
**SCIENCE AND TECHNOLOGY FOR
SUSTAINABLE FOOD SECURITY,
NUTRITIONAL ADEQUACY, AND
POVERTY ALLEVIATION
IN THE ASIA-PACIFIC REGION**



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PREFACE

Agricultural science and technology development played a pivotal role in meeting the challenge of producing enough food to feed the additional billions in the last 50 years. In the Asia-Pacific Region, the green revolution, ushered in during the mid-1960s, secured major increases in grain yield, more-than-doubled cereal production, and halved the proportion of hungry and poor people.

Yet, nearly two-third of the world's poor and undernourished have their homes in the Asia-Pacific Region, and the reduction in their number is far short of the 1996 World Food Summit target. The green revolution generally by-passed the vast unfavourable rainfed and other non-congenial production regimes which are inhabited mostly by poor, and had often added to land and water degradation and biodiversity erosion.

There are significant inter country differences in yield increases and per capita calorie availability, depending on technological capacities, policies and investments in agricultural R & D. Towards the years 2015 and 2030, about half of the increase in world's population will materialize in Asia, further stressing the land, water and biodiversity resources. Most farmers are small-holders and poor. These challenges call for more focussed and intense research to generate problem-solving technologies, strategies and policies. While greater resources need to be channelled to research strategies that directly benefit the poor and the less-favoured lands, the efforts in favoured lands must not slacken to ensure steady overall national agricultural output.

This study has examined agro-biophysical, socio-economic and environmental settings in the Asia-Pacific Region and suggests R & D strategies to fight hunger and poverty. Needs, aspirations, priorities and constraints inevitably vary widely by region, sub-region and country-hence the importance of a science policy and research strategy for every country. It must be recognized that technology is only one instrument in fighting hunger and poverty and that no technology can be a magic bullet to solve veritable problems. The science-led growth must therefore be seen within the broader context of agriculture-led national growth and development efforts involving different stakeholders.

FAO's role in fostering national, regional and global capacities in agricultural research and technology development has been analyzed. Highly constructive and valuable comments received from various FAO colleagues in finalizing this publication are greatly appreciated. It is hoped that scientific and technological innovations will be matched nationally and internationally by policy and partnership innovations and political commitment to achieve the goals set by the World Food Summit.

R.B. Singh

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ACRONYMS and ABBREVIATIONS

ACC/SCN	Administrative Committee on Coordination/Subcommittee on Nutrition
ADB	Asian Development Bank
Agric Popn	Agricultural Populations
AMBIONET	Asian Maize Biotechnology Network
APARIS	Asia-Pacific Agricultural Research Information System
APAARI	Asia Pacific Association of Agricultural Research Institutions
ARBN	Asian Rice Biotechnology Network
BSE	Bovine Spongiform Encephalopathy
CBD	Convention of Biological Diversity
CCA	Common Country Assessment
CGIAR	Consultative Group on International Agricultural Research
CIMMYT	Centro Internacional de Mejora miento de Maiz y Trigo (International Maize and Wheat Improvement Centre)
DNA	Deoxyribonucleic Acid
DPSIR	Driving Force-Pressure-State-Impact-Response
ESCAP	Economic and Social Commission for Asia and the Pacific
excl.	exclude
FAO	Food and Agriculture Organization of the United Nations
RAP	Regional Office for Asia and the Pacific
FIVIMS	Food Insecurity and Vulnerability Information and Mapping Systems
GDP	Gross Domestic Product
GIS	Geographic Information System
GMOs	Genetically Modified Organisms
GNP	Gross National Product
GR	Growth Rate
HACCP	Hazard Analysis Critical Control Point
Ht	Herbicide tolerant
HYVs	High Yielding Varieties
IARC	International Agricultural Research Center
IARI	Indian Agricultural Research Institute
IDA	International Development Assistance
IFAD	International Fund for Agricultural Development
IFPRI	International Food Policy Research Institute
ILO	International Labour Organization
IMPACT	International Model for Policy Analysis of Commodities and Trade
IPM	Integrated Pest Management
IPNM	Integrated Plant Nutrient Management
IPNS	Integrated Plant Nutrient System
IPR	Intellectual Property Right
IRRI	International Rice Research Institute
ISAAA	International Service for the Acquisition of Agri-biotech Applications
IWMI	International Water Management Institute

kcal	kilocalorie
kg/ha	kilogram per hectare
NARS	National Agricultural Research System
OECD	Organization for Economic Co-operation and Development
PRSP	World Bank's Poverty Reduction Strategy Paper
PSR	Pressure-State-Response
R&D	Research and Development
SIMA	Statistical Information Management and Analysis
SMEs	Small and Medium Enterprises
SNA	System of National Accounts
SOFI	State Of Food Insecurity
SPFS	Special Programme on Food Security
SSR	Self Sufficiency Rate
TAC	Technical Advisory Committee
TAI	Technology Achievement Index
TFP	Total Factor Productivity
TRIPS	Trade-Related Aspects of Intellectual Property Rights
UNCTAD	United Nations Conference on Trade and Development
UNDAF	United Nations Development Assistance Framework
UNDP	United Nations Development Programme
UNDP, HDR	Human Development Report
UNESCO	United Nations Educational Scientific and Cultural Organization
UNIDO	United Nations Industrial Development Organization
WAICENT	World Agricultural Information Centre
WFS	World Food Summit
WHO	World Health Organization
WTO	World Trade Organization

EXECUTIVE SUMMARY

The past and present situations

The science- and technology-led synergism among enhanced genetic potential (improved seeds), irrigation and fertilizers, coupled with political will and policy support, ushered in the Green Revolution in the Asia-Pacific (A-P) Region in the late 1960s. It more than doubled the cereal production, halved the real price of major food grains, increased the per caput food consumption by about 30 percent, more than doubled per caput GDP, and halved the percentages of hungry and poor people.

Yet, the region is home to nearly 500 million undernourished - including 160 million children, and 800 million poor people - two-thirds of the world's hungry and poor. House-hold security and access to food thus continue as major main challenges, as do access to education and to primary health care. With a "business-as-usual" approach, the target of halving by 2015 the number of hungry and poor (as resolved by the World Food Summit and the Millenium Summit) will not be achieved.

Problems

The Green-Revolution intensification process was accompanied by degradations of land, water, biodiversity, and other environmental features. The Green-Revolution technologies generally bypassed the vast rainfed and other marginal areas where hunger, poverty, instability (of production) and resource fragility are concentrated. In the A-P Region (the home of three-fourths of the world's farmers), the per caput availability of land (less than one-fifth of that in the rest of the world) and of water is lower than in any other UN-System region, and is still declining.

Despite substantial yield gains during the Green Revolution, average yields of most commodities in most developing countries are low, and there are serious yield gaps. Moreover, total factor productivity (TFP) growth rates for major commodities have decelerated (and in some production systems may have shrunk); there is general and considerable scope for improving overall productivity and input-use efficiency.

Investment in agriculture and agricultural research and technology development is low and declining - despite a very high rate of return on investment in A-P agricultural research (48 percent during 1958-98). The Technology Achievement Index (TAI) of most developing countries in the region is low to modest. The technological and digital divides between developing A-P and the developed countries are wide.

Challenges

By 2030, the population in South and East Asia together will have increased by nearly one billion to 4.22 billion (then constituting 52 percent of the world population). Together with increase in incomes, this population surge will require 80 percent increase in total agricultural production, including an additional production of 380 million tons of cereals - an increase of 53 percent. Because there is negligible scope for expansion of cultivated area, 83 percent of the increase in grain production must

accrue through yield increase, and 12 percent through increased cropping intensity. This intensification implies one ton additional grain per ha - analogous to the gains achieved during the Green Revolution era. But, this will have to be achieved from lesser land and water resources. Also, pre- and post-harvest losses in the region need to be reduced: they range from 15 to 30 percent, with losses particularly high in livestock, fish, fruits, vegetables and other perishables.

Increasing income and urbanization (in 2030, 53 percent of the Region's population will be urban, against the current level of 34 percent) have triggered greater demand for meat, milk and dairy products, eggs, vegetable oil, fruits, vegetables, processed food and other high-value products. To meet the demand, the Region has intensified livestock and aquaculture production, and is witnessing a revolution in this subsector - though often at high environmental cost. High growth rates during 2002-2015 (3 to 4 percent) in fruit, vegetables, and livestock production will be more than double that of the cereals. Peri-urban agriculture will increase. Fodder and feed demands will intensify - especially in East Asia, where 45 percent of the total cereal (mostly maize) consumption will be for animal feed. Demand for cereals and livestock will outstrip production - necessitating escalation of net imports, particularly in East Asia, of both cereals and livestock products.

The role of science and technology

Science and technology development must address five interdependent aspects for attaining the desired productivity and sustainability in order to break the unholy alliance of hunger, poverty, and environmental degradation:

Protecting the yield gains, bridging yield gaps, and enhancing yield and productivity levels, including quality upgrading, value addition and prevention of post-harvest losses: This should be achieved within the bounds of technological, social, economic, biological, cultural and environmental (soil, water, other inputs) constraints and potentials. Sustaining the TFP growth and raising competitiveness should be the primary goal. The dominant farming systems in South Asia are rice-wheat, rainfed mixed, rice, and highland mixed, and in East Asia lowland rice, upland-rice intensive mixed, temperate mixed, and tree-crops mixed. Those with highest potential for poverty reduction are rice-wheat in South Asia, and tree-crop mixed in East Asia. Livestock and horticulture are integral components of these systems. The yield gaps and potentials of each system need to be clearly identified, and suitable technology packages designed to bridge the gaps.

Biotechnology: Harnessing the gene revolution: Biotechnology interventions are already in use, and have the potential to enhance yield levels, increase input-use efficiency, reduce risk, increase resistance/tolerance to biotic and abiotic stresses, lessen pesticide use, lower production costs and food prices and improve nutrition; they can be positively pro-poor. However, there are genuine and perceived food biosafety, environmental, socio-economic, and ethical risks of biotechnology; these must be scientifically and transparently assessed, minimized, and managed.

Benefiting from information and communication technology revolution and promoting knowledge-based development: Current networking and knowledge-sharing opportunities must be captured to empower people (including farmers and fishermen)

to harness technology to expand the choices in their daily lives. Knowledge must substitute monetary inputs, and help improve efficiency and competitiveness - a major and urgent necessity in today's liberalized world.

Managing natural resources - land, water and biodiversity: Science and technology must be harnessed to map and to match the potential of natural and other resources with production goals and to ensure conservation and sustained, efficient, and equitable use of those resources through an integrated and participatory approach. Science and technology must provide necessary tools and direction for implementation of various global treaties on land, water and biodiversity - such as the FAO Global Plan of Action under the International Treaty on Genetic Resources for Food and Agriculture.

Addressing environmental and climate-change concerns and minimizing adverse impacts of natural disasters: Based on decision-support systems, technology packages such as integrated pest management (IPM), integrated plant nutrient management (IPNM), and integrated soil-water management should be developed and widely adopted through participatory approaches, such as Farmer Field Schools. Using the driving force-pressure-state-impact-response (DPSIR), the environmental monitoring and technology response should be streamlined. Anticipatory multidisciplinary research for mitigating adverse effects of climate change and natural disasters should be strengthened. Capacities in GIS, weather forecasting, linkage to regional and global weather data and forecasts, are crucial for adequate preparedness.

Policies and strategies

Scientific discoveries and technological innovations proceed apace. Such innovations must be matched by genuine policy innovations and strategies - nationally and internationally - to meet development goals: food security, nutritional adequacy, poverty alleviation, and environmental sustainability. "Foresight studies" have been undertaken by many countries; they must be intensified to link science and technology policy more coherently to socio-economic and environmental needs.

Many A-P developing countries lack adequate research and technology development capacity. This lack must be remedied on a long-term basis, since access to technologies is declining, and it is unlikely that the global market place shall supply the required technologies. Although research and development policies and programmes shall be country-specific, the following six component are likely to be common to each of them.

First: for almost all developing countries, comprehensive food security and poverty alleviation must be the foremost priority of the science and technology agenda. High attention should be directed - in all ecozones - to the small-holder and resource-poor farmers and consumers (and especially to the women among them); the rainfed and marginal ecozones must be expressly favoured in such agendas.

Second: the Green Revolution must be transformed into an Evergreen Revolution by generating and disseminating eco-technologies based on a systems, integrated, and interdisciplinary approach, with a participatory mechanism rooted in the principles of

socio-economic uplift and equity, environmental sustainability, and employment security.

Thirdly: investment in agriculture, agricultural science, research, education, extension, and technology development must be strengthened to create, procure, assess, adapt and disseminate appropriate technologies that lead to enhanced productivity and sustainability. Notably - recognizing the wide technological and digital divide between developing and developed countries - the developing countries should increase their investment in agricultural research and technology development from the current 0.2-0.5 percent of agricultural domestic product (ADP) to at least 2 percent of ADP.

Fourthly: the centrality of technology to agricultural diversification must be emphasized. Research priorities and activities must be defined so as to develop and transfer technologies that promote diversification - as in livestock production (especially in mixed farming systems) and in crop-nutrition and disease management; priorities also for environment-friendly aquaculture development, and for promotion of horticultural, medicinal and specialty crops that are consistent (within a trade-globalization and liberalization regime) with socio-economic and environmental viability and acceptability.

Fifthly - and noting recent global undertakings and declarations on regulatory measures - countries should institute intellectual-property-rights-, breeders'-rights, and farmers'-rights legislations that ensure equitable sharing of technologies, technological products, and genetic resources, and that facilitate public-private linkages and private-sector investments in agricultural research - each in accordance with country-specific needs and aspirations.

Sixthly, and based on national goals, values, culture, strengths, weaknesses, opportunities, and comparative advantages, countries should create and manage innovative partnerships for research and technology development, and for sharing the various tasks among government, private sectors, academia, non-governmental organizations, and civil society. There must correspondingly be strengthened efforts to ensure both empirical and integrated approaches to research, and to ensure transparency of information, decision-making processes, and research governance.

FAO's role in promoting agricultural science and technology

FAO shall have various roles in promoting agricultural science and technology.

It shall assist member nations in formulating and implementing policies, priorities, and programmes to harness science and technology - including new science such as biotechnology and informatics - and for alleviating hunger and poverty. It shall help strengthen national capacities to undertake international negotiations relating to agricultural science and technology.

It shall provide technical support to needy countries to strengthen their capacities (including their human-resource capacity) in agricultural research and technology procurement, and in technology assessment and transfer. It shall assist and encourage (through its Investment Centre and by other means) the World Bank, ADB, and other

international and regional institutions and donors to help developing countries to invest in agricultural research and technology development - particularly in circumstances where the private sector is unlikely to invest.

Through its WAICENT programme, FAO will provide to member nations the latest information, databases, and analyses on agricultural research and technology development, and on production, trade, nutrition, poverty, and policy. It will also strengthen national agricultural information systems that link farmers, fisherfolk, and foresters with national and international information networks.

FAO will help increase developing countries' capacity to formulate and implement regulatory measures for the development and use of science and technology and of products derived from those technologies. FAO can advise on property rights (including plant breeders' and farmers' rights), and can facilitate access to proprietary technologies, and to procedures of food safety, biosafety, environmental and health safety, sanitary and phytosanitary measures, and containment and eradication of animal diseases; it can help harmonize standards and guidelines and advise on their implementation.

As a Co-sponsor of the Consultative Group on International Agricultural Research (CGIAR), and as host to its Science Council and Secretariat (successors to the Technical Advisory Committee - TAC), FAO influences the agenda, activities, and inter-linkages of the International Agricultural Research Centers (IARCs) - helping ensure their attention to hunger and poverty alleviation - and helps build bridges between IARCs, National Agricultural Research Systems (NARSs), and FAO to facilitate dissemination of validated IARC technologies. FAO can also foster the activities of regional networks and associations - such as the Asia-Pacific Association of Agricultural Research Institutions (APAARI) - and can assist in establishing new associations to improve regional capacity to capture the opportunities currently presented by the substantial progress in science, technology, communications, and globalization.

Conclusion

Science and technology are the engine for agriculture-led national progress. Recognizing that "technology can be *not only* a reward for successful development, *but also* a critical tool for achieving it", the partnership between technology and development must be nurtured, strengthened, and kept dynamic by increasing national capacities through adequate investment and appropriate institutional and policy support.

I. INTRODUCTION

Science, agricultural research, and technology development played a pivotal role during the last 40-50 years in achieving spectacular increases in food and agricultural production to feed the billions of additional people. World population at 6.3 billion is twice that of the mid-1960s. It is gratifying that for most parts of the world this huge increase in world population was accompanied by significant progress in food security. The share of the world population that has adequate access to food has continued to rise. World per caput food supplies are today some 17 percent above what they were 30 years ago - agricultural production has thus kept pace with and even outstripped population growth (FAO, 2000a).

The Asia-Pacific Region¹ has undergone an unprecedented transformation in food and agricultural production, food security, and rural development during the past 35 years. The Green Revolution, a science-led synergism among enhanced genetic potential (improved seeds), irrigation, and fertilizers in the mid-1960s, was the engine of this transformation. During 1969-99, Asian cereal production more than doubled - reaching nearly one billion tons. Notwithstanding the addition of 1.3 billion people to the region's population, average per caput food availability increased by 30 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 a considerable decrease in the number of hungry people. Increased agricultural productivity, rapid industrial growth in many countries, and expansion of the non-formal rural economy resulted in a near-tripling of the per caput GDP; poverty incidence decreased from 60 percent to less than 30 percent.

Despite continuous growth in the world economy, and considerable food availability in major exporters, the aggregate food-security situation of the (all-countries) developing world has shown little progress in recent years; however, among developing-world between regions and countries, food security varies widely. Of the 777 million malnourished people in the developing world, 497 million live in the Asia-Pacific (A-P) Region (FAO, 2001a). Projections indicate that with a continuation of current trends, the World Food Summit (WFS) target (of halving by Year 2015 the numbers of undernourished persons) is not likely to be achieved. The achievement gap can be attributed to the unsatisfactory state of development of science and technology, general indifference to investment in agriculture (including agricultural research and technology), and social and economic barriers.

Child malnutrition exacts its highest toll in the A-P Region (A-P R) - especially in South Asia. Likewise, nearly 800 million - two-thirds of the world's poor - live in the A-P R. It is disquieting that in recent years the numbers of hungry and poor people remain

¹Asia-Pacific Region refers to the 37 FAO member countries that fall within the geographical jurisdiction of the FAO's Regional Office for Asia and the Pacific (RAP). These include 26 South Asian, Southeast Asian, and East Asian countries, and 11 Oceania and Pacific islands.

stubbornly high. This may be attributed in part to the declining rate of growth in food and agricultural production in the 1990s. Moreover, agricultural intensification in the region has often been associated with land, water, and overall environmental degradation. The per caput availability of land in is one-sixth of that in the rest of the world. Further, nearly three-fifths of the future increase in world population will occur in A-P R, which already houses 57 percent of the world's population, thus exacerbating the imbalance.

Future increases in food and agricultural production will have to be achieved from ever-shrinking and generally deteriorating land, water, and other production resources. 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 the conservation and improvement of natural and other production resources while pursuing intensification, 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. Science and technology must play an important role in meeting these challenges and opportunities.

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 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. This paper analyzes the past and forecast trends and explores how science and technology can be harnessed to bring about a more just, equitable, and sustainable pattern of agricultural growth and development for raising levels of nutrition, standards of living, and overall livelihood security.

II. STATE OF FOOD AND AGRICULTURE

Food consumption and nutrition

During the 31 years 1965-1996 (the Green-Revolution period), developing-countries per caput food consumption increased by 28 percent; from 2053 to 2626 kcal/person/day (Table 1). Increases for South Asia and East Asia were respectively 20 and 43 percent - the latter being the highest among the world's regions and sub-regions. Between 1980 and 1997, developing-world under-nourishment declined by 11 percentage points (FAO, 2000a) - with the bulk of that decline in Asia. In East and Southeast Asia, the percentage of undernourished population decreased from 29 to 13, and in South Asia from 38 to 23 (Table 2) (FAO, 2001b).

Table 1: Per caput food consumption (kcal/person/day)

Country Grouping	1964/66	1995/97	2015	2030
World	2357	2761	2960	3100
Developing countries	2053	2626	2860	3020
South Asia	2013	2424	2790	3040
East Asia	1953	2783	3020	3170
Industrial countries	2945	3374	3490	3550

Source: Agriculture: Towards 2015/2030, FAO

Table 2: Undernourished population (percentage, developing regions)

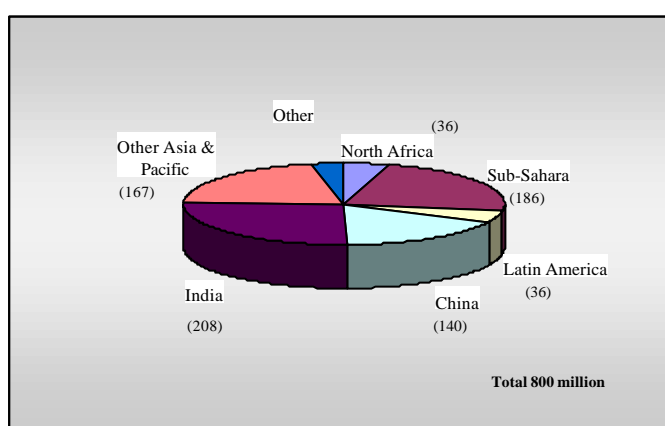
Region	Percentage undernourished		
	1979-81	1990-92	1996-98
Sub-Saharan Africa	37	35	34
Near East and North Africa	9	8	10
East and Southeast Asia	29	17	13
South Asia	38	26	23
Latin America and the Caribbean	13	13	11

Source: FAO, CFS: 2001/2

Notwithstanding these significant declines, A-P R continues to be home to two-thirds of the world's malnourished people - with India home to one-fourth of them (Figure 1).

Mortality rates for children under five provide a good indicator of the nutritional status both the children and of their mothers. In 1998, child-mortality rate in developing countries was 13 times that of OECD countries (Table 3). Malnutrition is acknowledged to be the major cause of child mortality in developing countries. The child-mortality rate in developing countries declined by 14 percent between 1990 and 1998, against a targeted decline of 30 percent; declines in East Asia and Pacific and in South Asia were respectively 22 and 26 percent.

Figure 1: Undernourishment (numbers of persons, by region)



Source : SOFI 2000, FAO

Table 3: Mortality (per 1000) children under five; (selected years: 1970-98)

Region	1970	1980	1990	1997	1998	Reduction 1990-1998
East Asia & Pacific	126	82	55	46	43	22%
Europe & Central Asia	n.a.	n.a.	34	29	26	24%
Latin America & Caribbean	123	78	49	41	38	24%
Middle East & North Africa	200	136	71	58	55	22%
South Asia	209	180	121	100	89	26%
Sub-Saharan Africa	222	188	155	153	151	3%
Developing countries	167	135	91	84	79	14%
OECD	26	14	9	6	6	30%

Source: World Bank Statistical Information Management and Analysis (SIMA) database.

Note: n.a. = Not Available

The distribution (WHO Global Database on Child Growth) of the numbers of underweight, stunted, and wasted children (0-5 years) indicates that in 2000 the developing-countries total number of underweight (low weight-for-age) children was 149 million or 27 percent - ranging from 3.2 percent in South America to 44 percent in South-Central Asia.

Between 1980 and 2000, stunting decreased (globally) from 221 million (47 percent) to 182 million (32.5 percent). Southeast Asia experienced the strongest decline, followed by South Asia and South America. South-Central Asia has the highest prevalence of children underweight and stunting; because that sub-region has very high population, it accounts for about one-half of the global total of malnourished children. More than half of South Asia's young children suffer from protein-energy malnutrition - about five times the prevalence in the Western hemisphere, at least three times the prevalence in the Middle East, and more than twice that of East Asia.

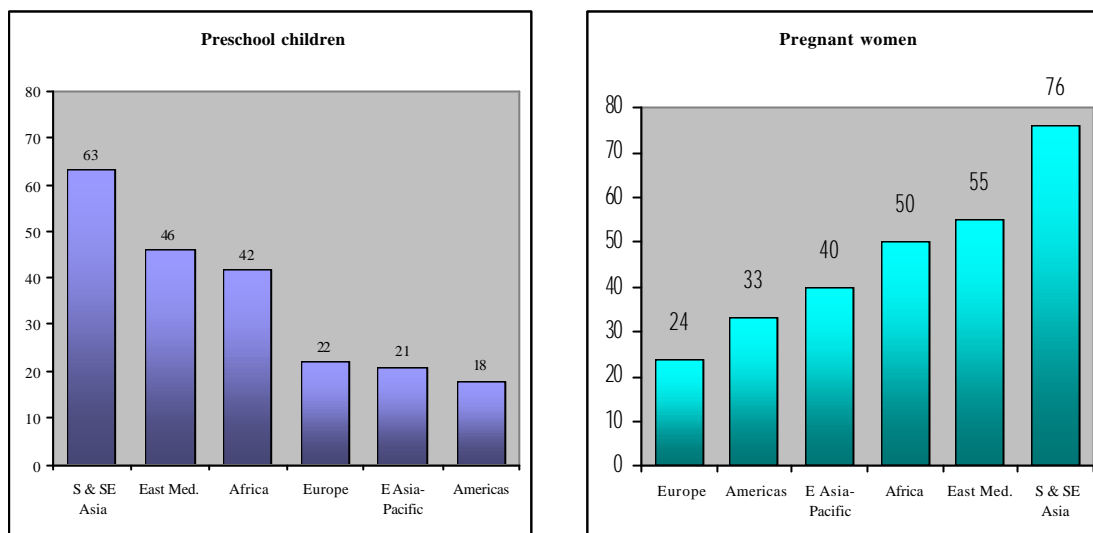
There are gender as well as rural-urban divides in nutritional attainments. Female children face gender bias in the allocation of food: the nutritional status among girls, particularly in South Asia, is inferior to that of boys. Similarly - and primarily due to higher poverty and illiteracy - rural-area children are more malnourished than their urban counterparts. These divides have implications for the inter-linkages of social, economic, biological, and physical sciences.

Micro-nutrient deficiencies - as well as calorie and protein malnutrition - are severe in Asia, causing serious health and human-development problems. Nutritional deficiencies of iron, iodine, and Vitamin A are major concerns in South and Southeast Asia; rickets and zinc and selenium deficiencies are additional concerns in some areas. Anemia, caused mainly due to iron deficiency, is most prevalent in South and Southeast Asia, where 76 percent of pregnant woman and 63 percent of pre-school children are anemic (Figure 2). In Bangladesh, India, Myanmar, and Nepal, more than 70 percent of pregnant women are anemic, and South Asia accounts for about 50 percent of the world's anemic women (WHO, 1999; FAO, 1998a). Babies of anemic women are more likely to be born prematurely, to be underweight, or to die as newborns or to remain anemic if they survive; thus by their very birth they compound their nation's health and development problems. Although not well appreciated, besides the depressed overall physical and mental ability, there is a devastating effect on economies: in South Asia alone there is an estimated total annual loss of \$ 5 billion (ACC/SCN and IFPRI, 2000).

Two hundred million people in the world suffer from goiter. In addition, 6 million have cretinism (severe mental retardation). About half of these are reportedly in South and Southeast Asia. Nepal, Indonesia, Bhutan followed by Myanmar, Sri Lanka, Bangladesh, India, Mongolia, as also China, Thailand and South Korea have high incidence of iodine deficiency. Children born to mothers with goiter, on attaining adulthood, are likely to be 10 percent less productive than the children born to mothers without goiter (Gillespie and Haddad, 2000). Iodized salt intake has fortunately caught up rather fast and has been effective in reducing iodine deficiency. Agricultural approaches such as dipping

potassium iodate into irrigation water and genetic manipulation for efficient absorption of iodine by crops could greatly supplement the other efforts in managing the deficiency.

Figure 2: Anaemia: pre-school children and pregnant women (by region, 1999)



Source : ACC/SCN and IFPRI, 2000

Although the incidence of severe Vitamin A deficiency is declining, as many as 125 million children are currently at risk in South and Southeast Asia. A recent report reveals that in Bangladesh 0.62 percent of school children and 2.7 percent of pregnant women suffer from night blindness. Massive Vitamin-A dosing programmes have been instrumental in fighting the malady. While this approach must continue, there is need to strengthen production and consumption of Vitamin A-rich foods.

Nexus between hunger and poverty

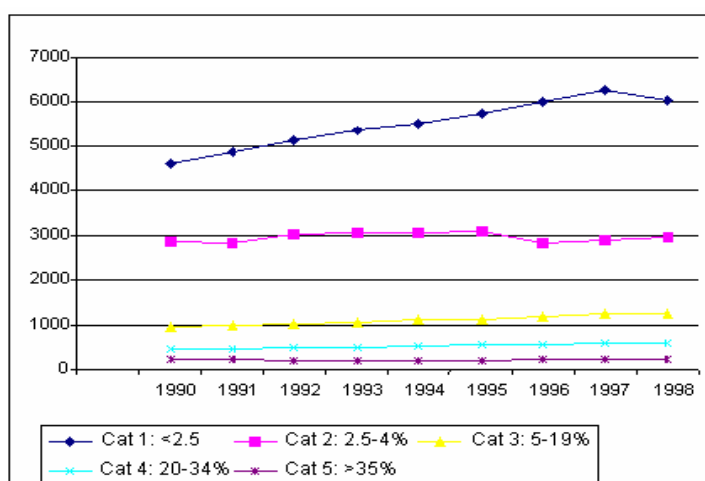
There is a strong link between poverty and food insecurity. As seen from Table 4, during the period from 1987 to 1998, as the incidence of poverty fell in Asia and the Middle East-North Africa, the prevalence of undernourishment concurrently declined. South Asia, which in 1998 had 522 million people with incomes less than US \$ 1 a day, 44 percent of the world's people in this category, also had the largest number of undernourished people, 294 million, over 39 percent of the world's hungry people. National incomes (measured by per caput GNP) are lowest in the countries where undernourishment is high (Figure 3). It is a matter of concern to note that during the last decade of the 20th century, there is a negligible improvement in per caput incomes in those countries that have over 20 percent of their population undernourished. Therefore, the twin objectives of the World Food Summit (WFS) and the UN Millennium Summit of halving undernourishment and poverty by 2015 are highly interconnected and interdependent.

Table 4: Poverty and undernourishment compared

Region	1998	1996-98	1996-98	1998
	People living in households that consume less than \$1/day (percent)	Share undernourished (percent)	Number of undernourished (million)	Number of poor (million)
South Asia	39.99	23	294.2	522.00
East Asia	15.32	12	155.0	278.32
Eastern Europe and Central Asia	5.14	6	26.4	23.98
Latin America and the Caribbean	15.57	11	54.9	78.16
Middle East and North Africa	1.95	10	35.9	5.55
Sub-Saharan Africa	46.3	34	185.9	290.87

Source: FAO, CFS, 2001/2

Figure 3: GNP per caput (1995 \$ US) by prevalence of undernourishment



Source: World Bank, World Development Indicators, 2000

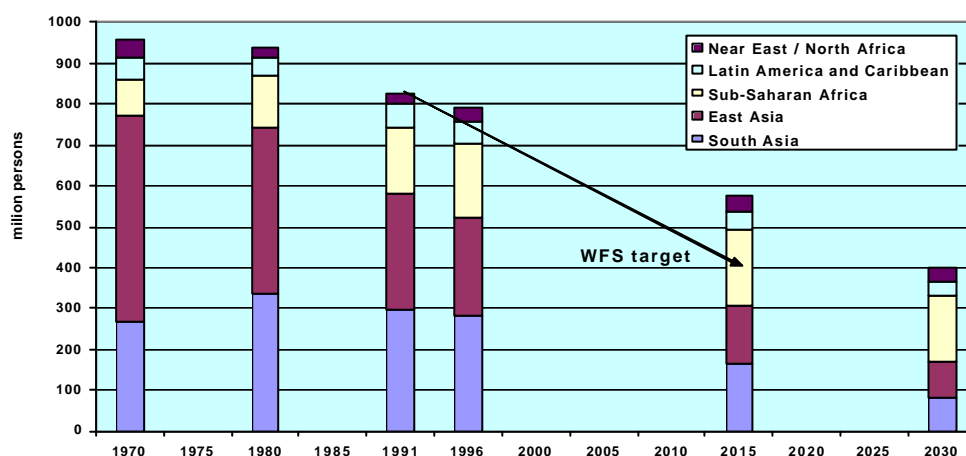
It is projected that per caput food consumption in developing countries will increase to 2860 and 3020 Kcal in 2015 and 2030, respectively (see Table 1). In South Asia the corresponding figures are 2790 and 3040 Kcal. In East Asia, the figures are still higher at 3020 and 3170 Kcal. These increases would lead to a further significant drop in the share of persons undernourished: to 10 percent in 2015 and 6 percent in 2030 for the developing countries, to 10 percent and 4 percent for South Asia and to 7 percent and 4 percent for East Asia (Table 5). However, due to demographic growth, in absolute numbers, globally the decrease of persons undernourished will be to 576 in 2015 and 401 million in 2030 from 790 in 1995/97; for Asia to 309 in 2015 and 168 million in 2030 from 524 in 1995/97. Likewise, Asia's share of persons undernourished in the world will

decrease from 66 percent in 1995/97 to 42 percent in 2030. Thus, the Asian countries are not too far from meeting the target set at the World Food Summit in 1996. However, as the things stand today, largely due to the unsatisfactory situation in Sub-Saharan Africa, the WFS goal of halving the number of undernourished persons no later that 2015, will only be reached toward 2030 (Figure 4) (FAO, 2000b).

Table 5: Undernourishment: developing countries

Region	Million persons			Percent of population		
	1995/97	2015	2030	1995/97	2015	2030
Developing countries	790	576	401	18	10	6
South Asia	284	165	82	23	10	4
East Asia	240	144	86	13	7	4

Figure 4 : Undernourishment (million of persons)



Source: Agriculture: Towards 2015/2030, FAO

Source: SOFI 2000, FAO

The latest FAO analysis of the State of Food Insecurity in the World (FAO, 2001a) reveals that the world is further slipping away from the target rate of reduction of undernourished people. Continuing at the current rate, it would take more than 60 years to reach the target. In the Asia-Pacific Region, the number declined from 565 million in 1990-92 to 497 in 1997-99: an average annual reduction rate of 9.7 million against the target figure of 11.2 million. Performance of the individual countries, however, varied widely (Table 6). In 1990-92, India, with 215 million and China with 198 million, had the largest concentration of undernourished in the world. Seven years later, in 1997-99, while China had lessened by 77 million its total of hungry, India had added 11 million to its total.

Table 6: Undernourishment: Asia-Pacific region

Region/Sub-region/country	Number of people undernourished (millions)		Proportion of undernourished in total population (%)	
	1990-92	1997-99	1990-92	1997-99
Developing world	816.3	777.2	20	17
Asia and the Pacific	564.8	497.1	20	16
East Asia	197.6	126.9	16	10
China	192.6	116.3	16	9
DPR Korea	3.4	8.8	17	40
Mongolia	0.8	1.0	34	42
Oceania	0.9	1.2	24	26
Papua New Guinea	0.9	1.2	24	26
Southeast Asia	77.6	65.9	17	13
Cambodia	4.3	4.6	43	37
Indonesia	16.7	12.0	9	6
Lao PDR	1.2	1.4	29	28
Malaysia	0.6	0.4	3	-
Myanmar	3.9	3.2	9	7
Philippines	16.0	17.2	26	24
Thailand	16.9	12.9	30	21
Viet Nam	18.0	14.2	27	19
South Asia	288.8	303.0	26	24
Bangladesh	39.2	44.1	35	33
India	214.6	225.3	25	23
Nepal	3.5	5.0	19	23
Pakistan	26.5	24.4	25	18
Sri Lanka	5.0	4.3	29	23

Source: SOFI, 2001, FAO

Demand and supply at 2015/2030

Food demand in developing countries is essentially a function of population growth and income increase. As regards population, with 4.44 billion people in 1995/97, developing countries accounted for 77 percent of the world population (Table 7). In 2030, the proportion will increase to 83 percent with an estimated population of 6.7 billion. South and Southeast Asia together will continue to account for more than 50 percent of the world's population, 53 and 52 percent towards 2015 and 2030, respectively, although the rates of growth will decelerate considerably, especially in East Asia. Given the high base level population and not-so-low growth rate, the share of South Asia in the world's

population will increase from the current level of 22 percent to 24 percent in 2030, annually adding 19 million towards 2015 and 16 million people towards 2030. The corresponding increments for East Asia were 16 and 9 million. During the next 30 years, nearly one billion additional people will be added to the population of South, Southeast and East Asia, and half of this addition will take place in India and China.

Table 7: Population: current and projected

Region	1995/97		2015		2030		Growth rate %	
	million	% of world	million	% of world	million	% of world	1995/97 – 2015	2015- 2030
World	5745	100	7154	100	8112	100	1.2	0.8
Developing countries	4436	77	5778	81	6718	83	1.4	1.0
South Asia	1251	22	1651	23	1915	24	1.5	1.0
South East Asia	1800	31	2133	30	2307	28	0.9	0.5

Source: Agriculture: Towards 2015/2030, FAO

Growth in per caput income (GDP) in Asian sub-regions between 1995/97 and 2015 and between 2015 and 2030 ranged from 3.6 to 5.7 percent and was generally higher than the corresponding growth for the developing countries as a whole (Table 8). This growth will greatly help in reducing poverty level in the region and maintain a fairly high demand for food and agricultural products, with potential to reduce undernourishment.

Table 8: GDP growth (%/ann)

Region	Total GDP		Per caput GDP	
	1995/97 – 2015	2015 – 2030	1995/97 – 2015	2015 – 2030
World	3.1	3.6	2.0	2.7
Developing countries	4.8	5.4	3.4	4.3
South Asia	5.1	5.1	3.6	4.0
East Asia	5.8	6.3	4.9	5.7

Source: Agriculture: Towards 2015/2030, FAO

Other important features of the demographic shift are the increased proportion of youth, and rapid urbanization. By the year 2010, 50 percent of the population in Asia will be below age 25. Since agriculture will continue to be the main source of employment in the region during the next 25 years, effort must be made to render the agricultural profession both intellectually attractive and economically rewarding so that young persons shall engage in agricultural production and transformation,

Another major demographic shift will be that the urban population will swell to 53 percent of the total population in 2030, from the current level of 34 percent. This shift will cause a significant change in the food basket, necessitating enhanced consumption and production of high value commodities such as animal products, including fish, horticultural products and edible oils. Moreover, to feed the cities, the proportion of marketed grain, processed food and other food products will expand rapidly, necessitating much greater emphasis on food processing, value addition, transport infrastructures, sound market institutions and on peri-urban agriculture.

An analysis of the changes in the commodity composition of food by country groups brings out the relative emphasis to be given between crops and animal production systems in the sub-regions. The data given in Table 9 indicate that in developing countries the use of cereals as food will stabilize at around 178 kg/person/year. In South Asia it will increase from 169kg/person/year in 1995/97 to 192 kg/person/year in 2030, but the reverse is the trend in East Asia, dropping from 194 kg to 187 kg. The relatively higher cereal consumption (as human food) in South Asia may be ascribed to the predominance of vegetarians and to relatively slower rate of urbanization in the sub-region as compared with that in East Asia. The share of pulses in South Asia – a main source of protein and an important group of crops in crop rotation – is expected to decrease, which is a set back from the points of view of nutrition and soil fertility. But

Table 9: Composition of food (by commodity and major country groups)

Commodities	Developing countries as a whole			South Asia			East Asia		
	1996	2015	2030	1996	2015	2030	1996	2015	2030
Cereals, food	172	178	178	169	186	192	194	193	187
Roots and tubers	65	69	74	21	26	30	63	62	63
Sugar	20	23	25	24	29	33	11	14	16
Dry pulses	6.9	6.8	6.8	10.6	9.1	8.0			
Veg. oils, oilseeds and oil products	9.4	12.4	14.8	8.5	11.9	14.6	8.6	12.2	15.3
Meat (carcass wt.)	23	30	34	5.5	8.2	11.8	33	47	55
Milk and dairy, excl. butter	42	53	67	59	81	116	10	14	19
Total food (Kcal/person/day)	2626	2860	3020	2424	2790	3040	2783	3020	3170

Source: Agriculture: Towards 2015/2030, FAO

the intake of animal products, particularly meat in East Asia and milk and dairy products in South Asia, and of vegetable oils and oilseeds is expected to increase by 80 percent in the two sub-regions. Among meat products, poultry will grow at high rates throughout

the region, especially in India, while pig production will particularly be high in China and other East Asian countries.

A livestock revolution is underway in the developing countries, particularly in Asian countries, with profound implications for crop-livestock balance, nutrition, income and the environment. Asia had registered the highest growth rate in the world in livestock production in the past decades and is projected to maintain this trend towards the year 2030 (Table 10). South Asia, in particular, will register much higher growth rates, 3.2 percent against 1.7 percent for the world as a whole. East Asia will also maintain a high growth rate particularly during 1997-2015. The projected production growth-rate of livestock is double of that of cereals.

Table 10: Livestock production growth (% ann)

Region	1987-97	1995/97 – 2015	2015 – 2030
World	1.8	1.7	1.4
South Asia	4.3	3.2	3.2
East Asia	8.9	2.6	1.6

Source: Agriculture: Towards 2015/2030, FAO

Despite the high production growth rate, Asia is and will further be a major net importer of livestock products for meeting the fast-growing demand. South Asia, which consumes relatively smaller quantities of meat, from its current status of a marginal net exporter, is expected to turn into a minor net importer of meat, 80 000 tons in 2015 to 310 000 tons in 2030. The sub-region will further intensify its relatively high level of milk and dairy products consumption by enhancing its net import from 0.6 million tons in 1995-97 to 1.9 million tons in 2015 and 4.8 million tons in 2030. East Asia's net imports will also greatly expand. The current net animal meat import of 0.24 million tons will increase ten-fold to 2.5 million tons in 2015 and fifteen-fold to 3.6 million tons in 2030. As regards milk and dairy products, the already high current net import of 6.7 million tons will grow to 11 million tons in 2015 and 15 million tons in 2030 (FAO, 2000a).

In developing Asia, small farmers who constitute nearly 80 percent of all farming and households and practising integrated farming systems, account for the bulk of livestock production. This trend is likely to continue in the foreseeable future. The insufficient supply of fodder and feed has been a major bottleneck in enhancing livestock productivity in the region. Moreover, frequent natural disasters in the Asia-Pacific region have high depressing effects on livestock population and productivity.

Fisheries and aquaculture contribute significantly to food security in the Asia-Pacific region. The region produces almost 90 percent of the aquaculture products of the world and 52 percent of the capture fisheries products (1998) (Table 11). Between 1988 and 1998, the Asia Pacific production of total fisheries increased by about 27 million tons,

while in the rest of the world it declined by 10 million tons. The production increases of 11.4 percent annually in aquaculture in the region were particularly notable. The developing Asia-Pacific countries are net exporters of fish and fish products, annually amounting to over US\$9 billion during the late 1990s.

Table 11: Fish catch and supply (million tons/ann)

Fish supply	Asia-Pacific region			Rest of the world		
	1988	1998	GR (%/an) 1988-98	1988	1998	GR (%/an) 1988-98
Marine capture	31.2	38.0	2.0	51.3	40.3	-2.2
Inland capture	2.9	4.9	5.5	3.3	3.1	-0.6
Aquaculture	9.3	27.1	11.4	2.4	3.7	4.6
Total	43.4	70.0	-	57.0	47.1	-

Source: Agriculture: Towards 2015/2030, FAO

Fish make up more than 50% of animal protein in most countries of the region; additionally, they provide nutritional benefits such as calcium, vitamin A, omega-3 fatty acids and iodine; deficiencies in these entities are highly detrimental to the physical and mental development of all people, especially children. Greater recognition must therefore be given to the nutritional role of fish for the poor, especially those living on and near the coast and other water bodies. Fish and other aquatic resources, even when eaten in small quantities, often have a defining role in nutritional security, and it is this security that is most threatened as the natural supplies disappear. Fish should be added adequately in FAO and other world food models and outlook to obtain a more complete picture of food availability and nutritional adequacy.

Cereals and oilcrops are the main group of crops which are consumed both by humans and animals, and allocation of these commodities to livestock is likely to grow faster than in the past. Based on the cereal balances (rice, wheat, and coarse grains) in the production and demand scenario (Table 12), it is seen that in South Asia demand growth will outstrip production growth by 0.1 percentage point up to the year 2030; whereas in East Asia demand will outpace production by 0.2 percentage point up to the year 2015, and will break even afterwards. As regards oilseeds, oilcake and oil: in South Asia consumption will exceed production by 0.7 percentage points up to the year 2015, after which it will even out (Table 13). But in East Asia a gap of 0.3 percentage point will persist up to 2030. The projected production and consumption growth rates for oilseeds and vegetable oils in the region are about 80 percent higher than those for cereals.

Table 12: Cereal: growth in demand, production, and human population (% ann)

Region	Demand		Production		Population	
	1997-2015	2015-2030	1997-2015	2015-2030	1997-2015	2015-2030
World	1.4	1.1	1.4	1.1	1.2	0.8
South Asia	2.0	1.3	1.9	1.2	1.5	1.0
East Asia	1.4	0.9	1.2	0.9	0.9	0.5

Source: Agriculture: Towards 2015/2030, FAO

Table 13: Vegetable oils/products: production and consumption growth (%/ann)

Region	Total food use (in million tons)	Production growth rate		Consumption growth rate	
	1995/97	1995/97 – 2015	2015 – 2030	1995/97 – 2015	2015 – 2030
World	62.9	2.1	1.9	2.2	1.9
South Asia	10.6	2.5	2.4	3.2	2.4
East Asia	15.6	2.3	1.9	2.6	2.2

Source: Agriculture: Towards 2015/2030, FAO

By year 2030, world cereal production shall need to increase to 2.8 billion tons: an addition of nearly 1 billion tons (Table 14). Of this increment, nearly half will be for food, and about 44 percent for feed, with the balance 6 percent for seed, industrial non-food use and other uses. In South, Southeast, and East Asia, cereal production is expected to increase by 380 million tons (based on milled rice), from 720 million tons in 1995/97 to 1100 million tons in 2030. Comparing the sub-regions, South Asia is expected to register an increase of 73 percent, whereas East Asia (including Southeast Asia) is expected to register an increase of 44 percent. Non-food use of cereals in South Asia is currently about 10 percent and is expected to increase slightly to 12 percent towards 2030. But in East Asia (the non-food use proportion - fuelled by the increased livestock and associated feed demands) is much higher: 33 percent in 1995/97 and 45 percent in 2030.

Cereals demand is expected to outstrip production both in South and East Asia, the self-sufficiency rate in South Asia falling from 97 to 94 percent and in East Asia from 94 to 90 percent over 1995/97 – 2030 (Table 14). In order to close the gaps between local production and consumption, South Asia which is currently a net importer of about 1 million tons of cereals, will become a net importer of 16 and 26 million tons in 2015 and 2030, respectively (Table 15). East Asia which is already a high net importer of 37 million tons of cereals, will be enhancing its net import to 60 and 79 million tons in 2015 and 2030, respectively. Most of this increase will occur in China - primarily for meeting the increasing demands for animal feed. The bulk of this increase will consist primarily of

coarse grains, particularly maize, as in 1995/97 nearly 79 percent of the use of maize grain in China was for non-food purposes, mostly as feed. After its entry into WTO, China's import of rice is likely to increase.

Table 14: Cereal: balance (million ton/ann) of demand and production

Years	Demand		Production	SSR* %
	Food	All Uses		
World				
1995/97	979	1844	1836	100
2015	1257	2393	2397	100
2030	1428	2801	2805	100
Developing countries				
1995/97	765	1107	996	90
2015	1029	1550	1352	87
2030	1197	1886	1615	86
South Asia				
1995/97	211	235	227	97
2015	306	343	327	95
2030	368	418	392	94
East Asia				
1995/97	348	526	493	94
2015	413	683	624	91
2030	432	787	708	90

*SSR = Self Sufficiency Rate = Production / Demand (all uses)

Source: Agriculture: Towards 2015/2030, FAO

Table 15: Cereals: net trade (million ton/ann)

Region	19965/97	2015	2030
Developing countries	-107	-198	-270
South Asia	-1	-16	-26
East Asia	-37	-60	-79

Source: Agriculture: Towards 2015/30, FAO

Prospects for agricultural production

Agricultural production as a whole at the global level has kept pace with demand. Had there been greater demand, world agriculture would have positively responded to meet the demand. Three main factors were responsible for the limit on the demand side: (a) the slow down in population growth, (b) a growing share of world population has attained fairly high levels of per caput food consumption, and (c) the undernourished were too poor to purchase more food or were too resource-poor to produce more food. The existing situation and projected trends of these factors suggest a slowing of demand. On the other hand, the production side will be greatly influenced by the per caput availability of material and other production resources, the levels of various yield gaps, overall environmental conditions, new technologies, appropriate policies, and nature and quality of socio-economic settings.

As seen from Table 16, demand growth rates for the world, the developing countries, South Asia and East Asia have declined during the period 1997-2015 when compared with those during 1977/1997. This deceleration was in line with population growth rates during the two periods. Production growth at the global level matched the demand growth rates. For the developing countries as well as for South and East Asia the demand growth marginally outstripped production growth. The decrease over the two periods was most pronounced in East Asia, primarily due to the trend in China; the demand growth rate dropping from 4.8 percent in 1977-97 to 1.9 percent in 1997-2015 against corresponding production growth rates of 4.7 and 1.8 percent.

Table 16: Growth (5/ann) in aggregate demand, production, and human population

Region	Demand		Production		Population	
	1977-97	1996-2015	1977-97	1996-2015	1977-97	1996-2015
World	2.1	1.6	2.1	1.6	1.6	1.2
D'v'p'ng countries	3.7	2.2	3.6	2.1	2.0	1.4
South Asia	3.3	2.6	3.3	2.5	2.2	1.5
East Asia	4.8	1.9	4.7	1.8	1.5	0.9
idem, excl. China	3.5	1.9	3.2	1.9	1.8	1.2

Source: Agriculture: Towards 2015/2030, FAO

By 2030, total agricultural production in the developing countries is projected to be 87 percent higher than in 1995/97, while the projected increase for meat is 120 percent and for crops 75 percent. By 2030, the developing countries will account for 72 percent of world crop production, up from 66 percent in 1995/97 and 53 percent in 1961/63.

As regards crop production, during the 30-year period 1967 to 1997, the developing countries registered a satisfactory crop production growth rate of 3.1 percent (Table 17). East Asia, with a growth rate of 3.6 percent, played the eminent role in pushing the global average. South Asia, with a growth rate of 2.8 percent, also performed well. During the succeeding 34-year period, the growth will slow down to 1.2 percent in East Asia but will maintain a moderate rate of 1.9 percent in South Asia.

Table 17: Growth (%/ann) in crop production

Region	1967-1997	1995/97 – 2030
South Asia	2.8	1.9
East Asia	3.6	1.2
All Developing Countries	3.1	1.6
Industrial Countries	1.4	0.8
World	2.2	1.3

Source: Agriculture: Towards 2015/2030, FAO

There are three sources of growth in crop production: (i) arable land expansion (ii) increase in cropping intensity and (iii) yield growth. Yield growth will account for 83 percent of production growth in Asia, whereas the net area expansion will contribute only 5 percent and the remaining 12 percent will be through the increase in cropping intensity (Table 18). In other words, 95 percent of the crop production growth in Asia will accrue through crop intensification, while in other regions net area expansion will be contributing between 20 to 30 percent. As regards individual major crops, more than 80 percent of the growth in wheat and rice production in the developing countries will have to come from gains in yield, whereas for maize the area expansion will be an equally important source, even more so than in the past. In Asia, for wheat and rice, there will be negligible or zero net area growth (even negative in some major producing countries), thus yield growth will be the exclusive source of production growth. Since intensification is closely linked with use of new and modern technologies - albeit in conjunction with indigenous technologies and knowledge, science and technology development in Asia-Pacific region will be called upon to play a still greater role than in the past.

Table 18: Proportionate Sources of growth in crop production

Region	Arable land expansion		Increase in cropping intensity		Yield increases	
	1961-1997	1995/97 – 2030	1961-1997	1995/97 - 2030	1961-1997	1995/97 - 2030
South Asia	7	5	14	12	79	83
East Asia	26	5	-6	12	80	83
All developing countries	24	20	5	11	71	69

Source: Agriculture: Towards 2015/2030, FAO

III. SALIENT FEATURES OF ASIAN FARMING SYSTEMS

South Asia

Key features of the South Asia sub-region in terms of potential of the farming systems are summarized in Box 1. Of the 11 farming systems of the sub-region, 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.

For the sub-region as a whole, cereal production is expected to reach 392 million tons by the year 2030. The large-ruminant population is expected to stabilize or even decline. 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 current level of 28 percent 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 now to 44 percent in 2030. 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 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.

Southeast and East Asia

Key features of the East Asia sub-region in terms of potential of the farming systems are summarized in Box 2. Of the 11 farming systems identified for this sub-region, 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.

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 to 53 percent by 2030. There are eight low-income food deficit countries in the

Box 1: Characteristics and potentials of farming systems: South Asia

Farming systems	Land area (percent of region)	Agric popn* (percent of region)	Principal livelihood	Incidence of poverty	Potential for poverty reduction	Potential for agric. 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 included	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.

Box 2: Characteristics and potentials of farming systems: Southeast and East Asia

Farming systems	Land area (percent of region)	Agric popn* (percent of region)	Principal livelihood	Incidence of poverty	Potential for Poverty reduction	Potential for agric. 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.

region. The current average food intake is 2783 kcal/person/day and is expected to increase to 3170 kcal by 2030, accompanied by improvement in the quality of the diet 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. Wheat production is expected to rise by 1.4 percent per annum during the period 2000-2015. Substantial increases in production of maize and barley are expected, while little increase in production is anticipated for millets, sorghum, cassava, and pulses. 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 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.

IV. THE CHALLENGES

Significant progress was made in the past 30 years and must continue to be made in the coming years in raising food consumption levels, improving nutrition, and reducing poverty through agricultural transformation in most developing countries. Yet, as highlighted earlier, the region is home to two-thirds of the world's hungry and poor people. Moreover, average yields of most commodities in most developing countries are relatively low and there are wide yield gaps. The foremost challenge for South, South-east and East Asia is to fight hunger and poverty and to improve yields. The agriculture-led broad-based economic growth – the main recourse to fight the maladies – must take place under the settings where the natural base of production resources, such as land, water and biodiversity, have shrunk, and there is widespread environmental and agro-ecological deterioration. The worrying signs of degradation of bread baskets, such as the fatigued rice-wheat lands in the Punjab and other parts of South Asia, and irresponsible fishing and aquaculture in the region, must be seen as warning signals. Such destructive trends must be halted to avert collapse of the production bases.

New socio-economic regimes have emerged, especially globalization and liberalization, with both positive and negative implications for developing countries. Liberalization of agricultural markets would be beneficial to developing countries by forcing adoption of new technologies, shifting production functions upwards, and attracting capital flow in agriculture - but only if the process is mindful of the interests of small-scale farmers and fisherfolks who constitute the bulk of the farming population in the region. Therefore, trade agreements must be accompanied by operationally effective measures to ease the adjustment process for small farmers in developing countries. Otherwise, the poor- rich divide will widen further, exacerbating livelihood-security problems. Can science and technology development increase agricultural competitiveness of developing countries and their small and resource-poor farmers, and help provide a more-level playing field?

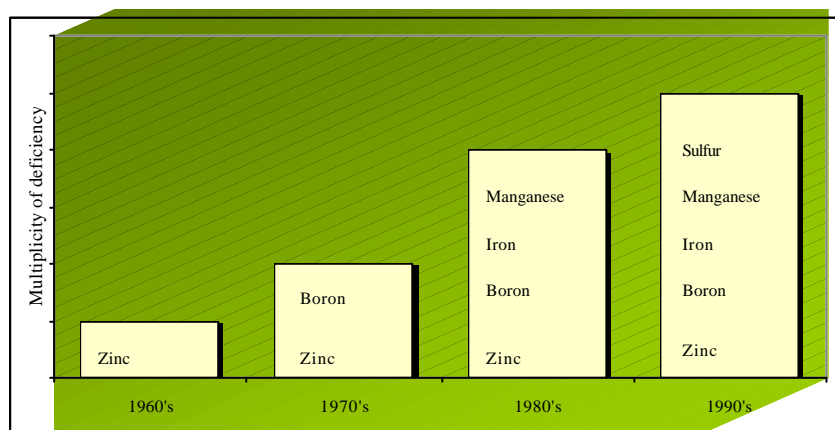
At the global level, the limits to agricultural production were posed by the limits on demand. But, this may not long hold true for the Asian region, as that region has to feed 57 percent of the world's population from only about 33 percent of the world's arable land; moreover that land area has been shrinking at a much faster rate than elsewhere, and land per caput has steadily been declining. In the next 30 years, one additional ton of grain must be produced from each hectare to meet the projected food demand. Producing this increment shall increase environmental pressures. Moreover, equity and other socio-economic concerns must be addressed in order to realize potentials of new technologies. Can science and new technologies, coupled with modern management approaches and effective policies, assist in minimizing the negative trends and perhaps in promoting positive effects? Can it do so even if the growth in agricultural research expenditure has been slowing and the digital divide is widening?

Pre- and post-harvest losses generally range from 15 to 30 percent in the region, adversely impacting productivity, quality and export, and hence food security and income. Livestock, fruits and fish are highly perishable foods, requiring proper handling and processing if these are to be utilized in a cost effective and efficient way for the

benefit of those who rely on them for nutrition and income. For fish, for example, FAO estimates that up to 20 million tons of fish is wasted by being discarded at sea immediately after catch. Improved post-harvest processing conforming to HACCP and ISO 9000 is seen as a way of developing the fishery industry without increasing harvests. Sanitary and phyto-sanitary and food-safety aspects are expected to play major roles in both domestic marketing and exports.

Over the next 30 years, as noted earlier, demands for cereals and meat are expected to grow annually by 1.5 and 2.5 percent, respectively. Self-sufficiency ratio of cereals production in Asia will continue to be above 90 percent, thus underpinning further intensification to meet the expanding demand. In other words, most of the additional food production must materialize in the countries which are already food deficient - albeit at household level. There is need to guard against, and to monitor, impacts of reaching the limits of the agricultural carrying capacity, of coping with the requirement to sustain natural resources, of over-exploitation of resources leading to faster rate of land degradation, deforestation, cultivation of marginal lands, water depletion and contamination, ecosystem acidification, and loss of bio-diversity. The mining of soils under the intensification process of the green revolution has been associated with deficiencies of increasing the number of micronutrients (Fig 5). Soil quality, top-soil protection and soil organic matter maintenance, nutrient cycling, prevention of soil toxicity due to waste disposal, and maintaining soil-microbiological activity against the threat of agro-chemicals, all pose soil-management challenges for sustainable agriculture. Science and technological developments hold the key to the alleviation of the intensification-related constraints.

Figure 5: Progression of multiple micro-nutrient deficiencies in soils



Intensive animal production systems generate ammonia (causing eco-system acidification), methane, and nitrous oxide. By year 2030, methane emission in Asia will have more than doubled (Table 19). Concentrated liquid and solid wastes cause leaching of nitrates and eutrophication. In peri-urban areas, swine and poultry industries pose problems of environment pollution, high cost of managing wastes and foul odour. Antibiotics used in intensive animal production have led to the emergence of antibiotic-

resistant strains of salmonella, listeric and e-coli. Transmission of the zoonotic diseases (tuberculosis, BSE, foot-and-mouth) is a growing concern within intensive animal production systems; they pose a technological challenge to prevent their recurrence. Heavy metals, such as cadmium, which are introduced via feed phosphates, can enter the human-food chain.

Table 19: Methane emission from livestock (million ton/ann)

	Year	Dairy cows	Cattle & buffalo	Sheep & goats	Total
South & East Asia	1995/97	1.9	16.9	2.7	21.2
	2030	5.3	38	5.6	48.9
Industrial countries	1995/97	6.5	10.9	207	20.1
	2030	7.9	11.6	3.4	22.9
World	1995/97	16.6	51.4	10.5	78.5
	2030	25.6	85.5	16.9	128.0

Source: Agriculture: Towards 2015/30 – Technical interim report, FAO Rome (2000)

The “grow now, clean up later approach” must be shaken off: the environmental degradation in the region is already pervasive and accelerating. Declining environmental quality and increasing pressure on natural resources are constraining the economic growth that is needed to reduce poverty and enhance food security in the region. Strong political commitment is needed to forge congruence between technology adoption, economic productivity, and environmental improvement.

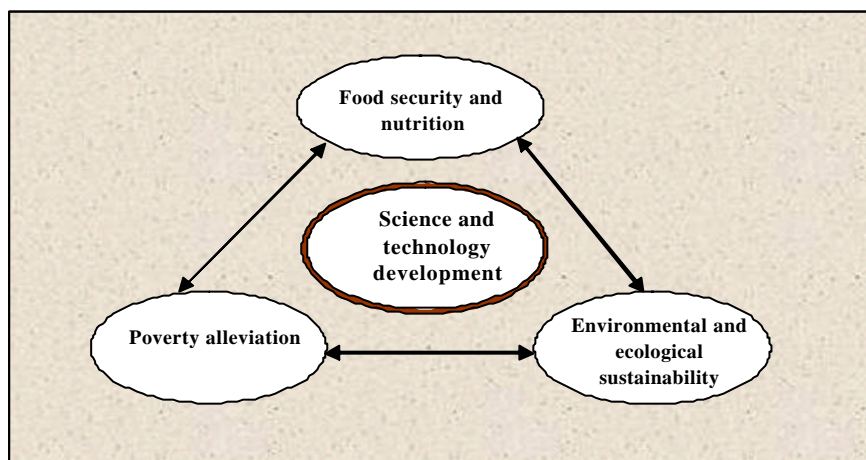
Water must be used as a precious resource - both at home and on farm. In India, it is projected that the per capita water availability will reduce from 2000 m³ to the stress level of 1700 m³ in the next two to three decades. In particular, agriculture’s water share will reduce from the present 89 percent to about 75 percent by 2020: more shall need to be produced from progressively less water. In Asia, Asian Development Bank reports that one in three Asians lacks access to safe drinking water within 200 meters of their home.

Climate change, variability and global warming and their impact on agriculture and vice versa emerge as new threats and challenges. Expected sea-level rises of between 15 to 94 cm over the century will adversely affect the coastal ecosystem: island states (such as the Maldives and Sri Lanka) may thereby face serious threats.. Tropical and sub-tropical agriculture will be negatively impacted by adverse changes in temperature, precipitation, and sea-level rise - further threatening the livelihoods of the poor persons dwelling in those climate zones. Moreover, in the A-P Region during recent decades those livelihoods have been adversely affected by an increased intensity and frequency of natural disasters. Indeed, since the mid-1970s, the A-P Region has suffered four-fifths of the world’s loss of life (and associated damage) from natural disasters.

V. SCIENCE AND TECHNOLOGY TO MEET THE CHALLENGES: FOOD-SECURITY, POVERTY-ALLEVIATION, AND SUSTAINABILITY

Science is an essential contributor to solving the triangle of the global problems of hunger, poverty, and environmental degradation (Figure 6). Without sound scientific input of different kinds, the challenges will not be addressed. Science, including the biological sciences and increasingly the social and physical sciences, must be applied to agriculture, fisheries, and forestry, and to those rural, coastal, and urban ecosystems and human systems within which hunger and poverty persist.

Figure 6: The critical triangle to be served by science



Science and technology must address (for crops, livestock, fish, and forests) various issues in order to attain higher productivity and sustainability and thereby help alleviate hunger and poverty:

- Enhancing yield and productivity, bridging yield gaps, and protecting yield gains;
- Exploiting the gene revolution (biotechnology);
- Benefiting from information and communication technology revolution and promoting knowledge-based development;
- Managing natural resources (land, water, and biodiversity);
- Addressing environmental concerns;
- Managing climate change; and
- Minimizing adverse impacts of natural disasters.

Moreover, more empirical and integrated approaches to research, and transparency of information, decision-making, and governance, will be needed (Fresco, 2000).

Enhancing yield and productivity, bridging yield gaps, and protecting yield gains

The Green Revolution (particularly of rice and wheat) was initiated by the development and large-scale adoption of dwarf and semi-dwarf, lodging-resistant, fertilizer- and water-responsive, photoperiod-insensitive, widely-adaptable and disease- and pest-resistant cultivars (the high-yielding varieties - HYVs), together with appropriate crop and resource management. *Irrigated* areas in many countries benefited greatly, as yields and returns per hectare doubled or tripled. *Non-irrigated* lands - constituting two-thirds of Asian agricultural lands - generally did not benefit, and their yields still continue to be low and unstable. These non-irrigated (“rainfed”) areas are inhabited predominantly by poor people; they are highly risk-prone - notably to aberrant monsoons. Thus, in the interests both of improving household food security and lessening socio-economic inequity, and also of raising national agricultural production, research and technology development must give *greater attention to the rainfed areas*, while maintaining and further increasing the gains made in irrigated areas.

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 20, 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 are expected to increase by 20 percent between 1990 and 2010 (Table 21). As cropping intensity becomes increasingly important, the features of crop duration and high per day productivity become preferred attributes.

Table 20: 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

Table 21: 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	10 000	67
1990	Various indica	130	10 000	77
2010	New plant type	130	12 000	92

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

The biotechnological and information revolutions have hastened the pace and precision of development of new super ideotypes, hybrids, and new life forms characterized by greatly enhanced yield, productivity, and adaptability. Thus *for rice*, the Super New Plant Types yielding up to 13-14 tons/ha (in semi-tropical ecozones) will soon be available for commercial production (IRRI, 2001). Super rice hybrids, with demonstrated yield of over 17 t/ha, are already giving an average yield of 10 t/ha in large areas in China (Yuan, personal communication). A new “breed” of “aerobic” rices that grow on dry but irrigated land instead of in flooded paddies is being created to fill the longstanding gap of high-yielding cultivars under low water availability conditions (IRRI, 2001). *For wheat*, raising of yield ceilings shall soon be possible through extra-long-spike cultivars with exceptionally high harvest index (CIMMYT, 2001). Quality, consumer preferences, cost effectiveness, and environmental aspects of production, distribution, and consumption of these new types will need to be critically analyzed in order to assess efficiency and efficacy of their large scale popularization in the broader context of food security, poverty alleviation, sustainability, and equity.

With newly-improved methodologies for systems analysis, and greater access to relevant data, reliable estimates of potential yields in specific agro-ecological regimes are increasingly available. Such estimates will assist in estimating more reliably the gaps between actual and potential yields, and will assist also in charting strategies to bridge yield gaps. For India, Aggarwal, Talukdar and Mall (2000) have analyzed potential yields of rice, wheat, and rice-wheat systems in various districts/states of the Indo-Gangetic Plain using validated crop growth simulation models, spatial weather data, land-use patterns, agronomic-management details, and GIS. Simulated potential grain yield varied between 12.0 and 19.5 ton/ha (Table 22) - higher in the northern compared to the eastern region. Temperature and solar radiation during crop season had high impact, suggesting the need for matching the genetic potential, phenology, and ecological features.

Such models can be used to calculate yield gaps in different regions, and to identify pathways for bridging those gaps. Indeed, in north India and using currently-available cultivars, several farmers already harvest nearly 16 ton/ha from rice-wheat systems - indicating negligible yield gaps. These yields are among the highest in the world, but their large-scale realization will require development of precision agriculture and due

concern for economic and environmental costs. Therefore, a systems approach with effective decision support systems is needed.

Table 22: Yield potential: of rice-wheat systems in the Indo-Gangetic plains

State	Average potential yield, t ha ⁻¹					
	Optimal rice and wheat planting			Late wheat planting		
	Rice-wheat	Rice	Wheat	Rice-wheat	Rice	Wheat
Punjab	18.29	10.60	7.69	17.18	10.60	6.58
Haryana	17.87	10.53	7.34	16.87	10.53	6.33
Utar Pradesh	17.48	10.34	7.14	16.46	10.34	6.12
Bihar	16.43	9.73	6.70	15.47	9.73	5.75
West Bengal	13.37	8.07	5.30	13.35	8.07	5.28
Indo-Gangetic plains	16.70	9.88	6.82	15.85	9.88	5.97

Source: Aggarwal, P.K. *et al.*, 2000

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) forecasts a declining real world food price between 1995 and 2020. While the low grain prices have been extremely helpful in improving poor persons' access to food, the farmers, especially those with marketable surpluses, have suffered and will further suffer. With hindsight, it may be visualized that should economic growth in Asia return to a rapid 8 to 10 percent per annum, there are chances that increased demand for livestock feed, livestock products, and other high-value commodities will precipitate price increases. This will induce system intensification, diversification, and enhanced TFP growth.

FAO analysis of yield gaps in selected Asian countries indicates that 50 to 100 percent transferable yield gaps are not uncommon. In India, for rice (the most important food crop), the gap between the national average and the experimental trials average was more than 3 tons per ha - more than 50 percent of potential yield. State-average yields were on average 52 percent less than national-average experiment yields. Yield gaps differed widely from state to state; lowest (800 to 600 kg/ha) in Tamil Nadu, and highest (4 900 kg/ha) in Rajasthan. Likewise, the state average yields also varied widely. Led by Punjab with an average yield of 5 tons per ha, Tamil Nadu and Haryana, in that order, also recorded yields higher than 4 tons/ha; yields were generally low in Bihar, eastern U.P., Madhya Pradesh, Rajasthan, Assam, Himachal Pradesh, and Orissa (Singh, 2001a).

Generally, yield gaps across sub-regions are high for rainfed crops, such as coarse grains and groundnut. These gaps can be bridged by : (i) extending the area under high yielding varieties; (ii) increasing the use of pulses and fertilizers based on soil test results, (iii) timely planting using quality and treated seed, (iv) ensuring desired plant population, (v) strengthening agricultural services, including appropriate processing and timely disposal of surplus production, and (vi) ensuring efficient use of irrigation water.

Inter-country differences in yields are rather high. Rice and wheat yields in 10 percent of the highest-yields developing countries were more than five times higher than those in the lowest-yields countries (Table 23). For wheat this gap is expected to remain until 2030, while for rice the gap between the top and bottom deciles may be somewhat narrowed by 2030; yields in the bottom decile are forecast as 28 percent of yields in the top decile. This suggests that in rice the yield ceilings are being approached faster than in wheat. The average yield levels obtained by the largest producers, accounting for the bulk of global production, are about half of those achieved by top performers. In spite of continuing yield growth in the largest producing countries, their average yield levels will still at 2030 be only 54 percent of yields in the top decile.

There are several agro-ecological and socio-economic causes for the gap in bridging the exploitable yield gaps. With increasing emphasis on precision agriculture, there are greater chances for narrowing the yield gaps. For example Australia, from an already-high average rice yield of 6.8 tons/ha in 1985/89 has pushed it to 8.4 tons/ha by 1995/99, with many individual farmers obtaining 10 to 12 tons/ha. The existing exploitable yield gaps should be seen as an opportunity for future growth that is consistent with agro-ecological, socio-economic, political and technological settings in the major producing countries and regimes. An important question is whether such opportunities exist for

Asia's resource-poor small-holder farmers, most of whom live in rainfed and other less-favoured areas.

Table 23: Wheat and rice yields: selected country groups

Country groups	1961/63		1995/97		2030	
	tons/ha	as % of top decile	tons/ha	as % of top decile	tons/ha	as % of top decile
Wheat						
No. of developing countries included	32		30		35	
Top decile	2.14	100	4.83	100	7.11	100
Bottom decile	0.40	19	0.85	18	1.22	17
Decile of largest producers (by area)	0.87	41	2.53	52	3.82	54
All countries included	0.97	45	2.13	44	3.02	42
Major developed country exporters	1.75		3.06		4.10	
World	1.18		2.42		3.23	
Rice (rough)						
No. of developing countries included	44		52		56	
Top decile	4.51	100	6.43	100	8.05	100
Bottom decile	0.71	16	1.12	17	2.27	28
Decile of largest producers (by area)	1.82	40	3.45	54	4.38	54
All countries included	1.88	42	3.06	48	4.31	54
World	2.09		3.30		4.54	

Source: Agriculture: Towards 2015/2030, FAO

- Notes: 1. In all country groups only countries with over 50 000 harvested ha are included;
2. Countries included in the deciles are not necessarily the same for all years;
3. Average yields are simple averages, not weighted by area.

Notwithstanding the success in piercing yield ceilings for intensively managed production regimes, the crux of the problem in a global sense of food security through large scale production gains is to narrow the exploitable yield gaps. In 1999, an *expert consultation on bridging the rice yield gap in the Asia-Pacific region* (FAO, RAP, 1999) made the following observations and recommendations:

- 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.
- The efforts to break the rice yield ceiling (new plant type rice, hybrid rice, 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.

Although not a widespread phenomenon, under certain production regimes there are signs of decline in actual yields. The long term (*but atypical*) decline in yield potential of rice, recorded under a continuous cropping experiment at IRRI was attributed to a degradation of the soil resource base and/or a decline in the genetic potential of breeding materials. Further analysis of the results, after compensating the highest yields with an amount equal to the annual rate of decline in IR-8 yield, indicated that the highest yields were increasing significantly. This suggested that yield decline was due to a faster rate of degradation of the submerged-soil environment, which may be greater than the rate of growth in the yield potential. However, as indicated in Table 21, part of the *supposed yield-potential decline* may reflect nothing more sinister than a shortening of rice-crop maturity.

The foregoing findings nonetheless suggest that a long term strategy and a site-specific and knowledge-intensive soil-fertility orientation are needed for the fertilizer-use technology, transfer, adoption and monitoring by the extension advisory system and the farmers themselves. Soil-test based fertilizer application, real-time nitrogen management by leaf chlorophyll meter or leaf colour chart (IRRI) and soil nutrient budgeting, will be the elements of precision agriculture to sustain high yields and lessen the fertilizers-related deceleration of partial factor productivity. This approach calls for a paradigm shift in the technology transfer approach, based on intensive knowledge and higher capacity of extension agents of both public and private sectors. Therefore, the need for improving training and information access to extension workers and farmers through

continuous interventions for providing science-based support to farmers can hardly be overemphasized.

The countries of the region are at various levels of development, especially with respect to transfer and use of technology and policy support. Hence no single formula with respect to technology transfer and policy support can be applied across the board. While the yield ceiling must be raised and stabilized, the declining growth rates of TFP should be reversed and the yield gap narrowed. At the same time, the production systems must remain sustainable and environment-friendly. Increasing attention must be paid to the management of soil, water and other production resources. Problems in bridging the yield gap under the limitations of social, biological, cultural, environmental and abiotic constraints need close scrutiny. But, on a positive note, most Chinese farmers, and groups of farmers in Punjab, Haryana, Andhra Pradesh and other states in India and in other countries have been able to achieve yields close to the yield potential for their respective locations. A clear understanding of factors contributing to this phenomenon could lead to the recovery of a significant part of the current yield potential and boost production and farm income.

Biotechnology: exploiting the gene revolution

Progress in molecular biology, genetic engineering, and biotechnology can greatly and most-effectively supplement conventional breeding approaches (preceding section) in enhancing yield, productivity, income, sustainability, and equity. It is fortunate that as we enter the new millenium and seek technological breakthroughs, modern biotechnology with multiple and far reaching potential has become available. It may spearhead agricultural production in the next 30 years at a pace faster than that of the past 30 years (the Green Revolution). Biotechnology interventions are already being used (and have additional potential) to enhance yield levels, increase input-use efficiency, reduce risk (and lessen effects of biotic and abiotic stresses), and enhance nutritional quality - all leading to increased food security, nutritional adequacy, poverty alleviation, environmental protection, and sustainable agriculture. Often referred to as "Gene Revolution or Bio revolution", *biotechnology* - if judiciously harnessed, blended with traditional and conventional technologies, and supported by policies - can lead to an ever-green revolution synergizing the sustainable pace of growth and development (Swaminathan, 2000a). The uncommon opportunities provided by fast developments in functional genomics, proteomics, DNA microchips and microarrays *must* be brought to developing countries - otherwise the technology divide will further widen.

But there are also numerous uncertainties and some perceived or potential risks associated with these technologies. There are biosecurity and access and trade-related concerns; often the following questions are raised: How can developing countries harness the accomplishments of biotechnology to promote their own agriculture - particularly in view of the restrictions to access and to the ability to reap the benefits of the new technologies? How can agricultural biotechnology help in the fight against hunger, malnutrition and poverty? Will the needs of developing countries, and those of "orphan"

commodities, be taken into account in the research efforts of developed countries? or shall developing countries be left to fend for themselves? Moreover, there is the risk of the assumption that genetic engineering is a “silver bullet” technology that will solve all the problems of agricultural growth and development. There is need for a balanced assessment (by researchers, policy makers, farmers, and consumers) of the potential of biotechnology to raise output, quality, input efficiency, income, and equity - without damaging the environment or society.

GMOs are increasingly being commercialized. Soybeans, maize, canola, and cotton represent almost 100 percent of area grown with GM crops globally (Table 24). Herbicide tolerant (Ht) soybeans alone account for 59 percent of global GM-crop area. Bt cotton (having received the resistance gene from Bacillus thuringiensis) and Ht soybeans have spread extremely fast in the countries of adoption. Between 1996 and 2000, global area of GM crops increased 25-fold, from 1.7 million ha to 44.2 million ha (Table 25). Although seven developed and eight developing countries are reported to grow GM crops, three countries (Table 26) account for 98 percent of the global area: the USA (68 percent), Argentina (23 percent) and Canada (7 percent).

Table 24: GM crop area as a percentage of global area, 2000

Crop	Global area (million ha)	GM area as a share of total area (%)	GM area (million ha)	Crop GM area as share (%) of total GM area
Soybeans	72	36	25.8	59
Ht Soybeans			25.8	59
Maize	140	7	10.3	23
Bt maize			6.8	15
Ht maize			2.1	5
Bt/Ht maize			1.4	3
Canola	25	11	2.8	6
Ht canola			2.8	6
Cotton	34	16	5.3	13
Ht cotton			2.1	5
Bt cotton			1.5	4
Bt/Ht cotton			1.7	4
Total	271	100	44.2	100

Source: Clive James, ISAAA Briefs, No. 21, 2000

Notwithstanding that impressive global growth in GM-crop area, the growth in the developed countries has slowed. In Canada, GM-canola area was in Year 2000 1 million ha less than in 1999. This was attributed to lower canola prices and to the introduction of a non-GM herbicide tolerant canola variety, which, other things being equal, is preferred

by consumers for biosafety reasons. The developing-countries increase was essentially due to the expansion of Ht soybeans. In A-P Region, only Australia and China grow GM crops commercially; but several other A-P R countries have elaborate biotechnology capacity and ongoing programmes.

Table 25: Area of GM crops: global, 1996 to 2000

Year	Number of countries	Million hectare	Area increase (million ha)	Area increase (%)
1996	6	1.7	-	-
1997	-	11.0	9.3	547
1998	9	27.8	16.8	153
1999	12	39.9	12.1	44
2000	13	44.2	4.3	11

Source: Clive James, ISAAA Briefs, No. 21, 2000

As regards the traits engineered, insect resistance and herbicide tolerance have been predominant and commercially exploited. Bt-based insect resistance has particularly been effective both in reducing cost of production and environmental pollution caused due to excessive use of pesticides. Herbicide tolerance has particularly been useful in reducing production cost and saving time for the farmer. These two traits are now combined in one variety - and already commercialized - in cotton and maize. In addition to gene stacking, transgenics for these traits are likely soon to be commercialized in sugar beet, rice, potato, and wheat; new releases of virus-resistant varieties are expected for fruits, vegetables, and wheat. Fungus-resistant crops are in the pipeline for fruits and vegetables, potatoes, and wheat.

Table 26: Area of GM crops: major growing countries, Year 2000

Countries	Million hectare		Percent of global GM crop area	
	1999	2000	1999	2000
Developed	32.8	33.5	82	75
USA	28.7	30.3	72	68
Canada	4.0	3.0	10	7
Australia	0.1	0.2	<1	<1
Developing	7.1	10.7	18	24
Argentina	6.7	10.0	17	23
China	0.3	0.5	1	1
Total	39.9	44.2	100	100

Source: Clive James, ISAAA Briefs, No. 21, 2000

Efforts to produce and commercialize transgenics tolerant to abiotic stresses, such as drought, extreme temperatures, soil acidity and salinity, have not yet been successful.

However, promising results have been obtained for salinity and cold tolerance; and GM crops are likely to be commercialized soon. These efforts are of high interest to resource-poor farmers in rainfed areas and on marginal lands.

The second generation of GM crops is expected to offer higher output together with better nutritional (and other) qualities in the produce. Many of the desired traits have been developed, but are yet to reach the market. They comprise a large range of different crops: notably soybeans with higher and better protein content, and crops with modified oils, fats, and starches to improve processing and digestibility (as with high-sterate canola and low-phytate or low-phytic-acid maize. Another promising application is cotton with built-in colours, and colour variants in various flower species. Nutraceutical transgenics are of great importance to undernourished and poor people. “Golden rice”, a beta-carotene enriched cultivar (also rich in Fe content), will help combat Vitamin-A deficiency and thereby save millions of persons from blindness. This is particularly significant to the A-P Region - which produces and consumes 90 percent of the world’s rice, and is home to the largest number of the world’s undernourished and Vitamin-A deficient and anemic children.

Other GM technology-based products include speciality oil, biodegradable thermoplastics, hormones, “plantibodies”, vaccines, and pharmaceuticals. GM poplars which demand less energy and produce less waste during processing are already grown in France. In the Asia-Pacific region, poplar plantations are expanding fast and the GM poplar could prove highly cost-effective.

As regards GM animals, although more than 50 transgenes have been inserted into farm animals, their expression and stability is not quite satisfactory. Ethical and consumer biosafety concerns are also intense in case of animals. Ingesting or being injected with certain pharmaceutical products from transgenic animals seems more acceptable to the public. GM fish, especially aquaculture species, have received genes that control the production of growth hormones impacting fish yield, but are yet to be commercialized and face the same biosafety concerns.

Genomics (structural and functional) - which is the determination of the DNA sequence and the locations and functions of all the genes in an organism - has progressed rapidly and has opened many opportunities for genetic engineering. The sequencing of entire genomes of organisms as diverse as bacteria, fungi, plants (*Arabidopsis* and rice), and animals (human) is leading to the identification of the complete set of genes found in many organisms. With the high degree of synteny among diverse species, and with many traits being common among species, and with understanding of the function and expression of the sequences, several useful traits (genes) are increasingly known (discovered) that improve crop plants, farm animals, fish, and forest species for human benefit.

Molecular breeding (the molecular-marker-assisted selection and marker-based genetic-distance analysis) is widely used for gene pyramiding. These approaches help to accelerate back-crossing procedures and to predict the performance of progeny. These

techniques and the products derived from them do not suffer from the biosafety concerns associated with GMOs, and hence are more likely to become popular.

The way ahead must map out ways to optimize the benefits and minimize the negative effects of biotechnology on a case by case basis (Singh, 2000). The potential of biotechnology should be approached with a balanced perspective by integrating it within the national research technology and development framework and using it as an adjunct to - and not as a substitute for - conventional technologies in solving problems identified through national priority setting mechanisms. Priority setting should also take into account national development policies, private sector interests, market possibilities, potential for adoption by farmers, public perceptions of safety, and consumers' views. Accordingly, various stake holders, public sector, private sector, industries, NGOs and wider segment of civil societies should be involved in the formulation and implementation of national biotechnology policies, strategies, plans and programmes. Pro-poor features of biotechnology should be judiciously harnessed to attack directly the issues of food insecurity, malnutrition, and poverty (Persley, 2000; Pinstруп-Andersen, 2000a).

Technology-inherent as well as technology-transcending risks must be critically and scientifically assessed in a transparent manner. Capacities and measures should be in place to manage the risks, minimize negative effects, and promote the positive impacts (FAO, 2001c). Each country must have the necessary infrastructure, human resources, financial support, and policy for meeting the challenges and capturing the novel opportunities. Competence will particularly be needed in the formulation of country-specific rules and regulations on biosafety- and intellectual-property-rights management regimes, along with commensurate financial, institutional, information and human resources for their effective implementation.

FAO, UNIDO, CGIAR centres and other concerned international organizations should assist developing countries both in the R & D aspects of biotechnology - which are expensive and often beyond the reach of many developing countries - and also in the regulatory processes, particularly biosafety and intellectual property rights. National capacities must be created/strengthened to implement the Cartagena Agreement on biosafety. FAO, with support from Japan, is establishing a regional project and network to assist countries in the A-P Region. The FAO Regional Office for Asia and the Pacific (RAP) will implement this project in close collaboration with other relevant and international initiatives. The proposed Asian Biotechnology Network will strive also to create a regional biotech consortium, strengthen public-private sector linkages, and harmonize various regulatory measures and standards suitable to the needs and prospects of countries of the Asia-Pacific region.

Information revolution: knowledge-based development

Strides in the field of informatics, including bio-informatics, have greatly enhanced the potential to ensure that knowledge and information on important technologies and practices are accessible to the masses. Information is now the least expensive input for

agricultural and rural development. Instantaneous transfer of knowledge and information to the rural masses could thus ensure knowledge-based development and substitute knowledge for monetary inputs. Rural communities require data and information not on only agriculture but also on associated economic and social aspects as also on new technologies, early warning systems, credit, market, prices, etc.

Information is power and will underpin future progress and prosperity. Efforts must be made to strengthen informatics in agriculture by developing new databases, linking national and international databases and adding value to information to facilitate decision-making at various levels. Development of production models for various agro-ecological regimes to forecast production potential should assume greater importance. Using remote-sensing and GIS technologies, natural and other agricultural resources should be mapped at micro and macro levels and effectively used for land and water use planning as well as agricultural forecasting, market intelligence and e-business, contingency planning and prediction of disease and pest incidences. The bulging youth population will find these developments challenging. With their skills in computer use and information handling, they should be attracted to run agricultural clinics, technology transfer and advisory services, and e-business in agriculture. Knowledge must increasingly substitute monetary inputs, increase efficient use of resources, and reduce cost of production - thus enhancing overall competitiveness of agriculture: a necessity in the trade-liberalized world.

Table 27: Internet users: (percentage of population, by region)

Region	1998	2000
United States	26.3	54.3
High-income OECD (excl. USA)	6.9	28.2
Latin America and the Caribbean	0.8	3.2
East Asia and the Pacific	0.5	2.3
Eastern Europe and CIS	0.8	3.9
Arab States	0.2	0.6
Sub-Saharan Africa	0.1	0.4
South Asia	0.04	0.4
World	2.4	6.7

Source: Human Development Report, UNDP 2001

There exists a serious digital divide - which will further expand the economic divide. Today 79 percent of Internet users live in OECD countries, which house only 14 percent of the world's population (UNDP, 2001); however, numbers of internet users in many developing countries are increasing rapidly. Nonetheless, only 0.4 percent of South Asians were Internet users in 2000 (Table 27) - this despite India being an information-

technology hub. Telecommunication and internet costs are particularly high in developing countries - one reason for the low number of connections. Monthly internet access charges amount to 1.2 percent of average monthly income for a typical US user, compared with 278 percent in Nepal, 191 percent in Bangladesh and 60 percent in Sri Lanka. To address this cost problem, it will be useful to establish community telecentres, particularly in rural areas. Within a given country also there are great disparities. For instance, among India's 1.4 million internet connections, more than 1.3 million are in only five States: Delhi, Karnataka, Maharashtra, Tamil Nadu, and Mumbai. The public and private sectors should work together to help bridge these divides.

Yet, as the technology takes a giant leap forward in the region, there is a widening gap between the urban and rural sectors in the gains realized from advanced and emerging technologies. The widening gap is pronounced in the case of rural women since the technology development process generally does not take into account their workload and technology needs. Rural women continue to maximize their productivity with limited understanding of these emerging technologies. The technology transfer professionals are also lagging behind in updating their knowledge on these emerging technologies. Furthermore, effective utilization of these emerging technologies requires a basic level of education which most Asian rural women lack. The know-how gap among rural women as users of technology and emerging technologies could continue to widen. Agricultural-services support provided to rural women should be tailored to match the local realities of women's specific contribution to the food sector. Providing support to women is most often viewed simplistically as assistance to women, but in reality it is interventions to improve the prospects for household food security (Balakrishnan, 2000).

Through initiatives of FAO and APAARI (Asia-Pacific Association of Agricultural Research Institutions), and under the overall umbrella of WAICENT (World Agricultural Information Centre), it is proposed to establish an Asia-Pacific Agricultural Research Information System (APARIS). Its objectives are to : (i) improve communication and exchange of knowledge on agriculture and natural resources, (ii) improve the efficiency of the research/extension/market interface, by opening new technology uptake pathways, and (iii) foster national information capacity building. To achieve these objectives, APARIS will formulate a regional information strategy, create a management information system for R&D institutions, and establish a regional reference centre. It will also provide a forum and services for knowledge sharing for agricultural growth and development.

Managing natural resources: land, water and biodiversity

Land, water, and biodiversity are the base not only of agriculture but of the very life and existence of humankind. Conservation, sustainable use and development of these resources are fundamental to the survival and progress of humanity. Science and technology therefore must play a leading role in arresting and even reversing the ongoing trend of degradation and erosion of these basic resources. Per caput agricultural land availability in the Asia-Pacific region is one-sixth of that in the rest of the world (FAO-

RAP 2001) and per caput water availability in the region is also the lowest (3.3 cubic kilometers per year) among regions of the world (against 28.3 cubic kilometers per year in South America) (Ayibotele, 1992). East and Southeast Asia have almost run out of any further land disposal for agricultural expansion. In South Asia, agriculture has encroached into land that should have never come into cultivation. Therefore, the need for most judicious and efficient use of land and water resources through the blend of appropriate technologies, policies and people's power can hardly be over emphasized.

Average cumulative loss of global cropland productivity since the Second World War as a result of human-induced soil degradation is 12.7 percent, and in Asia 12.8 percent (Oldeman, 1998). In certain agro-ecological pockets in some countries, primarily due to wrong technologies, poor management and greed, the resources have degraded almost to the point of no return. These trends must be noted as warning bells against the threat of dwindling of the very livelihood system and even of society and civilization.

The relative impact of soil degradation will vary under different agricultural settings. For instance in Asia, it is projected that by 2020 the economic effects of future soil degradation will be most severe in densely marginal lands followed by that in irrigated lands (Table 28). National policy priorities for managing degraded lands will thus vary widely and must be determined by each country's resource endowment, the structure of agricultural supply, distribution of poverty, and the principal agricultural sources of economic growth (Scherr, 1999). Research and technology development priorities will thus need to be set in consonance with the individual production regimes.

Table 28: Soil degradation in various agricultural pathways

In order of global policy priority	Anticipated impact of soil degradation on				Severity of problem	Dependence on direct policy action to resolve
	Consumption by poor farmers	Agricultural market supply	Economic development	National wealth		
1. Densely populated marginal lands	***	**	***	**	***	***
2. Irrigated lands	**	***	***	***	**	**
3. High-quality rainfed lands	**	***	***	***	*	*
4. Urban and peri-urban agricultural lands	*	*	*	*	*	***
5. Extensively managed marginal lands	**	*	*	*	*	*

Source: Scherr, 1999

Notes: To resolve soil degradation problems (see last column), all of these agricultural pathways require a strong agricultural economy, so that farmers have incentives and capacity for good land husbandry. This calls for sensible general agricultural and rural policies, infrastructure investments, and so on. The last column refers to the need for policies and public investments specifically aimed at controlling soil degradation. *** indicate high, ** medium, and * low.

Sustained soil fertility and overall soil health are prerequisites to a sustained agricultural production. Strenuous efforts are thus needed to maintain and restore soil health and fertility. At the same time, production systems must be promoted and developed according to soil capacities to optimize production and sustainability. Location-specific generation and transfer of technology demands a detailed understanding of the soil resource, its variability, potential, and limitations through detailed soil survey, classification and mapping. Suitable soil management technologies in the areas of soil conservation, soil tillage, including zero tillage or conservation tillage, soil-water-nutrient management in an integrated approach need to be refined appropriate to the soil units (types) and the type of farming systems that are practised. Reclamation technologies must be fine-tuned and made cost-effective. Bio-remediation for abiotic stresses must be appropriately dovetailed with an overall soil management strategy. These practices must in the long run ensure restoration of soil quality. Monitoring soil health, in all its aspects, will be crucial for ensuring sustainable agriculture, centred on good husbandry of both seed and soil.

Agriculture is the biggest user of water, accounting for over 70 percent of global water withdrawals. There are pressures for diverting water from agriculture to other sectors. IFPRI has warned that re-allocation of water from agriculture can have a dramatic impact on global food markets. It projects that availability of water for agricultural use in India may be reduced by 21 percent by 2020, resulting in a drop of yields of irrigated crops, especially rice, a price rise, and withdrawal of food from poor masses. Policy reforms are needed from now to avoid negative developments in years to come. These reforms may include the establishment of secure water rights to users, the decentralization and privatization of water management functions to appropriate levels, pricing reforms, markets in tradable property rights, and the introduction of appropriate water-saving technologies. Community land and water care movements should be launched to ensure commitment of the masses towards conservation and judicious use of these resources.

The needs of other sectors for water cannot be ignored. Therefore it is necessary that an integrated water use policy is formulated and judiciously implemented. Several international initiatives on this aspect have been taken in recent years. Developing countries should critically examine these initiatives and develop their country-specific system for judicious and integrated use and management of water. National institutions should be established to assess the various issues, regulatory concerns, water laws and legislations, research and technology development and dissemination, social mobilization and participatory and community involvement, including gender and social equity concerns and economic aspects.

Commonly encountered environmental degradations such as waterlogging, salinization, overextraction, use of fossil aquifers, pollution of surface and ground water, and their associated economic and social costs, can be minimized through appropriate and timely management interventions. Land and water investment decisions also have serious implications for global warming and climate change. The potential for carbon sequestration in soil may be as high as 40 percent of total amount of annual atmospheric increase in CO₂ concentration. Water management practices can greatly impact methane

emission from paddy fields - an important point of consideration for Asia-Pacific as about 90 percent of the world's paddies fall in this region.

Land and water are intimately interrelated resources. The extent, quality and productivity of the two resources are highly interdependent. Therefore, while there must be land-specific and water-specific conservation, development and utilization policies, strategies and programmes, there is a need to have a clear policy and approach for synergistic development and effective integration of land and water to enhance overall productivity, sustainability, profitability and reduction of environmental costs.

Agricultural area expansion in land-hungry Asia-Pacific is largely dependent on gross cropped area expansion (increased cropping intensity), which is closely linked with irrigation intensity. It is often noticed that the expansion of irrigation when uncoupled with drainage facilities and efficient on-farm water management have resulted in vast land degradation in the form of waterlogging and salinity, thus negating the gain. This highly costly and negative trend can be and must be discouraged and reversed only by integrating the development of the two resources. Clearly, an interdisciplinary approach involving land and soil specialists, water and irrigation experts, agronomists, engineers, designers, economists, sociologists and even anthropologists, and above all the peoples themselves, working as partners in a participatory mode, is essential. Therefore, an integrated approach of policies and investment is needed to promote land and water protection, rehabilitation, development and quality improvement leading to sustainable agricultural supply, economic growth, rural welfare and long-term national wealth.

Based on the various considerations discussed in this section, the following priority areas for research and technology development in the land and water sector are suggested:

- mapping and utility classification of land and water resources;
- improving the efficiency of land and water use in agriculture;
- policy, institutional, economic and social aspects of land and water management;
- management of watersheds for multiple functions;
- management of aquatic ecosystems, in particular those with boundaries with terrestrial ecosystem;
- recycling of wastewater, conjunctive use of water, improvement of water quality and reduction of water pollution;
- restoration of fertility and structure of degraded lands and prevention of further degradation, bioremediation; and
- integrated soil- water-plant- nutrient management and fertility improvement.

Water accounting methods developed by the International Water Management Institute (IWMI) can help planners to improve water productivity by analyzing where water goes, who uses it, and how productive it is per cubic meter, and whether it is available for re-use. Likewise, soil fertility and health indicators are becoming increasingly available and should be used for assessing the resources and investment priorities.

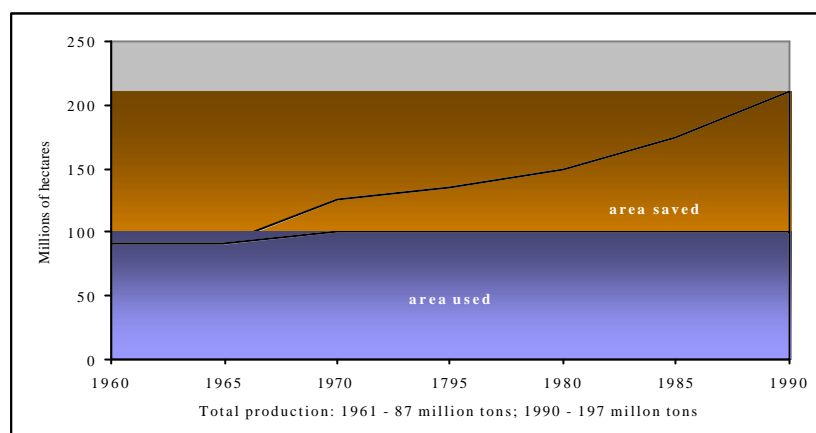
For the third group of natural resources – biodiversity - it may be reiterated that genetic resources are the building blocks of functions and forms of living organisms and will always be needed to produce new genotypes to meet the ever changing needs of humankind. New sciences of biotechnology and bioinformatics, coupled with conventional sciences, should be judiciously used for developing efficient and effective methods of conservation, utilization and exchange of genetic resources. Due to economic and population pressures the resources are eroding fast. Moreover, their availability is getting increasingly restricted due to their propriety protection under several systems. The Cartagena protocol for conservation, biosafety and sharing of genetic resources provides largely accepted and harmonized current practices and standards, and should be accepted by all countries. Along with Plant Breeders Rights, Farmers' Rights should be honoured and implemented for equitable and fair sharing of genetic resources. In this context, the indigenous rights over genetic knowledge and women's sphere of plant knowledge should be recognised under any intellectual property rights regime (Swaminathan, 1998).

The FAO-led International Treaty and Global Plans of Actions on Plant Genetic Resources for Food provide the mechanism for rationally conserving and utilizing genetic resources. Dynamic national research systems should be in place to address the research, development and sharing issues of germplasm. Biotechnology should increasingly be used for characterization, conservation, and utilization of genetic resources. Recognizing that the abundant genetic resources in developing countries could constitute invaluable bargaining chips to procure new technologies and products from industrialized countries, then appropriate documentation, registration and transfer agreements of the resources is a prerequisite for sharing of these resources. On the pattern of UNESCO's Human Genome and Human Rights, FAO should adopt a universal declaration on the "Plant Genome and Farmers' Rights" to provide a balance between the rights of conservers of biodiversity and the researchers, developers, and users of modern biotechnological products. In this gene-rich region there is an urgent need to develop guidelines and procedures for the realization of Farmers' Rights to sustain on-farm in-situ community-based conservation of biodiversity and associated traditional knowledge. A fair, transparent and implementable reward and recognition system should be created for this purpose.

Environmental concerns

For each agro-ecological zone, a suitable agricultural production system must be promoted with adoption of a package of technologies that optimize the productivity and minimize the negative impact on the environment. Depending on the level of intensification, the positive effects of agricultural intensification are in saving encroachment on forest lands (Figure 7), providing more crop cover on land, more carbon sequestration (Table 29) and above all in ensuring food and employment security and in reduction in poverty and hunger. Unscientific and unsustainable adoption of agricultural production methods will intensify environmental degradation, as described earlier.

Figure 7: Land area saved by the green revolution (India)



Source: Based on Production Year Books, FAO

Table 29: Annual carbon sequestered by cropped soils

Region	Total carbon (million tons)		Carbon (tons/ha)	
	1995-97	2030	1995-97	2030
South Asia	93-186	169-338	0.51-1.03	0.57-1.73
East Asia	176-352	265-529	0.82-1.65	1.18-2.36
Industrial countries	155-310	203-405	0.83-1.66	1.05-2.11
World	590-1181	927-1853	0.61-1.23	0.84-1.69

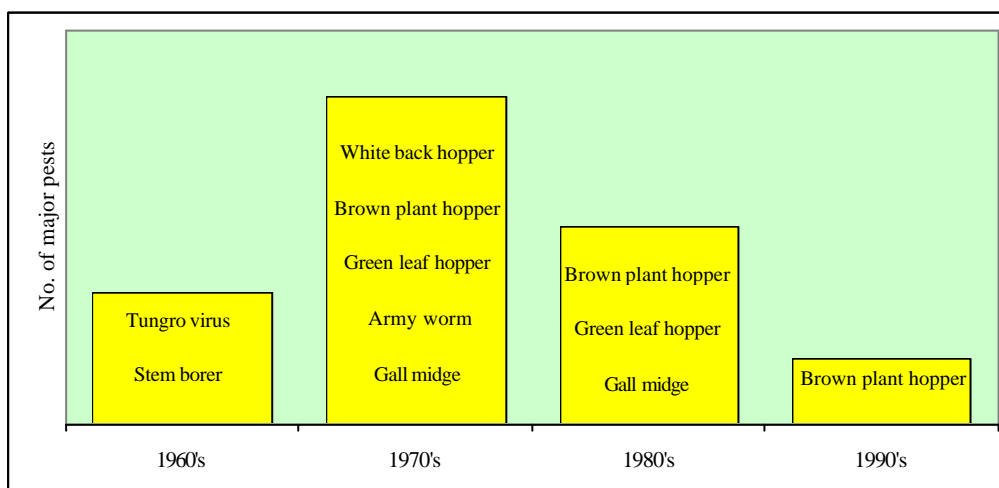
Source: Agriculture: Towards 2015/30 – Technical interim report, FAO Rome (2000)

In a land- and water-hungry region like Asia and the Pacific, the synergy of genetic engineering, water use and nutrients use must be maintained to boost yields. In doing so the sustainability and environmental concerns must be kept in mind. Poor management of water, mineral fertilizers and other agrochemicals in many parts of the world has caused widespread environmental pollution, depletion of water tables and degradation of soil fertility and nutrients base, particularly in the developing countries. In Asia, nutrient imbalances and deficiencies are already adversely affecting crop yield. Along with the use of inorganic fertilizer, the application of organic fertilizer, soil conservation measures, and the integrated management of plant nutrients sources (IPNM) will all need to be integrated in one programme so that the primary nutrients N, P and K, the secondary nutrients S, Ca, and Mg, and +micronutrients are available in the correct absolute and relative quantity and at the right time, place and price for high crop yields to be realized.

The technological package of IPNM should be coupled with effective and efficient pest, soil and water management technologies. Government policy should be geared to

promote this synergy between the different technological components by improving research, monitoring, participation, and the extension of effective integrated pest, soil, water and plant nutrients management approaches. New biotechnological inventions for increasing the efficiency of plant water and nutrients use systems should also be encouraged. Appropriate government policies on pricing of inputs and outputs and institutional and infrastructure supports will be essential to maximize the positive effects of technological and non-technological factors towards enhancing and sustaining crop and overall agricultural production. In this context, it may be noted that several Asian countries have explicit policies and programmes on integrated pest management, which are paying rich dividends. Almost two decades of active partnership of FAO and the national programmes, now through the Farmers' Field Schools, have succeeded not only in reducing pest incidences and crop losses but also in lessening the use of hazardous pesticides. In rice, with intensification under the green revolution process new pests and biotypes emerged, necessitating increased applications of pesticides, but with the adoption of IPM, the situation was controlled and the pest incidence returned to the pre-green revolution level (Figure 8).

Figure 8: Rice-pest dynamics: progression



Mindless expansion of industrial livestock production is creating several environmental problems. Creation of buffer areas (zoning) around the intensive livestock production sites will help in reducing the problem of odour, spread of diseases through insect vectors, and pollution of natural waterways. Research to minimize the build up as well as the negative impact of greenhouse gases such as methane should be undertaken and strengthened (Singh and Velayutham, 2001). Policy measures should promote gradual reduction of animal production and processing in areas with high animal concentrations and waste loads and increase of mixed farming system and specialized livestock crop-production systems in rural areas. Removal of subsidies on concentrates would increase the cost of feeds and hence favour grazing-based animal production systems. Several East Asian countries are striving to locate their industrial animal production systems away from urban centres (FAO, 1998b). A success story of private-sector cooperative

pig farming in Thailand (Sitanon Jesdapipat, 1998) shows one way for dispersed production systems in the rural areas. In this model, 50 farmers (households) in Nongwha Agricultural Village in Chachoengsao Province, who did not own any land, were in 1977 allotted 4 ha of land per household, on which pig rearing was integrated with mango cultivation. The project was financed by low-interest agricultural loans totaling 25 million Baht (then about US\$ 1 million). Each household was guaranteed a minimum monthly income of 2000 Baht. The model, with three working phases, has shown good results.

An effective system of environmental assessment and monitoring must be put in place at various levels of governance and through social groups. Such an agency and exercise should assess periodically the existing systems and their management levels, predict potential negative impacts of proposed development interventions, and monitor the state of environment due to these production systems, their management and development. Usually a *pressure–state–response (PSR)* framework is adopted in the analysis. *Pressure* identifies why is it happening – the activities that are causing environmental changes; *state* seeks what is happening – describing the physical/ecological state of the environment; *response* explores what is being done/to be done about it – describes the policies and actions that affect the way people use the environment. In combination, they lead to identification of solutions. Such a resource accounting – tracing the flow of natural resources through their life cycle from harvesting/extraction to marketing/disposal and environmental impacts – at national level can be linked to the UN System of National Accounts (SNA).

Appropriate indicators – which quantify and simplify phenomena and help understand complex processes and realities – are used in the PSR analysis. More recently, the *driving force–pressure–state–impact–response (DPSIR)* framework for reporting on environmental issues was developed (Steinfeld, 2001). These analyses add value in decision making in the sense that the physical indicators of change are linked with socio-economic indicators of pressure and political/institutional indicators of response. Suitably trained manpower and institutional support will be needed to fully deploy these frameworks and monitoring devices. The pressures like “pollutor pays” and “beneficiary compensates” should increasingly be mounted under globalization and international trade agreements. Asian countries must be equipped to handle these provisions and restrictions as the region intensifies crop and livestock productivity and improves its share and competitiveness in the international market (Singh and Velayutham, 2001).

Managing climate change

Climate change is a reality and it is now widely accepted that the change is currently taking place at a much faster pace than in the past. Recent global meetings on climate change have noted that about 80 years from now the average temperature will have increased by 3 to 3.5 degrees Celsius, and average on-land precipitation by 2 to 4 percent. The planet will divide into clear winners and losers. The winners will mostly be the developed countries and the losers will mostly be the developing countries. The studies have further revealed that India, with about one-sixth of the world population, will be the

biggest loser from global warming, losing tens of millions of tons from its potential cereal harvest each year because of climate change. An Indian study has shown that a 1 degree Celsius rise in temperature in North India would reduce the duration of the wheat crop by one week, thereby reducing yield by 500 to 600 kg/ha (Personal communication P.K. Aggarwal, IARI).

It is cruelly ironic that the poor in the developing countries who are least to blame for the global warming are the ones to suffer most. About 80 percent of the greenhouse gases contributing to global warming are emitted by developed countries. In this context, the stand currently taken by USA on the implementation of Kyoto Protocol and its overall energy policy in relation to global warming needs to be re-examined by US scientists and policy makers together. FAO and the entire United Nation system must influence policy decisions and the role of science for obviating and eliminating the catastrophic impacts of climate change. Anticipatory research, including conservation, characterization and utilization of topical genetic resources and use of biotechnology and other cutting-edge sciences, to meet the challenges of global warming and climate change must be initiated now. The countries likely to be negatively impacted by climate change should collaborate not only in strengthening their relevant research and technology development, but also in their negotiations at various international forums.

Natural disasters: minimizing adverse impacts

The A-P Region is the most disaster-prone region in the world - experiencing nearly one half of the reported disasters in the 1990s. Eighty percent of the 130 million people world-wide who since 1975 were killed, injured, rendered homeless, or otherwise affected by catastrophes were Asians.

The frequency of disasters is high and the impact intense because of climatic, geographic and natural resource diversity, high population density and poverty. Increasingly, environmental degradation, climate change and settlement of marginal lands are making people vulnerable to natural hazards. The A-P Region is subject to almost every conceivable natural hazard. Additionally, it is increasingly susceptible also to man-made disasters such as war, civil strife, economic crisis and plunder of natural resources. For both natural and man-made catastrophes, national capacities in GIS, weather forecasting, connectivity with regional and world weather data and forecast must be in place for appropriate preparedness.

Devastation is disproportionately high in the agricultural sector. Apart from human death and injury, there is damage and loss to standing crops, livestock, food stocks, tools, equipment, buildings, irrigation and drainage systems, transportation networks and other capital. There is underemployment and unemployment leading to destitution and undernutrition. Emigration to cities follows. The ill effects are transmitted from farms to rural communities and eventually to cities, as many vulnerable economies are agriculture based. For many low-income food-deficit countries, years of painstaking economic development can be erased by one or more natural disasters. Some vulnerable peoples

never recover: there are many A-P examples of such disaster-impooverished communities and countries.

It is hard to define cost-effective technologies, policies and programmes to deal with disasters because governments lack timely, comprehensive and accurate data on natural and man-made hazards. Until governments know (for individual communities) who are the vulnerable peoples, where they are located, and why, then measures and remedial resources will remain superficial, fragmented and thinly spread. The problem is further compounded by the fact that available technologies to combat storm, drought, flood and other natural hazard induced agricultural disasters are not good enough. More research and development in climate prediction, agro-meteorology, natural resource management, engineering works and farming systems is needed to mitigate repeated and prolonged natural hazards.

As the poor face a wide range of variable and unpredictable risks, their ability to invest in technologies is dynamic. Science should provide a diversity of options/choices that suit a wide range of investment profiles. Farmers will then be able to choose the most suitable options according to their particular circumstances, including contingency farming practices to mitigate adverse effects of natural and man-made disasters.

Governments and communities are finding it increasingly difficult to manage preventive, preparedness, relief and recovery measures due to paucity of resources. This is because of the rising frequency and scale of disasters, insufficient resources and rising costs of reaching vulnerable areas, and sometimes due to poor links and balance between public and private services. Priority must be to save those who are on the edge.

Further, there is the neglect of nutritional needs of the victims on a long-term basis. Food relief is generally provided to reduce hunger and starvation in the immediate post-disaster period. But, undernourishment and malnutrition prevail long after the disasters occurred. Much more could therefore be achieved if the victims were regularly surveyed and assisted to acquire adequate and balanced diets. In this context the role of women is particularly important – both for themselves and for their children.

The scale of the problem, nature of shortcomings, and required actions strongly suggest that governments must make disaster early warning, prevention, preparedness and management a component of the agricultural development process. These activities must not be fragmented, discontinuous, patchy and thinly spread as they are now. In short, governments must mainstream disaster management. FAO and other concerned international organizations should assist member nations in developing strategies and programmes to mainstream disaster management within the framework of national and regional self-reliance. Community involvement in building local seed, grain, and drinking-water banks, micro-credits and micro-irrigation will greatly mitigate the hardships caused by disasters.

VI. SCIENCE AND TECHNOLOGY POLICIES AND STRATEGIES

Expansions in science and technology have marked the onset of the Third Millennium. If harnessed rationally and effectively, these could help eradicate hunger, poverty, destitution and indignity. The progress in the fields of biotechnology, information and communication technology, medicine, space science and management science offers unprecedented opportunity for multifaceted development. The industrialized countries and a few developing countries (in some of the areas) are vigorously capturing these uncommon opportunities by innovating, adapting and regulating these technologies. But the majority of the developing countries are far behind and are further falling behind, thus widening the technology divide. Based on indicators of technology creation, diffusion of recent innovations, diffusion of old innovations and human skills, UNDP had the calculated technology achievement index (TAI) of 72 countries. Although somewhat flawed as it generally ignores the vast contributions of public sectors, which are mostly not under IPR, the index shows that Finland with a TAI of 0.744 was first, closely followed by the USA with a TAI of 0.733. Japan was fourth. Table 30 gives TAI of countries of the Asia-Pacific region (for which data were available). It may be seen from

Table 30: Technology achievement index (TAI): selected Asia-Pacific countries

Countries	TAI value	TAI Rank out of 72
Leaders		
Japan	0.698	4
Korea Rep. of	0.666	5
Australia	0.587	9
Singapore	0.585	10
New Zealand	0.584	15
Potential Leaders		
Hong Kong, China (SAR)	0.455	24
Malaysia	0.396	30
Dynamic Adopters		
Thailand	0.337	40
Philippines	0.300	44
China	0.299	45
Indonesia	0.211	60
Sri Lanka	0.203	62
India	0.201	63
Marginalized		
Pakistan	0.167	65
Nepal	0.081	69

Source: Human Development Report, UNDP 2001

the table that of the 15 countries (including Hong Kong and Singapore), five were listed as “Leaders”, two as “Potential Leaders”, six as “Dynamic Adopters” and two as “Marginalized”. A good number of the countries are in the “Marginalized” category. In order to bridge the technology gap, effective policies and programmes are needed in the countries with lower TAI.

For the agriculture sector, as seen from the preceding section, science and technology offer tremendous opportunities for enhanced and sustainable production, environmental protection and income enhancement - leading to comprehensive food security and overall prosperity. But, in order to be effective in its service to the humankind, science and technology development must be guided in such a way that it meets the needs and aspirations of the people identified through participatory approaches. An appropriate “environment” must be provided to realize the full potentials of new scientific developments by formulating and implementing suitable policies and strategies.

From the foregoing analyses it emerges that the most pressing need of the Asia-Pacific region is the alleviation of hunger and poverty through enhanced and sustained production, equitable distribution, and environmental protection. Science and technology must specifically address the needs and prospects of majority small and resource-poor farmers of the region and help mainstream the gender concerns. 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 congruence among productivity, sustainability, profitability and equity. Thus, it is not only biological and physical sciences, but also economics and social sciences, which must all interact dynamically to yield wholesome results.

Science has many roles including (i) to 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 transform the Green Revolution into an Ever-green Revolution.

Paradigm shift: Towards an evergreen revolution

The Green Revolution was a science-led process. Science and technology development must continue to spearhead the productivity-enhancement process - since intensification through increased yield per unit land area, water, labour, and capital is the only recourse for achieving the production targets. But based on the assets and liabilities of the Green Revolution process, which is now waning, the way ahead must follow a different path which should lead towards an Evergreen Revolution. This calls for major paradigm shifts in R & D systems.

The first paradigm 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 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, will assume high significance in the globalized and liberalized world.

Generation of need-based technologies, their effective assessment and innovative diffusion involving system approach and participatory processes are important means to improve agriculture productivity. Integrated pest management, integrated soil-water-irrigation-nutrient management, and post-harvest and value-addition management should be aggressively promoted to attain desired yield, quality and sustainability levels. Besides, efforts must be in place to defend the gains already made and to make new gains - particularly through the synergism of gene revolution, informatics revolution, management revolution and eco-technology. Decision support systems based on the principles of ecology, economics, equity and employment should be developed for realizing the Evergreen Revolution (Swaminathan, 1999).

Greening the technologies is a pre-requisite for realizing the Evergreen Revolution. 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, what Swaminathan calls Eco-technology. Legal systems and formal sectors must therefore duly recognize the traditional wisdom and technologies so as to broaden and sustain the knowledge base.

Technologies while promoting growth must also have a human face. The following features will humanize technologies for ensuring sustainable livelihood: (1) Enhance capabilities for sustainable livelihood, and provide for new livelihood opportunities for the poor, (2) Improve the productivity, profitability and sustainability of communities' assets, and establish effective linkages between community mobilization and the government and other service providers, (3) Ensure the congruence and synergism among environmental, economic and social (gender and other equities) securities, and (4) 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.

Investment in agriculture, agricultural sciences, and research and technology development

The efficacy and effectiveness of investment in agricultural sciences, research and technology development is closely linked with the overall investment in agriculture and rural development. Any imbalance between the two will depress the overall performance of the sector as a whole. For instance, the science-led Green Revolution which accelerated agricultural and economic development was greatly dependent on the congruent and simultaneous enhanced investment in technology generation, technology diffusion, inputs support (seed, fertilizer and irrigation), agricultural education and human resource development, market support and policy development.

During the Green Revolution, improvement in productivity was the key to sustained agriculture and rural development. Expansion of cultivable area is no longer a practical option in A-P as the frontiers were reached long ago. Agricultural productivity requires investment in human resources, farm-to-market roads and related infrastructure, and support services such as agricultural research and development and improved technology information and extension. In the past, technology has proven to be instrumental in accelerating agricultural and economic development. Improvement in yield was the primary source of growth and it will be more so in the future. Investments in agricultural research and technology development had very high rates of return, generally exceeding 30 percent per year (Table 31). This trend is expected to continue in the foreseeable future. Yet, average annual growth rates of public agricultural research expenditures in the A-P Region have slowed since the 1970s, and there is negligible increase in private expenditure on agricultural research (Alston, et. al., 2000).

Table 31: Return (percent) to agricultural-research investment

Location	Internal rate of return, 1958-98
All known locations	44
Sub-Saharan Africa	33
Asia and the Pacific	48
Latin America and the Caribbean	41
West Asia and North Africa	34
Multinational or International	35

Note: Shows average of 1809 public sector programmes

Source: Lipton, Sinha and Blackman 2001 (cited in UNDP Human Development Report 2001)

There is a tremendous gap between developed and developing countries in the extent of investment in agricultural research and technology development. Developing countries on average generally allocate only 0.1 to 0.5 percent of their agricultural GDP to agricultural research, compared to 2 percent or more in industrialized countries. The difference in absolute terms is much larger, since agricultural GDP of OECD countries is several times of that of the developing countries.

The disparity in investment in agricultural sciences and research is further aggravated when it relates to cutting edge technologies such as biotechnology, thus furthermore widening the gap in the ability of harnessing frontier scientific developments, resulting in highly skewed competitiveness in the globalized world. It was estimated that OECD countries' public sector annually invested nearly US\$ 1.8 billion on agricultural biotechnology research, whereas the developing countries' NARSs annually invested about US\$150 million, plus about US\$ 40 to 50 million donors support and around US\$25 million invested by the CGIAR centers (Byerlee and Fischer, 2001). Considering that in the industrialized countries the public sector accounts for only about 50 percent of the total investment in agricultural research, and in developing countries the public sector finances around 90 percent of total agricultural research, the total spending on agricultural biotechnology in the developing countries is about 6 to 7 percent of that in the industrialized countries. The developing countries can ill afford to miss the exciting opportunities of capturing the scientific revolutions in improving their agricultural production and competitiveness; they must increase their investment in agricultural research and technology development.

The World Food Summit (WFS) reaffirmed the right of everyone to have access to safe and nutritious food, consistent with the right to adequate food and the fundamental right of everyone to be free from hunger. The 112 Heads of State and Government of the 186 nations participating in that Summit pledged their political will and commitment to halving the number of undernourished people no later than 2015. However, as mentioned earlier, the progress towards achieving the target is woefully slow. This suggests the need for reconsideration of strategies and for strengthened, targeted and specific efforts to achieve the WFS goals. The WFS had envisaged that science, agricultural research, and technology development will play a major role towards achieving summit's goal and had recommended their strengthening.

In developing countries, generally more than 60 percent of the population is rural, and directly dependent on agriculture. Against this, 90 percent of these governments on average devote lower than 10 percent of their spendings to agriculture (FAO, 2001d). Moreover, the rural poor accounts for a majority share (70 percent) in poverty, which is expected to remain at more than 50 percent till 2035. Rural-urban disparity in mean income and in access to education, health and sanitation services is not falling. Rural poverty has been closely linked with low agricultural production and productivity and can largely be ascribed to the declining investment and the resultant declining capital formation in agriculture. Recognizing that the role of agricultural development in poverty and food insecurity eradication is crucial, it is paradoxical that agricultural and rural development is not being pursued with top-most priority. We must realize that if agriculture goes wrong, nothing else will go right.

There are wide differences among the developing 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 32). These two regions have 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 32: 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	1,598	553	1,101	1,062	1,133	1,473	1,132	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 is collapsing. 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. A recent study of Rural Asia by the Asian Development Bank (ADB, 2000) reiterated 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. Yet, direct lending and technical assistance to agriculture by ADB has sharply declined, from US \$ 1,242 million in 1990 to only US \$ 433 million in 1999 (FAO, 2001d). The World Bank/IDA halved their lendings for agriculture from 18 percent in 1990 to 9 percent in 1999. Financial support to FAO and other concerned UN agencies has also stagnated and declined. For instance, FAO's total annual budget permits an annual allocation of hardly 40 cents per malnourished person. Against this, almost US\$ 1 billion is spent everyday as agricultural subsidy in OECD countries. Insufficient investment and declining external transfers towards agriculture are bound to adversely affect the capacity of future generation to feed themselves.

The waning trend is a matter of still greater concern as the decline comes at a time when the agriculture sector faces issues (e.g. sustainability, improving rainfed agriculture, productivity of small farms, globalization and increasing competition) that are quite complex and increasingly crucial. Accelerated investment is needed to facilitate agricultural and rural development through: (i) strengthening of research, education and technology development capacities leading to enhanced productivity and sustainability, (ii) 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, (iii) 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 (iv) primary education, health care, clean drinking water, safe

sanitation, adequate nutrition particularly for children (including mid-day meal at school) and women. These investments will need to be supported through policies that do not discriminate against agriculture and the rural poor. Given the increasing role of small farmers in food security and poverty alleviation, development efforts must be geared to meet the needs and potential of such farmers through their active participation in the growth process (Pinstrup-Andersen, 2000b).

The waning trend must be reversed by appropriate policies and concerted advocacy at national and international levels. For this campaign, the underlying factors to the dwindling public investments in the agriculture and rural sector must be thoroughly examined and understood. The World Bank's Poverty Reduction Strategy Paper (PRSP) offers an opportunity to analyze this trend, but unfortunately, PRSPs elaborated so far are generally not giving due attention to agriculture and rural sectors. Individual countries, with technical support from FAO, IFAD and other concerned agencies, particularly through the CCA and UNDAF process of UNDP should ensure that the concern and prospects of agricultural and rural development are duly reflected in the PRSP. Investments must directly be made on those items which will most effectively and immediately improve agricultural production (supplies) and income.

FAO's analysis *Mobilizing Resources to Fight Hunger* (FAO, 2001d) concludes that lack of sufficient investment in agriculture contributed to insufficient progress in the alleviation of hunger during the 1990s, despite the fact that the desired reduction in undernourishment levels can be and has been achieved by directing more resources towards agriculture. It emphasizes that "to meet the WFS target the political will by both national governments and international foreign donors is needed to direct sufficient resources to food and agriculture in a way that will increase productivity, employment and access to food, in particular in the rural areas, and to lift the poorest of the poor from severe levels of undernourishment."

Pro-poor science development and technology transfer: science with a human face

Science can greatly promote inclusive development by addressing the needs and opportunities of poor, less-favoured areas, neglected and excluded communities. Even biotechnology can be geared towards this cause. Genetic engineering is possible for features such as improved productivity of orphan crops (millets, roots and tubers), indigenous fruits and vegetables, improved tolerance to pests and diseases and to drought and other physical stresses, increased mineral and vitamin-A contents, and other nutritional and quality traits generally inadequate in diets of poor people. For livestock, low-cost and effective diagnostic kits and vaccines have a special appeal for the poor, as in most developing countries the bulk of the animal population is owned by small-scale farmers. Science with a human face (Dar, 2001) has a special appeal for the A-P Region – the home of two-third of world's poor and hungry.

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 diarrhoea 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.

In delivery of science and technology products to the end users, the lack of functional linkages between research, extension, farmers, and markets has resulted in farmers (and others) not receiving the know-how and technologies needed to increase yields and to realize potential income. Again, agricultural scientists cannot tackle this problem alone, however, they can work in diversified partnerships that confront those institutional barriers that prevent the functional linkages. The private sector can help farmers through contract cultivation and buy-back arrangements.

As we harness science for growth and development, we must be mindful of the interests of millions of small and marginal farmers and landless agricultural labourer and resource-poor fisherfolk and forest dwellers, and must not neglect their social aspirations for a more just, equitable and sustainable livelihood (Singh, 2001b). As repeatedly emphasized by Nobel Laureate Amartya Sen (1999), the lack of entitlement to basic resources is the main cause of hunger and poverty. Even a small piece of land or a single buffalo or a cow makes tremendous difference in the livelihood of a landless agricultural worker who has no access to these resources (Singh, 2001a). Agrarian reforms to grant titles to land and water, and increased access to credit, knowledge and markets, will enhance productivity, sustainability (through better land and water care) and income, thereby resulting in appreciable reductions in hunger and poverty. Technologies and socio-economic safety nets designed for small-scale and marginal farmers are essential for supporting rural livelihoods.

Off-farm employment and promotion of small-scale entrepreneurship will prove highly synergistic to agricultural production by small-scale farmers. Various technology and tool kits could be created for household, community, and village-level agroprocessing. Promotion of cooperatives, agri-clinics and agri-business centres will greatly enhance rural employment, particularly the rural youth, who often are unemployed or underemployed. As envisioned by Mahatma Gandhi, policies must support production by masses and not factory-based mass production to ensure employment security

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 (FAO, 1998c).

Prudent macroeconomic management to restore growth and to prevent erosion of past gains in poverty reduction must urgently be put in place. The growth-led poverty-alleviation strategy that has proven effective in the past, with an eye on equity and measures to bridge the various divides, must continue. Even in socialistic countries the rich-poor divide has been widening. For instance, China's Gini Coefficient now averages between 0.40 and 0.43, above the recognized danger level (UNDP, HDR, 2001). It is further feared that China's accession to WTO will only make matters worse, and rural poverty will further intensify. Based on hindsight, it is essential to develop appropriate institutions and national capabilities - including robust and well-regulated financial markets. This must be supplemented with appropriate input and output pricing policies, water rights and irrigation systems design and management to encourage efficient, equitable and sustainable use of resources and attract investment. Future 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. Until recently agriculture tended to be a gamble on monsoons in South Asia, but it is now becoming a gamble in the markets. Market and socio-economic analyses must help in reducing the uncertainties and risks which hit the poor most severely.

Rainfed and other-less favoured areas have the highest concentration of poor and malnourished people; these areas are characterized by low agricultural productivity, high natural resource degradation, limited access to infrastructure and markets, and other socio-economic constraints. During the Green Revolution, large investment was made in irrigation and irrigated areas, and in the development and promotion of HYVseed-fertilizer-irrigation technology. This approach paid off well, and rapid advances were made in food production. However, in recent years additional investments in favoured areas have faced diminishing returns and social and environmental problems, whereas there is evidence (Table 33) 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 33: 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

Science-led agricultural diversification

Science and technology development has been the main force in enlarging people's choice both by expanding human capacities to harness technologies and by providing a menu of products to meet fast-changing needs and demands of humankind. There are several excellent examples of science and technology led diversification in the Asia-Pacific region. The development of period-bound (from season-bound) varieties of rice and wheat that incorporated resistance to diseases and pests (the Green Revolution) rendered the rice-wheat sequence a major agro-economic success, with attendant socio-economic and agro-ecological implications. Thus, the extensive wheat belts of the Indian and Pakistan Punjabs, which before the mid-1960s grew little rice (except the long-duration Basmati rices), are now the leading rice-producing areas; they continue to produce wheat within a rice-wheat sequence. The converse happened in West Bengal and Bangladesh: historically a rice belt, this zone adopted the rice-wheat sequence and became a substantial wheat producer. Though this diversification promoted intensification, the overall crop-diversity index decreased.

Diversification has always been an important strategy in agricultural production and distribution in the A-P Region, for the following reasons:

- Responsive to market changes and to socio-economic and agro-ecological settings;
- Increases employment/income-generation opportunities and judicious use of land, water, labour, biodiversity and other resources;
- Reduction of the incidence and damage caused by pests and diseases and risk diffusion leading to higher and more stable production and income; and
- Promotes 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 the fore-listed possibilities, appropriate technologies shall need to be developed and diffused.

Scientific and technological developments must be matched with socio-economic and agro-ecological scenarios to achieve the required diversification. Under liberalized-trade regimes, dynamic and flexible systems must be in place to meet fast-changing demands and opportunities. Strong policy guidance and institutional and scientific supports will be needed to undertake effective diversification. Likewise, increasing urbanization and other demographic shifts will call for changes in the food basket, with increases in meat, milk, egg, fruits, vegetables, fats, and oils. Research priorities will need to adjust to these changes. Often, these realities are not reflected in the allocation and deployment of financial and human resources in many national agricultural research systems (NARSs). This shortcoming should be corrected.

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.

Farmers will respond to technology options, price signals, and market opportunities, but short-term gains to certain households and communities should not sacrifice the future and diverse options for growth. In Thailand, a positive combination of technologies and market opportunities triggered a conversion of rice fields into saline-water prawn-culture fields. There were initial economic gains, whereafter prices fell, prawn-culture fields were abandoned, and their high salinity and adverse soil properties rendered them unsuitable for rice or other crops. Highly fertile lands were thus permanently lost to the country. Clearly, there is a need for changing the technology, policy and regulatory policy options to ensure congruence of profitability, sustainability and equity in the diversification process. The Thailand experience should be shared by other countries to avoid the pitfalls.

Resolutions and declarations adopted at some of the major global summits, conventions, and conferences have called for significant policy adjustments at national and international levels; these shall impact strongly on technology development, technology acquisition, and agricultural diversification. The Millennium Summit (2000), the World Food Summit (1996), the World Bank, ADB, and G8 Summit (2001) all identified

poverty eradication and hunger alleviation as the foremost global priorities, and emphasized the role of science and technology in fighting these global social evils. The Global Plan of Action adopted at the WFS approved as FAO's core programme a Special Programme on Food Security (SPFS). The SPFS is based on four mutually reinforcing pillars, namely (i) development of water management and irrigation potential, (ii) intensified crop production, (iii) diversification into tree crop, fish, and small animal production and (iv) constraints analysis.

The diversification of production systems comprises :

- Introduction of aquaculture, and development artisanal fisheries, small animals (poultry, sheep, goats, pigs) and tree crops;
- Intercropping of trees and field crops;
- Training in use of crop residues for animal feed;
- Introduction of low cost methods of animal disease control;
- Support for post-production activities to promote income generation.

As globalization and trade liberalization gain momentum, regions, sub-regions, countries, and within-country ecozones (and depending on comparative advantages and compatibility with agro-ecological and socio-economic settings) will specialize. 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 (FAO, 2000a) 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 (Delgado et al. 1999). 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 entrepreneurs, 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.

The United Nations Conference on Trade Development (UNCTAD) is providing assistance (Mojarov, 2001) to commodity-dependent developing countries to undertake vertical and horizontal diversification which are complementary and interactive. The objectives of the concerned project are : (i) to promote horizontal, vertical, and geographical diversification of production and trade structures, (ii) to improve governments' capacities to formulate focussed, effective, and sequenced policies, (iii) to increase the competence of enterprises in adapting business strategies and supplies to the Post-Uruguay round trading framework, and (iv) to strengthen positive linkages between the commodity sector and the rest of the economy. In order to achieve these objectives, policy-oriented research on trade diversification, domestic needs, levels of self-sufficiency and self-reliance, markets and prices, and development implications of diversification (especially for disadvantaged segments of society) will be needed. Commensurate trained human resources and access to information must be in place to successfully undertake these studies.

Efforts are underway in different countries to identify specialty commodities, such as off-season varieties and production systems, new crops, and novel varieties and breeds to capture new opportunities. With the increasing demand for herbal medicines and botanicals, and for organically produced food, aquaculture and other products, several countries have developed specific production and distribution patterns. But, these diversifications must be consistent together with biodiversity conservation and economic security and sustainability. For instance, with the availability of high yielding and superior quality durum wheat varieties, the state of Madhya Pradesh in India is rapidly expanding production and marketing, including export, of these wheats. Because of the differential rust resistance mechanisms of durum wheats, large-scale production of these wheats in Central (Madhya) India provides a large scale natural barrier to the build up of rust epidemic on the bread wheat (aestivum) which constitutes the bulk of the country's wheat industry and is the major food security component (Pandey et.al., 2000). Public and private sector support in supplying seed, planting materials, processing, procurement and marketing to promote these initiatives is a sine qua non. Individual countries have developed or are developing policies, strategies and programmes on such diversifications. As several of these initiatives are innovative and diverse, there is good scope for sharing such experiences through the regional information system networks, including those

under FAO/RAP and APAARI. A well-designed regional mechanism involving national governments, international organizations and financing agencies such as FAO, ESCAP, UNIDO, UNESCO, UNCTAD, ILO, World Bank and ADB might be created to support and guide agricultural diversification as an instrument of poverty alleviation, food security, natural resource conservation and equity.

Building bridges for science: strategic partnerships and regulatory framework

Scientific discoveries, scientific information and technological products are multiplying geometrically. But much of this growth is taking place in developed countries. Among various disciplines, the progress in life sciences, especially molecular biology, biotechnology and bioinformatics, has been phenomenal, and the 21st century may be dubbed as the century of bio-revolution. Another major trend of development is the increasing role of the private sector in research in the developed countries, particularly in biotechnology and informatics - encouraged through the broadening of the scope of intellectual property rights into life forms. With the provisions of sovereign rights of nations on the genetic resources within their territories under the Convention of Biological Diversity (CBD), and as a consequence of the WTO/TRIPS, the trend of proprietary technologies and germplasm may intensify even in the developing countries.

The above trends have widened the technology and digital divides. Considering that scientific and technological capacities of institutions, communities, regions and nations will underpin their competitive abilities in this ever competitive world, those with poor abilities to generate, adapt, adopt, and diffuse technologies will get poorer and poorer. But, this will be against the very spirit of one “global village” and truly liberalized world. Bridges will therefore need to be built between public and private sectors, north and south and the haves and have-nots to bridge the various divides.

Research is carried out in both public and private national and international institutions. Generally, the stated goal of public research organizations is to maximize societal benefits, particularly geared towards comprehensive food security, poverty alleviation and environmental protection, through the production and diffusion of knowledge and products which are national, and through international public goods freely available to the entire humankind. The private sector, on the other hand, operates to maximize its profits within acceptable levels of risk and to protect their competitive edge. Consequently, private-sector research and technologies are confined to those areas and commodities which will earn maximum returns on investments; their products, processes, and associated information are not freely available.

Based on goals, values, culture, complementarity and strengths and weaknesses, partnerships between the two systems should be forged and nurtured for their mutual benefits. For instance, public sector is generally rich in germplasm resources, indigenous knowledge, and national and international networks for technology assessment and dissemination and in setting, harmonizing, and implementing rules and standards. The private sector (particularly in developed countries) is generally stronger in frontier technologies, speed, efficiency, marketing technologies, and accessing capital. A blend

of these attributes is bound to be much more effective than that achieved through the independent functioning of the two sectors. The main hurdle in bridging the two sectors is the IPR regime of the private sector. However, under the TRIPS agreement the public sector will also be evolving proprietary protection mechanisms, generally sui generis systems, consistent with national needs and aspiration. Thus, ultimately it should be possible to harmonize the IPR settings of the two sectors. In developing countries, public research institutions should have clear-cut policies on intellectual property, and adequate management capacity, which are presently lacking.

Geographically, the Asia-Pacific Region comprises 37 countries, 3 developed (Australia, Japan and New Zealand) and 34 developing (9 of which are Pacific Island countries, including Papua New Guinea). Thus, there is tremendous diversity among the countries. Among the NARSs of the developing countries, some, such as China, India, Malaysia, Republic of Korea and others, are scientifically advanced, an appreciable number have a moderately well developed NARS, and several have average to low capacities. Thus, there is ample scope for learning from the successful experiences. The Asia-Pacific Association of Agricultural Research Institutions (APAARI), established by the FAO Regional Office for Asia and the Pacific, is a vibrant regional association that successfully promotes inter-country cooperation in scientific research, information, expertise and product sharing, human resources development, and formulation of research policies, strategies, and priorities. Similar associations have been established by the FAO regional office in forestry (Asia Pacific Association of Forestry Research Institutions), in fisheries, livestock, marketing, credit, and seeds. Regional research and technology development associations established by other international bodies, such as the Rockefeller-Foundation-supported Asian Rice Biotechnology Network (ARBN) and the ADB-funded Asian Maize Biotechnology Network (AMBIONET), are also providing excellent inter-country cooperation. FAO, with financial assistance from Japan, is in the process of establishing Asian networks on biotechnology and plant genetic resources. These “consortia” comprise not only public institutions but also private institutions, provide an excellent mechanism for linking the public with the private sector, and are instrumental in improving the overall capacity of the region in international negotiations and technology generation and sharing. Those countries which have so far not joined these associations/networks should join, and all member countries should contribute to and actively participate in these regional bodies. An association like APAARI should strive to raise funds to be able to procure and transfer “protected” technologies, products and expertise to those who are in need of such technologies but lack the resources.

The Consultative Group on International Agricultural Research (CGIAR) constitutes a major international public sector research system with an excellent track record of generating effective technologies. 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, increasingly there is 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 is generally willing to license proprietary technologies to CGIAR but only on a negotiated basis (Dryden cited in Ryan and Spencer, 2001). But the private sector will most likely exclude frontline competitive technologies from such negotiations. The CGIAR must carve out 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. 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.

Globalization and liberalization: the role of science

A comprehensive poverty-alleviation and food-security strategy must be anchored on the acceleration of food and agricultural production, 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.

Countries with lower achievement in the Human Development Index and gender Development Index¹ 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 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

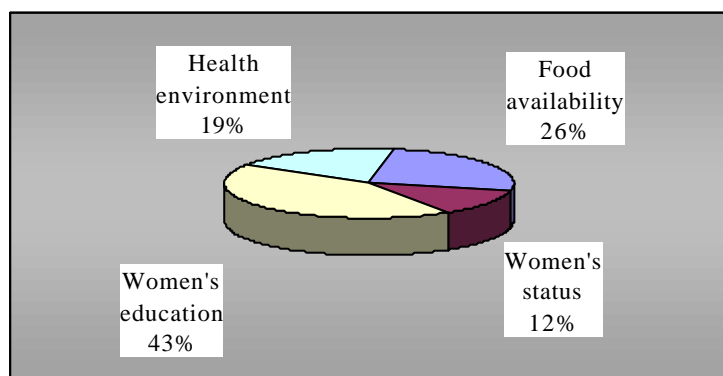
¹ Human Development Index (HDI) is based on three indicators; longevity, as measured by life expectancy at birth; educational attainment as measured by combination of adult literacy (two thirds weight) and combined primary, secondary and tertiary enrolment ratios (one third weight); and standard of living, 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.

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 (Smith and Haddad, 2000)on child malnutrition (Figure 9)

Figure 9: Determinants of reductions in child malnutrition (% impact, 1970-95)

Source: Smith and Haddad (1999)



Note: Malnourished children refers to underweight children

Science to adjust with and guide the pace of globalization and liberalization

Globalization of agricultural trade will highlight 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 the deprived sector. 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.

The Association of World Council of Churches Related Development Organizations in Europe (Madeley, 1999) analysed 36 case studies in Africa, Asia, and Latin America; it 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 (2000c) 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 economic agents in agriculture - technology, infrastructure, and social settings.

Trade agreements must be accompanied by operationally effective measures to ease the adjustment process for small-holder farmers in developing countries. Recalling that more than 80 percent of farmers are small-holders who constitute the bulk of the national population and of its poor and malnourished, the World Trade Agreement in Agriculture could destroy rural livelihood, since imports of food and agricultural products would amount to import of unemployment (Oxfam, 2000). 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, 2000b). In-depth socio-economic studies will be needed in individual countries to take full advantage of the provisions in the "Green Box". Unfortunately, several developing countries do not have the required capacity to undertake such studies, nor to make the necessary adjustments. FAO 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 non-food-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:

- Sanitary and phytosanitary regulations, risk assessment and management, quarantine and trade;
- 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 projects;
- Environment assessment and management; environmental accounting, and internalization of environmental costs in pricing and trade;

- Management of oceanic exclusive economic zones.

In this diverse scenario, it is difficult for countries to cooperate and to forge common positions on critical issues in food and agriculture. Some food and agricultural *exporting* countries have formed trade organizations (such as the “Cairns Group”) for liberalization advocacy; and some major food and agricultural *importers* have established strong links to block rice-trade liberalization. But the majority of developing countries have vague and oftentimes ambiguous positions on key issues such as opening of domestic grain markets, producers’ price support, consumers’ subsidy, reserves stocking, import levy, export taxes, and state trading. Moreover, their trade policy decision-making is complicated by the wish to gain international-market access for their own exportable agricultural products. Even within governments, opinions are divided. Trade liberalization and food security policy platforms are thus not well-defined in many countries: there is need for research to help develop appropriate policies and plans.

Developing member countries have made commitment to the World Food Summit Plan of Action; it is therefore important that they define their stand on further food and agricultural trade liberalization. Asian developing countries must similarly formulate clear policies and take positions in the best interest of their people (particularly the poor), their overall economy, and their national and household food security. Detailed socio-economic and market studies must be undertaken to guide policy decisions. Where necessary and requested, FAO should provide technical support to needy countries. Country-by-country analyses will help identify common problems and solutions, and pave the way for regional or sub-regional negotiating positions and trading blocks. FAO has already helped strengthen the capacities of some developing countries in trade negotiation, and in sanitary and phytosanitary and food safety aspects. Nonetheless, new and emerging technologies to strengthen sanitary and phytosanitary measures and risk analysis and management capacities should be introduced and adapted, as should locally-generated technologies. FAO provides also training and infrastructure facilities to enable countries adhere to the food safety and agricultural products standards of the Codex Alimentarius Commission of FAO/WHO.

Linking science, nutrition, and development

The International Conference on Nutrition, 1992, recommended that all nations should have explicit policies and programmes on nutritional adequacy. FAO, as a follow-up to the Conference, strengthened its technical assistance to help member nations build their capacities to address nutrition issues. In this context, the FAO-facilitate Special Programme on Food Security is now active in 15 A-P countries (and other countries are seeking to participate). This science and technology based programme undertakes a phased introduction of natural-resource management, efficient water-use, sustainable farming systems, and diversification of income sources. Several countries are now pursuing the Programme’s “expansion phase”.

There is increasing recognition and conviction that to improve food and nutrition security it shall be know who and where are the vulnerable people, and why they are vulnerable.

Identifying disaster-prone peoples is a major part of this essential task. Establishing national, regional and global Food Insecurity and Vulnerability Information and Mapping Systems (FIVIMS) is currently being attempted as a follow-up to the World Food Summit. FAO is the prime mover of this multi-country and multi-agency venture. The system is based on latest developments in GIS, space technology-based resource mapping, informatics, statistics, and understanding of socio-economic profiles.

Dietary energy must come from diverse food sources if it is to support an active healthy life. Lack of food diversity causes nutritional deficiencies such as protein-energy malnutrition and micro-nutrient malnutrition; it must therefore be addressed through integrated food-based strategies using a community-based approach. Such an approach can promote active participation of communities in partnership with governments and other partners to address issues of food insecurity and malnutrition. 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 should be promoted through wise policies and production and distribution systems.

Unless their planning is community-participatory, human-nutrition and development projects can seldom be sustained. Communities must therefore be involved in the identification, design, implementation, and monitoring of development programmes and technological and socio-economic interventions to improve food security and nutrition. Such an approach puts people at the centre of development and recognizes that poor people must themselves identify their own development priorities and select the most appropriate technologies and products.

Household food security and nutrition are good entry points for encouraging greater community participation. Since access to food, care, and health are daily problems, these topics are of immediate concern to poor communities and households. With appropriate assistance, they will be more likely to participate in finding appropriate solutions to their identified needs.

Community-centred approaches for improving nutrition aim at empowering communities to demand effectively the improved technologies and services to better their situation. This may involve building local capacity 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.

Central to this approach is the empowerment of community-level volunteers through a process of social mobilization. Community volunteers are selected by the community and receive appropriate training to enable them to function as mobilizers or “change agents” to translate vital nutrition improvement strategies into concrete actions. At a ratio of one mobilizer to ten households, a community can develop actions that are

feasible and fully compatible within their own community context. The approach significantly improves coverage and outreach of existing basic services and adoption of new technologies and products, thereby reinforcing local efforts for the alleviation of malnutrition.

Community-nutrition programming focuses on village development projects, strengthens multi-sectoral collaboration, promotes the use of essential minimum needs indicators, encourages social mobilization for implementing effective community-level actions, provides appropriate training for capacity building at district, sub-district and community levels, and develops appropriate sets of nutrition-relevant menus/activities for community implementation.

A range of food groups is essential in providing food security; this range is specific to the locality and to the resources and means of the people. Thus fish and 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.

Strategies and measures that can be adapted, adopted, and implemented by Asian countries hold the key to the 21st century in terms of linking science, nutrition and development. Past international initiatives were rightly concerned with hunger and malnutrition; thus several plausible sets of interventions and actions evolved. While many of these initiatives also showed concern for the poor, not all were able to translate the concern for improving nutritional well-being into action. Consequently, identification of successful ways and means for achieving progress is especially important.

Planners and policy makers need an effective policy and programme framework for making decisions and for formulating workable and effective interventions. These not only need to adapt easily to different country situations, but they need also to be sensitive and responsive to the Asian socio-cultural contexts and complexities, especially since the socio-economic situation is rapidly changing and urbanizing, and encountering threats of excess and deficits in both food and nutrition insecurity. Additionally, effective interventions require nutritional surveillance; provision of nutritional security is particularly needed during emergencies and economic crises.

Malnutrition is complex in its determinants; its elimination thus requires the use of broad-based economic and social policies, complemented by targeted interventions. Typically, the requirement is a diverse set of macro-economic policies in combination with measures that alleviate poverty and malnutrition, while serving also to support sustainable nutritional security. Education (particularly of women) and health care (Smith and Haddad, 2000) each help alleviate malnutrition - in adults and in children.

VII. CONCLUSIONS

Science and technology development constitute the engine that drives agriculture-led national growth and progress. Scientific discoveries and technological innovations proceed apace. Such innovation must be matched by genuine policy innovations and strategies - nationally and internationally - to meet development goals: food security, nutritional adequacy, poverty alleviation, and environmental sustainability. “Foresight studies” have been undertaken by many countries; they must be intensified to link science and technology policy more coherently to socio-economic and environmental needs.

Not every country needs to develop cutting-edge technologies. But every country does need a minimal national capacity to possess, procure, assess, and use judiciously such scientific knowledge and technology as is consistent with its people’s needs and aspirations. Sustained and coordinated support to, and adequate investment in, agricultural science, research, and development by public and private sectors, international donors, and technical-support organizations are crucial if governments are to create the knowledge and technology base wherewith to achieve and maintain comprehensive food security and poverty alleviation. Correspondingly, if the power and potential of science and technology are to be realized, complementary support and investment (from those fore-listed sources) shall be needed to strengthen skills and human resources, infrastructures and services, and policies and regulatory systems. Recognizing that “technology can be *not* only a reward for successful development, *but also* a critical tool for achieving it”, the partnership between technology and development must be nurtured, strengthened and kept dynamic.

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