards processed and manufactured products, greater emphasis will be needed for agro-processing and post-harvest technologies that convert primary products into quality products and value-added products. Horizontal and vertical diversification can together proceed to expand options for quality products that meet fast-changing demands of local and foreign markets. These moves will promote farmer-industry linkage, small and medium enterprises (SMEs), rural entrepreneurships, and off-farm rural employment. It will be necessary to create marketing infrastructures that pay increased attention to food safety (as by a cold chain) and to minimize post-harvest losses - particularly large for horticultural, livestock, and fish products. Institutional innovations will have to be explored, e.g. contract farming, nucleus-estate linkage systems, and futures markets. The agricultural research system will have to be reoriented towards these new challenges.

4.3.7 Green Agriculture

Low-input, but high return farm practices, integrated knowledge and farming systems based on organic farming principles (green agriculture and not strictly ‘organic’ agriculture), participatory, interdisciplinary and multidisciplinary research and extension approaches should be promoted towards meeting the food, nutrition and income needs of resource-poor farmers, increasing inclusiveness and ensuring resource conservation and sustainability. Use of locally available natural and man-made resources should be promoted so that outputs are efficiently and cost-effectively produced, generating direct benefits to the native poor populations, including the womenfolk.

Emphasis should shift from mere knowledge generation to innovations by involving all major stakeholders, namely, farmers, agro-industry, CSOs and market players. Demand-driven AR4D models should be duly verified by action research through formal, but participatory research and extension teams under real farming situations and, based on merit, the products/processes should be scaled up and scaled out.

4.3.8 Innovations through Partnership

The research led by commitment to a set of guiding values – poverty focus, gender inclusiveness, market-driven, local community demand-led and through partnerships can directly and quickly impact the poor. For instance, the widespread adoption of BRRI Dhan-47, a salinity tolerant rice variety in Bangladesh was facilitated by the Poverty Elimination through Rice Research Assistance Project (PETRRA), a multi-partner project which had impacted the livelihood of thousands of households. Another example on similar lines is from a World Bank funded programme of the Government of Andhra Pradesh, India where local knowledge based alternative methods of crop production through harnessing local knowledge and local natural resource not only for managing pests but also for managing crop nutrients (they called it "Community Managed Sustainable Agriculture – CMSA") succeeded in addressing distress in farming communities. It not only resulted in enhanced net profits of the farmers but even the production and productivity of the different crops increased. Renewed commitment to productivity growth, especially at small farms, is needed. Towards this goal, building on mutual confidence and respect and based on comparative advantages, PPP should be promoted for technology generation and sharing as well as for commercialization with public good in view. Incentives should be provided to those scientists whose researches have helped and are geared to improve the lot of the resource-poor smallholder farmers.

5. MOVING FORWARD: NOT BUSINESS AS USUAL

The "business as usual" has failed the poor and the hungry. Economic downturn, energy crisis, natural resource degradation and climate change challenges demand new modalities, mentalities and policies in agriculture and agricultural research as we move forward to attain the development goals.

In words of Robert T. Watson, Director of the International Assessment of Agricultural Knowledge, Science and Technology for Development (IAASTD), "*If we do persist with business as usual, the world's people cannot be fed over the next half-century. It will mean more environmental degradation, and the gap between the haves and have-nots will expand. We have an opportunity now to marshal our intellectual resources to avoid that sort of future. Otherwise we face a world nobody would want to inhabit*" (IAASTD, 2009).

Ismail Serageldin, former Chairman, CGIAR, has recently (2009) called upon the scientific community, jointly with other stakeholders, *to play an essential role in providing the tools for humanity to satisfy its moral imperative to feed the hungry*. He strongly feels "*It is possible to transform how we produce and distribute the bounty of this earth. It is possible to use our resources in a sustainable fashion. It is possible to abolish hunger in our lifetime, and we need to do so for our common humanity*".

5.1 Targeting the Hungry, the Poor and the Vulnerable

Under the policy umbrella of overcoming the food and agricultural crisis, three sets of complementary actions are needed for fighting hunger and child malnutrition (von Braun, 2009b):

- Promote pro-poor agricultural growth;
- Reduce market volatility; and
- Expand social protection and child nutrition action.

In line with the above, food insecurity and poverty – spread and depth, especially of child and women malnutrition, should be mapped alongwith main underlying factors. Dynamic monitoring, evaluation and impact assessment of various research and technology interventions and their linkages with related development programmes such as integrated child development scheme, rural primary health care etc. should be undertaken. These maps should be superimposed on maps of low yield areas and location-specific causes of the productivity gaps and land factor productivity. Specific land and water use decisions should be promoted by restructured and retooled national systems to realize the yield and income potential and to promote crop diversification in consonance with market opportunities, farmers' income and ecological sustainability. An eco-technology approach encompassing Integrated Crop Management (ICM) inclusive of Integrated Nutrient Management (INM), Integrated Water Management (IWM), and Integrated Pest Management (IPM) - all grouped under "Green Agriculture"; ensure that besides being eco-friendly, the technology should be cost effective and suited to the resource poor farmers, encompassing the three E concerns for sustainable food security: Economics, Ecology and Equity should be concurrently emphasised.

Given that South Asia has the highest concentration of the world's hungry and poor, and the situation has been persisting for the past 20 years or so, a special conference under the GCARD process may be convened to analyse the situation and to formulate an action plan to remedy the malady and ultimately to alleviate the suffering.

The island countries, more than 20 in the region, face the most serious threat from the climate change. A separate conference under the GCARD process on climate change management for island countries may be organised to agree on immediate actions to be taken to avert the crisis and to find long term solution.

5.2 Focusing on Smallholder Farmers

As majority of the farmers in the region are small, marginal and landless, special attention should be paid to knowledge, capacity and needs of such farmers, including women farmers (IAASTD, 2009). Fighting hunger and poverty as well as environmental destruction depends upon ensuring their secure access to and control over land, water, seeds, markets, capital, and basic human rights. Eco-technologies that can increase productivity and profitability in a sustainable manner, while strengthening ecosystem health and lessening the environmental impacts of agriculture, should be promoted. Special emphasis should be placed on enhancing the role of economically viable and technologically feasible renewable energy options and on non-polluting technologies. Governments should utilize agricultural policy tools that internalize environmental externalities, including policies rewarding conservation, stewardship and protection of ecosystem services. Agricultural research, investment, public policies, and trade should also be directed towards ecological farming practices that mitigate greenhouse gas emissions from agriculture, protect the quality and improve the efficiency and management of water resources, and enhance the resilience and adaptive capacity of agricultural systems.

The following policy actions are envisaged:

- Emphasize action research/technology needs of smallholder farmers and the centrality of the PC, successful farming systems of the local area, information dissemination, knowledge and innovation needs for the sustainability of small producers and their communities for development;
- Ensure balanced investment in action AR4D to : (i) cater to the needs of small producers and their communities, (ii) benefits to also focus on dry lands, hills and mountains, small island countries and coastal eco-regions, and (iii) attaining higher net incomes and purchasing power, economic gains by following the local green farming systems;
- Ensure appropriate action research by research institutions working more closely with development agencies and policy makers and also to address the needs of landless farmers, pastorals, small fishers and triblas; and
- Generate knowledge and transform it into development impact through harmonizing research findings with traditional knowledge, and impact will result from increased productivity of all resources, more effective use of products and enhanced capacity to meet new challenges as they occur.

Under land-scarce tropical settings, location-specific smallholder high intensity farms, homesteads and farmsteads should be promoted based on agronomically efficient, socially acceptable, ecologically balanced and economically viable multiple and multi-storeyed cropping systems. Scientific information on long term interaction effects of these systems on production trends, nutrient requirements of the plant community, synergistic effects if any etc, should be collected through intensive multi-disciplinary research efforts, and necessary support should be provided to facilitate effective adoption of the farming modules by the smallholders.

5.3 Political Economy, National Policies and Institutions

Managing the political economy of agricultural policies to overcome policy biases, underinvestment, and misinvestment as well as governance for the implementation of agricultural policies is poor in most Asia-Pacific countries. Domestic agriculture policy and international trade regimes are often not designed to support the basic principles of "right to food" and livelihood security. This has adversely affected implementation of recommendations of several national and international bodies and the ground level actions were unsatisfactory. Of late, however, the anti-agriculture bias in macroeconomic policies has somewhat lessened and governance measures are being put in place in some of the countries, but reforms specific to using agriculture for development are yet to be sharpened and widely implemented. A major hurdle is in the direct flow of funds allocated to the designated action point and the lack of transparency in actual utilization of the funds. A vigil must be maintained by all the partners.

The political economy has also somewhat changed in favour of agriculture and rural development in a few Asia-Pacific countries. For instance, the National Rural Employment Guarantee Act (NREGA) in India is the largest and latest experiment being conducted in rural India to eliminate abject poverty and hunger by giving most marginal sections of population constitution right to work by providing 100 days of guaranteed wage employment in every financial year – a unique positive political action. Democratization and the rise of participatory policy making through involving local self-governing institutions have increased the possibilities for smallholder farmers and the rural poor, including women, to raise their political voices, but the impact is yet to be felt. The private agribusiness sector has become more vibrant, of course, often to promote their own interest. However, the politicians, policy makers, local administration and donors must seize the new opportunities to internalize the voices of smallholders.

A favorable sociopolitical climate, effective governance, and sound macroeconomic policy are prerequisites for establishing effective AR4D systems. Country-specific feasible agenda should be sustainably implemented based on a combination of topical policy objectives, including (i) improving access to markets and establishing efficient value chains, (ii) enhancing smallholder competitiveness and facilitating market entry, (iii) improving livelihoods in subsistence farming and low-skill rural occupations, and (iv) increasing employment in agriculture and the rural non-farm economy, and enhancing skills, as emerged from the E Consultation and F2F Consultation. Proven successful experiences, such as China's Rural Township Development approach and the Producers Company approach should be adopted, and the regional forums, such as APAARI, should facilitate sharing of such experiences.

The market volatilities and financial crisis are impacting development in many developing countries. The tightening of credit is already adversely impacting access to food, inputs and other means of production and markets. Appropriate policy reforms and action are needed to address issues of governance, institutions, support to farmers, increasing the share of agriculture and AR4D in national budgets, capacity building, food quality, bio-security and value-chain, incentives for private investment, and partnerships. Global actors need to deliver on a complex agenda of interrelated agreements and international public goods. Civil society empowerment, particularly of producer organizations, is essential to improving governance at all levels.

Market failures are becoming common features and there is a need for public policy to secure desirable social outcomes. Creation of a sort of market stabilization fund by each Government should buttress the uncertainties. The state should provide core public goods, improve the investment climate for the private sector and strengthen natural resources management by introducing incentives and assigning property rights *viz.* Farmers Rights. Strengthening the capacity and reforming coordination mechanism of the state, particularly of ministries of agriculture, across sectors and partnering with the private sector and civil society is urgently needed for implementing the agriculture-for-development agendas. The “third sector”–communities, producer and other stakeholder organizations, and nongovernmental organizations (NGOs) can improve representation of the rural poor and, in so doing, governance, as amply evident from the E Consultation. Producer organizations can give political voice to smallholders and hold policy makers and implementing agencies accountable by participating in agricultural policy making, monitoring the budget, and engaging in policy implementation. Investment in the social capital of rural organizations, including women’s organizations, are important for such demand-side strategies of improving governance.

Selective decentralization should be promoted to better deal with the localized and heterogeneous aspects of agriculture, especially for extension. Decentralized institutions, complementing the efforts of community-driven development (CDD) programmes, need to address issues of social exclusion. In India, the reservation of seats for women in local councils has helped better target public investments to gender-specific needs, but the impact is not widely visible. Use of information and communication technologies (ICTs) to keep records, share information and monitor progress should be promoted. The CDDs could particularly be helpful in sequencing action on provision of basic services and public goods and engaging in income-generating activities.

5.4 Efficient and Effective Use of AR4D Resources

With the existing, albeit low and declining, resources for AR4D, there is much room for their efficient and effective use and allocation. Strategic result frameworks having built-in quantifiable, time bound and transparent and accountable monitoring system, evaluation and correction in each AR4D programme/project should be formulated and implemented by each Government. Suitable feedback mechanism should also be provided. Governments should also assure adequate and readily available funds for infrastructure, staff salaries and basic R&D facilities and operations.

In some countries, donor contributions represent 30 to 70 percent of agricultural development spending, and sometimes the real AR4D agenda does not get implemented. Country-led agricultural strategies and the broader poverty reduction strategies provide a framework for donors to align their support to the agricultural sector and with each other, using the government's public expenditure and procurement systems as mechanisms for program implementation. At the sub-regional levels, SAARC, ASEAN and SPC provide priorities for coordinating donor investments respectively in South Asia, Southeast Asia and Pacific Islands.

Generally, donors have not been quite as sensitive to the needs of the different sub-regions of the Asia-Pacific. Given the extremely low and lowest allocation per agriculture worker in South Asia, donors' apathy to invest in South Asian agriculture and AR4D can hardly be justified especially when the sub-region continues to be home to 40 percent of the world's malnourished children, thus eroding the human capital and perpetuating deprivation. Unfortunately, the hungry child can't wait. In some of the Southeast Asian countries also such situation prevails and needs to be remedied.

For enhancing magnitude and efficiency of funding, performance-based funding, innovative business models for revenue generation and competitive grant mechanism should be promoted. The related resources of different concerned Ministries should be synergized.

Judiciously and rationally allocate resources for concurrently pursuing research and technology transfer for : (i) maintaining the gains already made (maintenance research), (ii) extending the gains to newer areas, such as rainfed regimes, and (iii) achieving additional gains for piercing the yield, income and quality ceilings. With the increasing biotic and abiotic stresses, maintenance research will gain greater significance.

5.5 Expanding and Strengthening the Ownership of AR4D

Success is more ensured if there is strong ownership of the AR4D. This can only be done if multi-stakeholders/communities actively participate from planning to implementing and monitoring (impact assessments, etc.). There is also need for action research that combines different disciplines (e.g., socio-economic research).

Unilateral development of AR4D has limited impact. There is need to build partnerships and networks with CSOs, NARES, private sector, farmers' groups, etc. harnessing the comparative strengths of the partners. Cross-country NARES (like big brother-small brother types) should be explored. Enhanced south-south collaboration, sub-regional developments (e.g., Greater Mekong sub-region) should be tapped for:

- Value chain development and management, especially those that can link farmers to markets, farmers to technologies (envisage a technology supermarket where farmers can have a choice of technologies and select at competitive prices), knowledge flow and delivery; and
- Innovative business models for financing (through risk management), sustainable water and land use, and improve resilience and funding these measures (e.g., a Climate Change Adaptation Fund).

There is need for aggressive advocacy and communication to increase AR4D funding for Asia and Pacific for it to continue (but in a more efficacious fashion) its global food supplier and poverty alleviation roles. Specifically:

- AR4D needs of developing Asia and Pacific are about US$18 billion/year (current levels), raising from the present allocation of US$6 billion. Obviously will require funding sources from unconventional sources like private sector (supermarkets, agribusinesses, financial markets, development banks); and
- Immediately though, Asia Pacific Governments will need to commit to their national AR4D needs. They should, in the next 5-8 years, commit to increase AR4D support to 1% of their respective GVA for agriculture. Governments should also assure adequate and readily available funds for infrastructure, staff salaries and basic R&D facilities and operations.

5.6 AR4D Plus Plus

AR4D is not a sufficient condition for achieving inclusive food and nutritional security and overall growth of agriculture sector. Policy actions and infrastructure investments are also required:

i. Increase investment in agriculture and AR4D with focus on undernourished, poor, and resource-poor farmers and inclusiveness (women, youth and vulnerable) and emphasise income and productivity growth and alleviation of vulnerability;

ii. Ensure entitlement of the poor to land, water, biodiversity, socio-economic safetynets and markets;

iii. Integrate land and water use planning and management of natural resources, biodiversity, inputs and biotic and abiotic stresses, including climate change, transboundary diseases, and biosecurity;

iv. Build infrastructure needed for efficient value chain networks/highways and provide enabling policies for value chain management and partnerships, and innovative institutional links;

v. Strengthen human resource development, and immediately for capacity building and re-tooling of NARES and technical staff;

vi. Strengthen capacities – infrastructure, ICT, rural/urban markets, human resource capital – trainings and skill development of actors in value chain to meet new and emerging needs;

vii. Facilitate trade and market collaboration, strive for fair trade, pro-poor input-output pricing, access to domestic and international markets and management of market volatility, linking farmers with markets, supporting Producers' Companies and improving terms of trade for agriculture;

viii. Build innovative partnerships, such as farmers participatory plant breeding, to strengthen REE, innovation systems, community-based management of natural resources and mutual enrichment and use of traditional and modern technologies and knowledge systems;

ix. Provide informed options/opportunities to exit farming, particularly to those who are under acute farming-related distresses and to those marginal farmers who despite their best efforts are not able to have their two hands meet; and

x. Congrue and synergise policies and programmes of ministries of agriculture with those of relevant non-agriculture ministries to forge wider links and to benefit from the overall macro-economic policies and programmes, and also promote South-South cooperation.

5.7 Differentiating Responsibilities and Accountabilities of NARS and CGIAR While Strengthening their Collaboration

The responsibilities and accountabilities of NARS and CGIAR should be differentiated. The NARS in individual countries should lead research priority setting with focus on poverty reduction, capacity development and gender issues. The capacity of NARS, especially of the weaker ones should be strengthened to bridge existing wide yield gaps and to up-scale and out-scale proven successful technologies.

A decision-making framework should be in place to empower national programmes to allocate responsibility to determine their own priority research and technologies from technology providers, including CGIAR/IARCs. The international programmes, especially the CGIAR, should devolve some of the people-based programmes to NARS.

The NARS should connect beyond Ministry of Agriculture and expand NARES by converging related programmes in agriculture and concerned non-agriculture ministries/departments, such as Ministry of Finance, Ministry of Planning, Ministry of Rural Development, Ministry of Science and Technology, Department of Biotechnology etc. Further, regular monitoring, impact assessment and mid-course corrections should be built in all AR4D programmes.

While it is essential to create the minimum necessary R&D facilities in all countries, the NARS which are acutely short of finances and other resources may not be able to generate research products in cutting-edge areas. The CGIAR should provide global public goods in the frontier areas of agricultural research and environmental sustainability and enable weaker NARS to participate effectively in global agricultural innovation systems.

Notwithstanding the CGIAR's laudable reiterative objects – Food for People, Environment for People and Policies for People, akin to those of NARSs, as suggested by the F2F Consultation, the Strategy and Results Framework, currently under preparation by the Group's Strategy Team, may consider the following aspects:

- seeking greater involvement of regional fora and NARS and rationally internalizing the needs and aspirations of all the four sub-regions of the Asia-Pacific: South Asia, Southeast Asia, East Asia and the Pacific, and
- avoiding structural and bureaucratic complexities to render the process simple, accessible and exciting for the stakeholders, especially the resource-poor farmers.

5.8 Enabling Cutting-edge Technologies to Serve the People

Biotechnology is one particularly promising way to improve agricultural productivity, and the private sector has played a major role in this area, as witnessed in case of Bt cotton in China and India, which not only significantly increased yield and farmers income, but also reduced pesticide use. Some promising possibilities include golden rice, which could reduce vitamin A deficiency among the poor, and C4 rice, which holds out the promise of higher yields, lower production costs per ton, increased water use efficiency, and reduced nitrogen pollutions – all leading to enhanced and sustained productivity. But these innovations are still not ready to be taken up by farmers. Bt maize is in the offing in the Philippines and elsewhere and Bt rice has also made progress in China but is yet to be released commercially. A comprehensive biosecurity framework is needed that supports the introduction of safe new biotechnologically designed varieties with the potential for increasing the productivity of farmers and the well-being of consumers. Non-transgenic use of biotechnology, *viz* the development of submergence tolerant and blight resistant rice through molecular aided selection should be promoted. This approach should be used also for averting global damage to wheat from new rust races such as UG99.

5.9 Harmonizing Regulatory Regimes (IPR, SPS etc.) and Reorienting Global Institutions

Harmonizing regulatory regimes, standards and intellectual property rights, providing new technologies for the benefit of the poor, managing transboundary livestock, fish and plant pests and diseases, conserving the world's biodiversity, and mitigating and adapting to climate change are major international agendas. Narrow sectoral focus of most global institutions, despite their many achievements, cannot address the interrelated and multi-sectoral agendas. Institutional reforms and innovations are needed to facilitate greater coordination across international agencies, especially the World Bank, ADB, UNDP, CGIAR, FAO, IFAD, and with the new actors in the global arena, including civil society, the business sector, and philanthropy to unleash the powers of agriculture for development. Bill Gates and Melinda Foundation is making an outstanding contribution in this aspect.

5.10 Ensuring Bio-security

Food safety, biosafety, health safety, gene safety and environmental safety, which will also promote international trade, should be ensured. An Asia-Pacific bio-security umbrella for safe international movement of living materials and genetic resources, transgenics and biotechnologically (genetically engineered) designed plants, animals, fish, micro-organisms, and products derived from them would prove helpful. Risk analysis and management frameworks to achieve bio-security should be strengthened and collaboration among diverse interests and institutions (particularly agriculture, public health, environment, trade, and their associated stakeholders) should be improved to achieve bio-security in a mutually supportive manner, thus avoiding duplication and possible inconsistencies (Swaminathan, 2008).

Inter-country cooperation in research and surveillance, monitoring and control for managing trans-boundary movement of diseases and pests (of crops and animals) should be strengthened. This should be strongly linked to such efforts in human health. Monetary benefits should be provided to farmers practicing various safety measures and adopting Good Agricultural Practices. Advocacy dissemination to affected communities to ensure biosecurity is a pressing need. Safety standards and regulations are to be the domain of enforcement system that guide the agriculturists and relevant stakeholders about the global demands and national interest about these issues. Grassroot level literacy and awareness on these aspects can build up only when volumes of market-driven production find place in villages.

5.11 Promoting Agro-Processing and Prevention of Post-harvest Losses

Post-harvest losses, which range from 15 to 30 percent, should be minimized and value, quality and safety along the food chain should be enhanced by modernizing various operations including processing, packaging, transportation, storage and marketing through the value chain system. Emphasizing that unsafe food is not food, or is of little or of negative value for food security programmes and has little marketability, establish a literacy campaign for all involved in production-processing-distribution-consumption chain on quality and food and health safety and revamp university curricula, extension and farmers' trainings programmes to create desired human resources and skill for managing backward-forward linkages along the value chain. Farmers should be trained and aligned all along the value chain.

5.12 Bridging Technology Gaps: Retraining, Retooling and Reorienting Extension System

Scaled-up impact of technology and innovation systems on accelerated and inclusive development depends on more than technology adoption, which, in turn, depends on more than technology generation – underpinning the importance of socio-economic understanding, human resource capital and institutional support. Generation and adoption of technologies and innovations should be rooted in the goals of poverty alleviation, economic growth and environmental conservation.

In order to get technology moving and to ensure its access to farmers, need-based training, retooling and repositioning of cadre of extension workers as a part of the innovation chain should be undertaken. Increased investment, efficiency and systems support, rationalized subsidy and assured timely flow of cost-effective quality inputs credit, insurance and other institutional support are essential elements for efficient transfer of technology. Physical and economic connectivity of farms to market, on-farm grading and packaging, small scale rural agro-processing post-harvest operations including the role of food processing industries, cautious diversification without jeopardizing food security and ultimately enhancing farmers' income and rural employment security are essential components of the backward-forward linkages in the value chain. Inclusiveness should be promoted by enhancing access to land, water, credit, market, skills and technology on part of the poor and women should be empowered to effectively participate in the decision making, implementation and management activities.

5.13 Guiding the Pace of and Benefits from Globalization

Globalization of agricultural trade highlights various issues: access to markets, new opportunities for employment and income generation, productivity gains, and increased flow of investments into sustainable agriculture and rural development. It may force the generation and adoption of new technologies, shift production functions upwards, and attract new capital into deprived sectors. However, this will happen only when the interests of the majority of small- holder and subsistence farmers, fisher-folk, and forest dwellers are given due attention. As we globalise, it is imperative that we do not forget social aspirations for a more just, inclusive, equitable and sustainable way of life. The integration of biological, physical, and social sciences will be necessary to maximize the benefits and minimize the adverse effects of globalization. If managed well, liberalization of agricultural markets could ultimately be beneficial to developing countries and trade could become an important component of food security and income even for the smallholders.

The Association of World Council of Churches Related Development Organizations in Europe (Madeley, 1999, cited in FAO, 2000) analysed 36 case studies in Africa, Asia, and Latin America and concluded that structural adjustment programmes, including trade liberalization, have worsened the food security of rural poor in developing countries. Based on 14 country case studies, FAO (2000) suggested the need for a cautious approach to trade liberalization if social costs are to be minimized, as the trickle down theory has generally failed to operate in most developing economies. This calls for deciding the appropriate pace and sequence of trade liberalization, based on in-depth and dynamic research, and on the status and capability of the driving forces or the economic agents in agriculture - technology, infrastructure, and social settings. The liberalised regime could destroy rural livelihood, since imports of food and agricultural products could amount to import of unemployment (Oxfam, 2000), especially when there are little alternative employment options. Necessary trade protection and safety nets must be provided to protect the small producers whose only livelihood is agriculture. Developing countries and concerned UN agencies should develop and foster a new Trade Ethic, and work to introduce a livelihood security box in the revised World Trade Agreement on Agriculture (Swaminathan, 2000). The NCF (2006) had suggested establishment of national trading organisation in India to provide informed guidance to both production and distribution systems. Unfortunately, several developing countries do not have the required capacity to undertake such studies, nor to make the necessary adjustments. FAO, IFPRI and other relevant international systems must assist such countries.

Asia-Pacific is an economically diverse region, especially in agricultural trade and food security. It includes major net food exporters that suffer food insecurity, and also major net food importers that are relatively food secure. It includes also food- insecure nonfood-trading countries, food-insecure importers, relatively food-secure self-sufficient countries, and food-secure exporters. The differences among them are accentuated by the level of development and the structure of the agricultural sector. Policy researches by the different groups of countries must be carried out, and experiences shared through existing networks. The countries differ widely also in the degree of integration of their science, technology, trade, and liberalization policies. The following key areas could be effectively linked and integrated towards developing suitable trade policies and guidelines.

- Sanitary and phytosanitary regulations, risk assessment and management, especially of transboundary diseases and epizoonotics and quarantine;
- Food quality and food-safety standards, harmonization/implementation of regulations;

- Intellectual property rights, plant-breeder's rights, farmers' rights;
- Regulations and ethics of development and sharing of biotechnology and biotechnological products;
- Environmental assessment and management; environmental accounting, and internalization of environmental costs in pricing and trade; and
- Management of oceanic exclusive economic zones.

Conclusion

Asia-Pacific agriculture must liberate the region from the twin scourges of hunger and poverty and from the curse of carrying over 70% of world's undernourished children and women. It must continue to supply its region and world with food and agricultural commodities. Given that the land, water and agro-biodiversity resources have been fast declining and degrading and the environmental footprint of agriculture has been intensifying, the task is difficult, but not insurmountable.

Accelerated science and innovation-led agricultural growth must be inclusive and address the needs and aspirations of resource-poor smallholders. Most importantly, it must bridge the income divide between farmers and non-farmers which continues to widen from 1:2 about 40 years ago to 1:4 now. Developing Asia-Pacific would need to triple its investment in AR4D, requiring US$ 18 bn/year to generate and adopt agricultural research, technologies and innovations which must be rooted in the principles of economics, equity, and environment to increase productivity, income and livelihoods in perpetuity.

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Agro-ecological Indicators of Selected Countries in the three Sub-regions of the Asia Pacific, 2005

Sub-region/ Countries	Total Popln (000)	Agricultural Popln (000)	%age of Agrl Popln to Total Popln	Ratio of Agrl. Land to Agrl. Popln. (ha/caput)	% Irrigated Land to Agrl. Land (2003)
South Asia					
Afghanistan	25067	19506	77.8	0.41	33.8
Bhutan	637	596	69.1	0.30	23.5
Bangladesh	153281	72029	47.0	0.12	56.1
India	1134403	566140	49.9	0.30	32.9
Maldives	295	74	25.1	0.18	-
Nepal	27093	25211	93.1	0.10	47.1
Pakistan	158080	76192	48.2	0.29	82.0
Sri Lanka	19120	9294	48.6	0.21	38.8
Southeast Asia					
Cambodia	13955	9590	68.7	0.40	7.0
Indonesia	226063	90889	40.2	0.40	12.4
Lao PDR	5663	4479	79.1	0.24	16.5
Malaysia	25652	3656	14.3	2.07	4.8
Myanmar	47967	34663	72.3	0.32	17.0
Philippines	84566	30195	35.7	0.35	14.5
Thailand	63002	28907	45.9	0.61	28.2
Vietnam	85028	54987	64.7	0.16	33.7
East Asia					
China	1320509	843401	63.9	0.18	35.6
DPR Korea	23615	5972	25.3	0.50	50.3
Mongolia	2580	553	21.4	2.17	7.0
Rep. of Korea	47869	3042	6.4	0.60	47.6
Pacific Island					
Fiji	828	318	38.4	0.90	1.1
PNG	6069	4393	72.4	0.20	-
Samoa	183	57	31.1	2.26	-
Solomon Island	472	340	72.0	0.23	-
Tonga	99	31	31.3	0.84	-
Vanuatu	215	71	33.0	1.48	-
Developed Countries					
Australia	20310	849	4.2	58.59	5.3
Japan	127896	3676	2.9	1.28	54.7
New Zealand	4097	331	8.1	10.19	8.5
Asia-Pacific	3753802	1920986	51.2	0.30	31.4
Rest of the World	2760844	689554	25.0	1.40	9.9
World	6514646	2610540	40.1	0.60	17.9

Socio-economic indicators

Sub-region/ Countries	GNI/caput (US$) (2006)	GDP growth (1995-2005)	Agrl. GDP Growth (%) (1995-2005)	Share of Agr in GDP (%) (2005)
South Asia				
Afghanistan	-	-	-	36.1
Bangladesh	480	5.3	3.7	20.1
Bhutan	1410	6.8	3.0	24.7
India	820	6.4	2.7	18.3
Maldives	2680	6.4	-	-
Nepal	290	3.9	3.4	38.2
Pakistan	770	4.0	3.5	21.6
Sri Lanka	1300	4.4	0.9	16.8
Southeast Asia				
Cambodia	480	8.2	4.5	34.2
Indonesia	1420	2.7	2.3	13.4
Lao PDR	500	6.2	4.0	44.8
Malaysia	5490	4.6	2.4	8.7
Myanmar	-	-	-	57.2*
Philippines	1420	4.2	2.9	14.3
Thailand	2990	2.7	1.9	9.9
Vietnam	690	7.2	4.1	20.9
East Asia				
China	2010	9.1	3.7	12.6
DPR Korea	-	-	-	-
Mongolia	880	4.1	-0.4	21.7
Rep. of Korea	17690	4.4	0.8	3.4
Pacific Island				
Fiji	3300	2.3	-0.1	14.2**
PNG	770	1.4		29.0***
Samoa	2270	4.1	-2.6	13.6
Solomon Island	680	-0.4		-
Tonga	2170	2.0	0.1	28.9**
Vanuatu	1710	0.9	1.9*	15.0***
Developed Countries				
Australia	35990	3.6	4.6#	3.4***
Japan	38410	1.2	-2.6#	1.3***
New Zealand	27250	3.1	2.6#	9.5*

Sources: FAO/RAP, 2007

* *Indicates figures for 2000-01*

** *Indicates figures for 2002*

*** *Indicates figures for 2003*

\# *Indicates figures for 2004*

Characteristics and potentials of farming systems: South Asia

Farming system	Land area (percent of region)	Agril. Popn* (percent of region)	Principal livelihood	Incidence of poverty	Potential for poverty reduction	Potential for agril. growth
Rice	7	17	Rice (both seasons), vegetables, legumes, off-farm activities	Extensive severe poverty	Moderate	Moderate
Coastal artisanal fishing	1	2	Fishing, coconuts, rice, legumes, livestock	Moderate to severe poverty	Moderate	Low
Rice-wheat	19	33	Rice, wheat, vegetables, livestock including dairy, off-farm activities	Extensive moderate and severe poverty	High	Moderate-high
Highland mixed	13	7	Cereals, livestock, horticulture, seasonal migration	Moderate to severe poverty	Moderate	Moderate
Rainfed mixed	29	30	Cereals, legumes, fodder crops, livestock, off-farm activities	Extensive poverty, severity varies seasonally	Moderate	Moderate
Dry rainfed	4	4	Coarse cereals, irrigated cereals, legumes, off-farm activities	Moderate Poverty	Moderate	Moderate-high
Pastoral	11	3	Livestock, irrigated cropping, migration	Severe poverty, especially drought induced	Low	Low
Sparse (arid)	11	1	Livestock where seasonal moisture permits	Severe poverty, especially drought induced	Low	Low
Sparse (mountain)	7	0.4	Summer grazing of livestock	Severe poverty, especially in remote areas	Low	Low
Tree crop	Little, dispersed	Little	Export or agro-industrial crops, cereals, wage labour	Moderate poverty, mainly of agricultural workers	Moderate	High
Urban based	Neg	Little	Horticulture, dairying, poultry, other activities	Moderate	Low	Low

Source: Weatherhogg, Dixon and de Alwis, 2001, FAO, Rome
Principal farming systems are shaded.
**Defined as those working in crop or livestock production or forestry and their dependents.*

Characteristics and potentials of farming systems : Southeast and East Asia

Farming system	Land area (percent of region)	Agril. Popn* (percent of region)	Principal livelihood	Incidence of poverty	Potential for poverty reduction	Potential for agril. growth
Lowland rice	12	44	Rice, maize, pulses, sugarcane, oilseeds, vegetables, livestock, aquaculture	Extensive severe poverty	Moderate	Moderate
Tree crops mixed	5	3	Rubber, oil palm, coconuts, coffee, tea, cocoa, spices, rice, livestock	Moderate poverty mainly of smallholders	High	High
Upland intensive mixed	20	28	Rice, pulses, maize, sugarcane, oil seeds, fruits, vegetables, livestock	Extensive moderate and severe poverty	Moderate	Moderate
Highland extensive mixed	6	4	Upland rice, pulses, maize, oil seeds, fruits, forest products, livestock	Moderate to severe poverty	Moderate	Moderate
Temperate mixed	6	14	Wheat, maize, pulses, oil crops, livestock	Extensive moderate and severe poverty	Moderate	Low
Pastoral	20	1	Livestock with irrigated crops in local suitable areas	Severe poverty especially drought induced	Low	Low
Root-tuber	1	<1	Root crops (yam, taro, sweet potato), vegetables, fruits, livestock (pigs and cattle)	Limited poverty	Good	Moderate
Sparse (forest)	11	1	Hunting, gathering	Moderate	Low	Low
Spare (arid)	20	2	Local grazing where water available	Severe	Moderate	Low
Urban based	Not available	Little	Horticulture, dairy, poultry	Low to moderate	Low	Moderate
Coastal artisanal fishing	Not available	Little	Fishing, coconut, mixed cropping	Moderate	Moderate	Low

Source: Ivory, 2001, FAO, Rome/Bangkok
Principal farming systems are shaded.
Defined as those working in farming, forestry or fishing and their dependents.

Agricultural Products Import and Export of Developing Asia-Pacific(Million US$)

Sub-Region/ Country	Imports			Exports		
	1995	2005	GR%	1995	2005	GR%
South Asia						
Afghanistan	81.8	536.0	20.7	49.2	57.0	1.5
Bangladesh	1474.1	2085.3	3.5	13.2	185.3	30.3
Bhutan	8.3	26.8	12.4	2.9	4.8	5.1
India	2390.2	5544.9	8.8	6804.3	10334.3	4.3
Maldives	34.5	128.5	14.1	0.5	0.9	5.2
Nepal	91.6	195.6	7.9	20.0	50.3	9.7
Pakistan	2399.0	2999.3	2.3	1683.2	2697.2	4.8
Sri Lanka	619.4	1351.1	8.1	657.9	198.5	-11.3
Southeast Asia						
Cambodia	372.2	496.9	2.9	49.1	33.2	-3.9
Indonesia	5377.8	6166.9	1.4	5497.5	10918.4	7.1
Lao PDR	119.2	197.4	5.2	23.7	35.4	4.1
Malaysia	4356.8	7170.9	5.1	8041.6	10550.1	2.8
Myanmar	603.0	483.5	-2.2	318.4	248.5	-2.4
Philippines	2609.5	3562.2	3.2	1890.9	1627.7	-1.5
Thailand	2796.6	4543.8	5.0	12140.9	15199.0	2.3
Vietnam	1096.3	2158.3	7.0	1445.7	2326.3	4.9
East Asia						
China	31058.0	47784.1	4.4	18394.6	23107.7	2.3
DPR Korea	229.4	534.6	9.4	73.1	29.4	-8.7
Mongolia	51.0	169.3	12.7	46.9	125.2	10.3
Pacific Island						
Fiji	68.25	199.57	11.3	211.48	362.12	5.5
PNG	131.24	235.02	6.0	368.44	366.65	0.0
Samoa	15.61	90.31	19.2	2.70	9.85	13.8
Solomon Island	13.29	14.29	0.7	1.94	4.52	8.8
Tonga	15.51	24.80	4.8	11.62	7.32	-4.5
Vanuatu	11.90	21.16	5.9	12.27	14.81	1.9
Developing Asia-Pacific	70199.6	105253.9	4.1	59480.8	83314.3	3.4

Source: FAO/RAP, 2007

Annexure VI

CGIAR Priorities for Asia, 2003

CGIAR: Prioritizing Areas of Work by Asia Panel
[Indicative allocation of 200 voting points)

Germplasm Improvement (45)	
1. Enhancing germplams through conventional approaches	15
2. Enhancing germplasm through biotechnology	10
3. Characterization of genetic traits in plants and animals	5
4. Stress resistance in food staples	5
5. Nutritional content of food staples	5
6. Work on high-value crops with export potential	5
Germplams Collection and Conservation, Saving Biodiversity (15)	
1. Sustaining biodiversity	5
2. Help partners live up to international obligations (e.g. CBD)	0
3. Collect, conserve, evaluate, enhance, distribute, etc. germplasm	10
Sustainable Production System (45)	
1. Defining production potential of the natural resource base	5
2. Synthesis, storage, dissemination of NRM information	5
3. Integrated Natural Resources Management: develop	5
4. Effective pest management/Integrated pest Management	
5. Integrated Crop and Livestock System	10
6. Forage and feed crops as component of systems	
7. Integrated Nutrient Management Systems	
8. Small-Scale Water management and Water Use Efficiency	5
9. System for drought prone areas	10
10. Farm mechanization	5
Improving Policies (25)	
1. Public and private sector issues	5
2. Incentives and market: input and output markets, seed	2
3. Study opportunities for post-harvest value-added/processing	8
4. Understanding farmers' acquisition and use of nutrients	
5. Studies to improve the funding levels/allocation of resources	5
6. Better understanding of poverty dynamics (especially in LFAs)	5
Strengthening NARSs and other Rural Institution (25)	
1. Training of scientists and research managers	5
2. Training materials on crops	
3. Research on empowerment of farmers and communities	
4. Build organization and management capacity NARIs	15
5. Research on agricultural innovation systems and innovation processes	5
6. Building capacity of SROs (sub-regional organizations)	0
Crosscutting Activities and Outputs (45)	
1. Identifying poverty: mapping location and correlates of the poor	10
2. Development of new research tools (e.g., biotechnology, genomics)	10
3. Development of new information tools (e.g., GIS, modeling of systems)	10
4. Doing better, stronger impact work in and on the system	15

Source: CGIAR (2003)

Agricultural Research Networks in Asia-Pacific

- Alternatives to Slash-and-Burn Programme (ASB)
- Asia and Pacific Regional Network of the International Network for Improvement of Bananas and
- Plantains (ASPNET)
- Asia Forest Network (AFN)
- Asia Pacific Grouper Network
- Asian Network on Sweetpotato Genetic Resources (ANSWER)
- Asian Rice Biotechnology Network (ARBN)
- Cereals and Legumes Asia Network (CLAN)
- Council for Partnership on Rice Research in Asia (CORRA)
- Development and Use of Hybrid Rice in Asia
- International Coconut Genetic Resources Network (COGENT)
- International Network for Genetic Evaluation of Rice (INGER)
- Network of Aquaculture Centers in Asia & the Pacific (NACA)
- Regional Co-operation in Southeast Asia on Plant Genetic Resources
- Regional Network for Conservation and Utilization of Plant Genetic Resources in East Asia (EA-PGR)
- Rice-Wheat Consortium (RWC)
- South Asia Network on Plant Genetic Resources (SANPGR)
- South Asia Vegetable Research Network (SAVERNET-II)
- Southeast Asian Network for Agroforestry Education (SEANAFE)
- Southeast Asian Sustainable Agriculture Knowledge Network (SEASAKNet)
- Tropical Asian Maize Network (TAMNET)
- Underutilized Tropical Fruits of Asia Network (UTFANET)

South Asia Sub-regional Report

Prioritizing the agricultural research agenda for South Asia: refocusing investments to benefit the poor

(Mruthyunjaya and Praduman Kumar)

Executive Summary

The Global Forum on Agricultural Research (GFAR) in collaboration with the Consultative Group on International Agricultural Research (CGIAR) aims to reshape the global agricultural research agenda for development and re-orient it to the needs of the poor through agricultural research synergized with adequate and rapid supply of agri-services. The effort is supported by Asian Development Bank (ADB) and Asia-Pacific Association of Agricultural Research Institutions (APAARI). The process consists of preparation of regional reports incorporating feed back from well structured and widely organized E Consultations with all the relevant stakeholders in the region and face-to-face regional and global consultations. The report on hand deals with South Asia which also includes the main feed back (voice of the stakeholders of the region) from E Consultation spanned from September 1 to 24, 2009 and F2F meeting held during 30-31 October, 2009.

South Asia comprising the countries of Afghanistan, Bangladesh, Bhutan, India, Maldives, Nepal, Pakistan and Sri Lanka has shown impressive growth of about 6.5% annually during 2001-06 owing to adoption of pro-growth policies. Rapid growth has significantly contributed to reduction of poverty as well. Progress in human development index is also observed. Notwithstanding these positive developments, South Asia still tops in the home of the poor in the world with about 400 million below poverty line people. The numbers of undernourished, under-weight and under-height children, and of low birth-weight infants in the South Asian region are substantial. There has been a rising inequality within and among the countries of the region. Agriculture is the main source of livelihood of people in these countries. Despite impressive GDP growth in agriculture in recent years, dependence of people on agriculture as a principal occupation has seen very little decline. Disparity between per worker income in agriculture and non-agriculture sectors is the main source of income inequality in South Asian countries. Further, agricultural productivity has considerably slowed down and further increase in productivity requires more and more use of expensive external inputs like fertilizer, plant protection chemicals, machinery, etc. There has been stagnation or deceleration in total factor productivity growth in majority of crops/enterprises. Technological breakthroughs are not visible owing to unfavourable, declining, degrading soil-water ecosystems, enhanced biotic and abiotic stresses, significant post-harvest losses, dwindling national and global funding support to agriculture in general and agricultural research and education in particular, restrictive knowledge-sharing opportunities, stagnating capacity and skills, uncertain policy support, collapsing service and support system and indifferent, inefficient and non-supportive governance system. Combined with these are deplorable basic facilities like health, sanitation, literacy, which have made rural life highly miserable, and agriculture unrewarding. New opportunities are also emerging in

the form of demographic advantages (more young people), new technologies (biotechnology, nanotechnology, information technology), diet revolution and changing demands, emerging value chains and super markets, entry of private sector, etc. Above all, the recent dramatic rise in the prices of basic foods has sent a shock wave through the world community, particularly poor people, arousing individuals and institutions from years of complacency about the state of the agricultural sector. Numerous studies have shown that investments in agricultural research typically rank first or second in terms of returns to growth and poverty reduction, along with investments in infrastructure and education. Fortunately, there is a consensus and also action in these countries towards higher investment in agriculture and related areas. The obvious questions in this context are how much this investment should be and where should it be focused.

The organization and management of agricultural research in the form of National Agricultural Research Systems (NARS) in these countries is at different stages of evolution. Some NARS like in India and Pakistan, are relatively large and strong whereas, in others they are weak. Over the years, they have tried to respond to the changing contexts by re-orienting their structure, functioning, priorities and activities. Some of these countries, particularly India, has made systematic efforts in agricultural research prioritization and utilised the results for research resource allocation. The efforts of APAARI in guiding the research prioritization process in the region are also significant.

Over the years, commodity, regional, within the countries, sub-regional, and Asia-Pacific region priorities have been defined through consultations as well as using standard prioritization methodologies. The results from this empirical exercise suggest that (a) cereals, horticulture, livestock and fisheries in commodity groups and rice and milk as commodities should receive greater attention in resource allocation at South Asia level with certain minor variations among the countries, (b) prioritization exercises need to explicitly target poor as otherwise their needs are under-funded, and at least 2-3 times (if the AgGDP growth is assumed at 2.1%) and 3-4 times increase (if the AgGDP growth is assumed at 4%) in funding support in these countries to agricultural research and education to attain food and nutritional security and social empowerment. The uniqueness of the analysis is that it has used standard methodology commonly understood by decisions makers, poverty focus, demand driven approach and estimated the research investment needs to sustain food and nutritional security and social empowerment. Four percent growth in agricultural GDP can only be achieved with greater emphasis on the development of livestock, horticulture and fishery sectors. The feedback from E Consultation suggest the over-arching non-commodity based priorities as NRM, socio-economics and policy research, germplasm collections, conservation and improvement, strengthening of NARS institutions, strengthening of basic and strategic research in frontier areas of agricultural sciences, major focus to be given to upgrading the skills of farmers and change agents, follow participatory action research in value chains and sustainable livelihood security, more investment on education, roads, markets, power supply, communication, health and sanitation services, strengthening farmers' organizations including aggressive strategy to involve private sector, and effective management of service and support system, safety net and income enhancement programmes and better governance and political will and commitment in general. Besides these, the F2F meeting identified specific investment areas requiring additional attention which include (a) Farming systems approach in ecosystem framework to pursue diversification (livestock, horticulture, fisheries), (b) Focus on women and youth in agricultural research, (c) Inclusion of local crops, along with wheat, rice and pulses as priorities, (d) Involve progressive successful farmers, NGOs and private entrepreneurs in technology transfer, (e) Address impact of climate change on agricultural production (f) Develop contingent plan for natural calamities, (g) Focus on post-harvest management, value addition, quality improvement and safety, (h) Improve risk management capacity by suitable farmer friendly policies, programmes and business models, (i) Linking farmers with market through value chain approach, (j) Policy dialogue with effective communication, (k) Blending modern technologies, innovations with proven indigenous technologies, and (l) Exploring income and employment opportunities beyond agriculture in rural areas. If these recommendations are attended, the growth in SOUTH ASIAN countries will be not only faster but also inclusive.

Southeast Asia Sub-regional Report

Prioritizing the agricultural research agenda for Southeast Asia: refocusing investments to benefit the poor

(David A. Raitzer, Johannes Roseboom, Mywish K. Maredia, Zenaida Huelgas and Maria Isabel Ferino)

Executive Summary/Synthesis

Agricultural research investments with the highest expected levels of benefits for the poor and the environment, and contrasts relative expected impact potential with current relative funding allocations across research areas were identified. Current investment patterns by National Agricultural Research Systems (NARS) in the sub-region and by International Agricultural Research Centers (IARCs) were quantified to explore present allocation patterns.

The value of production of the top 20 agricultural product groups was calculated, and projections were made based on recent growth trends for values of production in 2020. This was used to calculate the expected economic surplus effects of a 5% reduction in the average unit cost of production for commodities with the highest production values. A poverty weighted value of production was calculated by overlaying spatial crop production data with poverty maps, which was applied to estimate benefits to poor producers. Expected expenditures by the poor on different food items were calculated for 2020 and were used to estimate the portion of economic benefits accruing to poor consumers. These estimates were compared with indicative values for environmentally and nutrition oriented research.

A comprehensive inventory of past documented research benefits was performed, and patterns of economic benefits accruing from research on different commodities and from different activities are compared. This was complemented by an analysis of important changes in the context for agricultural research and agricultural production, which will affect future impact potential.

Projected potential benefits, patterns of documented historical impact, and implications of future trends were drawn together, and were compared with current investment levels. This analysis finds key gaps between current investments and expected impacts for productivity enhancing research on rice, vegetables, fruit and aquaculture, with the rice gap the most pronounced, as it was the source of 87% of documented past research impact and over 40% of quantified potential future benefits for the poor. In terms of research activities, genetic improvement was the most substantial investment gap, as it accounted for 80% of documented past impact, and recent advances in genomics were likely to continue this trend, but it received only 15% of NARS investment in the sub-region. Post-harvest research was also identified as an investment gap, given increasing demands for food quality. Livestock in aggregate was not a pronounced investment gap, as its aggregate funding share is rather high. However, within livestock, current investments seem overly targeted towards beef, dairy, sheep and goats, relative to pork and poultry, which are projected to have more impact potential (and which are currently associated with zoonotic disease risks).

Although some of these investment gaps may appear to represent areas of substantial prior research, new investments should not be interpreted as merely “more of the same”. For example, additional investments in varietal improvement will need to tackle new challenges, such as the effects of climate change, and developing traits that integrate effectively with expected changes in management systems and market demands, as well as particular environmental constraints. In so doing, the potentials of marker assisted selection, genomics and computational bioinformatics should be exploited, and the private sector should be increasingly engaged where appropriate. Post-harvest research should draw upon the potentials of nanotechnology and will need to be integrated with market development, agronomic research and varietal improvement. All of this implies substantial changes in how research is organized and supported, so that a new generation of agricultural technologies can fulfill their potential to generate extensive benefits for the poor and the environment.

Annexure X

GCARD 2010 Pacific Sub-Regional Report

Transforming Agricultural Knowledge into Development Impact for the Pacific

(Alan R. Quartermain)

Executive Summary

The Pacific sub-regional report sets out considerations for the prioritization of agricultural and natural resources research and development with the overall theme of transforming knowledge into development impact. It is based on a recognition of present capacity, constraints and challenges, as well as opportunities to address the real needs of the 80-90 percent of the island populations directly dependent on their sustainable use of renewable natural resources for sustenance, health and prosperity. While in half of the countries over half of the population is urbanized, these people need food security. The emphasis is on combating hunger, malnutrition, poverty and environmental degradation.

The 22 island countries under consideration are extremely diverse in every possible way – ecology, demography, economy and culture – but its rural people have a commonality of approach to agriculture or gardening, coastal or forest management, and community development. They share in common the Pacific Ocean with its resources, including Exclusive Economic Zones much larger in most cases than the land areas. Their opportunities are constrained by extremely small populations, limited land, vast distances between countries or even between islands within countries, high costs of transport and communications, and poorly developed policies or capacity for research and its application for development. Atolls have particular problems since they are not rich in biodiversity, there are shortages of fertile soil and fresh water, and they are extremely vulnerable to natural disasters and the predicted effects of climate change.

The key priorities of subsistence or smallholder farmers are for food security and income generation. Most rural people eat enough most of the time but their diets are so often nutritionally unbalanced. Over-reliance in some countries or in urban areas on imported food has led to increasing health problems. In other situations there is protein-energy imbalance and hidden hunger. Many communities are so isolated that they have very few opportunities for any form of income generation and so cannot purchase food in times of natural disaster such as drought. They are truly neglected. Domestic markets for agricultural products are small and export opportunities limited. Income from remittances sent by family living abroad, mining, logging, tuna fishing and a few exported agricultural commodities such as sugar, cocoa, coffee and palm oil give an illusion of wealth which is not reality for most rural people and urban immigrants.

The results of previous exercises in research prioritization were based on limited consultation with stakeholders and assessment as to feasibility and potential impact. High priority research areas covered crop production and improvement, livestock, forestry, fisheries, natural resource management, marketing, mechanization, socio-economic studies and bio-security. These are still valid since little has been done in most areas or countries over the past decade. Little is really known about which species or varieties of crops or livestock are best suited for specific local conditions, how much labour is

required to produce them, and what are the comparative nutritional advantages of each product. Traditional foods are not inferior foods and the focus should be on these with additions to reduce vulnerability and create new opportunities. There is continuing interest everywhere in the traditional basic staple food crops – roots and tubers, banana, breadfruit and sago – and new or renewed interest in traditional or indigenous fruit, nuts and vegetables.

There are a reasonable number of scientists working in the region but much of this resource is primarily engaged in tertiary teaching, administration or conduct of bio-security measures. Lack of research capacity is a very real constraint. The tertiary educational institutions with natural resource programmes vary in their abilities to attract and train research and development personnel. Agricultural science has always been an undervalued profession because its impact is not readily identified. Effective research requires a better understanding of the farmers and their systems, their traditional knowledge and capacity for innovation, and what they are willing and able to do. Then it is essential to include them and all other relevant actors in planning of the research right from inception and continuing their involvement. Uptake will then be likely to be more successful. Farmers are innovative if they are not desperate and can take risks, and good news spreads quickly in spite of poor communications. Participatory approaches fit well with Pacific social systems built on cohesiveness, sharing and democratic decision making.

The tendency in looking at priorities and gaps is to concentrate on the constraints of limited resources, isolation, rapid population increases, infrastructure, health and education. But natural resource research cannot deal with these. The challenge is to find ways around them. Farmers have needs and aspirations to meet but not at any cost and availability of labour will always be limiting. Hence we need products that are light weight and travel well, identification of niche export markets as well as domestic demand, and low input systems. Smallholder production of current export crops can be doubled with improved management and no further research but yet this is not happening because of social constraints. Innovation Systems studies may help to uncover weak linkages requiring attention. There are numerous identifiable success stories in technology uptake from which lessons can be learnt.

The Secretariat of the Pacific Community (SPC) and the Australian Centre for International Agricultural Research (ACIAR) are the key regional support agencies. SPC provides technical assistance, research support and capacity building in agriculture, forestry and fisheries while ACIAR is the primary collaborator and donor in these areas for six of the seven largest countries. The United States and France support those countries in their respective spheres of influence. Networking has been, and continues to be, of major value in making efficient and effective use of individual country strengths, capacities and donor support. There is a serious regional shortage of plant breeding expertise.

Areas of particular research need include readiness for climate change, means for improving human nutrition, soil and water management, communal fisheries management and stocks assessment, non-timber forest products providing incentives for forest retention and management, minimal labour and other input production, and improved crop and livestock productivity through selection and breeding as well as agronomy and husbandry, including pest and disease management. Networking and cooperation to share resources of knowledge, skill, bio-diversity and capacity, are critical to success. Other areas of research interest include livestock production systems, agro-forestry or farm forestry, fresh water and marine aquaculture, bio-prospecting or bio-discovery and assessment of products with medicinal or other valuable properties, the use of coconut oil for bio-fuel, organic production systems, seed selection processes, post-harvest handling and processing, marketing systems, and demand and supply analyses.

The critical need is to generate knowledge and transform it into development impact through harmonizing research findings with traditional knowledge. Impact will result from increased productivity of all resources, more effective use of products and enhanced capacity to meet new challenges as they occur. The following research areas are assessed as having the greatest priority in terms of meeting critical needs and challenges by filling gaps that need urgent attention with increased effort and support:

- Horticultural crops for meeting climate change challenges, especially for atolls
- Horticultural crops and varieties to improve human nutrition
- Communal coastal or reef fisheries management, including stocks assessment
- Incentives for forest retention and management
- Management of the pressures on soil and water use and soil fertility.

Horticultural crops include the traditional crops given prominence in a Pacific Crops for the Future workshop in September 2009. They also include those crops most likely to find export niche markets accessible by smallholder producers but relying on public-good funding for such development.

The Pacific working group at the GCARD 2010 Asia-Pacific Regional Meeting in October 2009 developed a set of broader themes which cover these identified research priorities. Integrating rural people's existing knowledge with new knowledge from research and the critical need for working with, and not for, rural people who, even if disadvantaged, will go to extraordinary lengths to maintain cultural integrity are at the heart of all Pacific Island proposals. The themes are:

- Value adding at a range of levels for domestic and export niche markets
- Crop improvement and breeding
- Meeting climate change through prediction, risk management and recovery strategies
- Community-based systems for managing all natural resources
- Bio-security, trade facilitation and market access.

Commonalities underlying all the priorities are capacity building, public and private investment, linkages or networking within and between countries and regions, continuity of effort, sustainability and strategic planning.

Pacific governments seem simply to take the natural resource sectors for granted and assume that these sectors will continue to put food on the table, generate export income and support the rural majorities. The greatest challenge of all is advocacy to persuade governments and influential persons to take agricultural and natural resource development seriously and institute policies to allocate adequate resources to these sectors before it is too late. Agriculture, fisheries and forestry need to be recognized and treated as the primary drivers of sustainable development. All other issues are secondary and all else necessary for improved livelihoods and prosperity should follow.