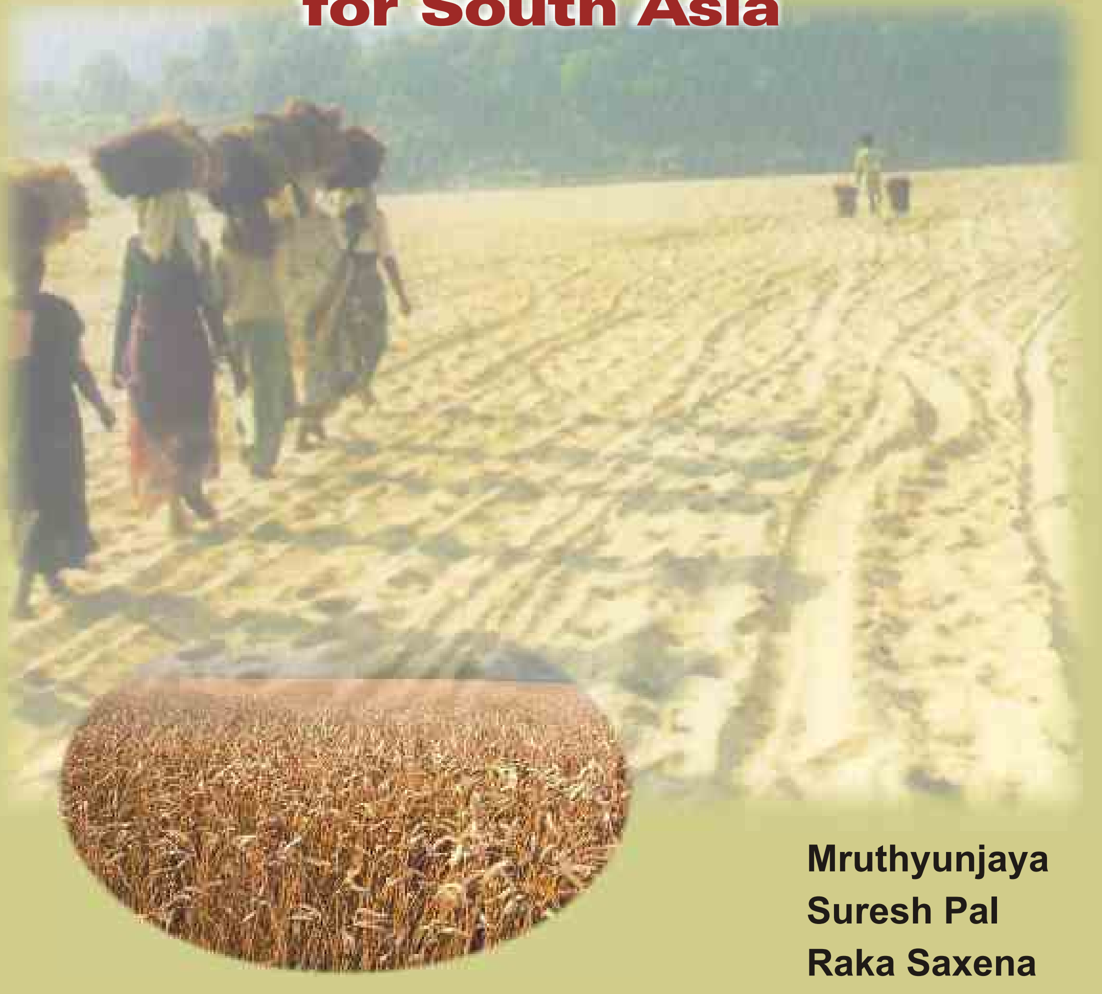
POLICY PAPER 20

Agricultural Research Priorities for South Asia



Mruthyunjaya
Suresh Pal
Raka Saxena

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NATIONAL CENTRE FOR AGRICULTURAL ECONOMICS AND POLICY RESEARCH

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भाकृअनुप
ICAR

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ACRONYMS AND ABBREVIATIONS

AERs	Agro-ecoregions
AgGDP	Agricultural gross domestic product
BARC	Bangladesh Agricultural Research Council
CGIAR	Consultative Group on International Agricultural Research
CLAN	Cereals and Legumes Asia Network
FAO	Food and Agriculture Organization
GDP	Gross domestic product
GIS	Geographical Information System
GNP	Gross national product
HA	Hot arid (agro-ecoregion)
HRH	High rainfall humid (agro-ecoregion)
HYV	High yielding variety
IARCs	International agricultural research centres
ICAR	Indian Council of Agricultural Research
ICT	Information communication technology
INM	Integrated nutrient management
IPM	Integrated pest management
ISH	Irrigated sub-humid (agro-ecoregion)
IWM	Integrated water management
NACA	Network of Aquaculture Centres in Asia-Pacific
NARC	Nepal Agricultural Research Council
NARS	National agricultural research system
PARC	Pakistan Agricultural Research Council
R&D	Research and development
SATS	Semi-arid tropics and sub-tropics (agro-ecoregion)
SCAM	Sub-humid to cold arid mountains (agro-ecoregion)
SHC	Sub-humid to humid coasts (agro-ecoregion)
TAMNET	Tropical Asian Maize Network
TFP	Total factor productivity
UTFANET	Underutilized Tropical Fruits Asia Network
VOP	Value of production

FOREWORD

Agriculture in South Asia has entered the new phase of development. The objectives of efficient and diversified growth and sustainable use of natural resources in the context of household food, nutrition and environmental security are now well recognized. The agenda is further widened with the need to participate in the trade-led growth opportunities and protection of rural poor from the negative impact of the globalization process. More recently, poverty alleviation impact of agricultural research is gaining acceptance, and therefore, it is becoming an explicit research objective.

The development strategy is also shifting from resource-based production to knowledge-based production and value-addition. In the process, traditional interventions by the governments like subsidies and other direct interventions are expected to decline. This paradigm shift places tremendous importance to efficacy of agricultural institutions and technology systems. It is the nexus between technology, trade and institutions which would determine the pace and pattern of agricultural development and poverty alleviation in future.

The message is loud and clear-the development and dissemination of technologies would provide competitive edge to agriculture in South Asia. This needs to be achieved in an era of shrinking public funding and expanding research objectives and complex agenda for agricultural research. How this can be achieved? Research managers need to put their expertise and wisdom together to enhance efficiency and effectiveness of the research system. The key to success is that we should integrate our efforts and direct them in the areas where they are likely to make maximum impact.

The Asia-Pacific Association of Agricultural Research Institutions has, therefore, done a commendable job to bring all the stakeholders together for developing research priorities for agriculture. Besides highlighting the developmental challenges and priority research themes to address them, the exercise has flagged a number of other important issues such as partnership between the research systems, capacity building in frontier research areas strengthening research infrastructure, policy support, etc. I am sure this report would be useful to policy makers, donors and research managers alike for directing their efforts. One may, however, further translate the priorities into specific research activities depending on the need and situation.

Panjab Singh
Secretary
Department of Agricultural
Research and Education, and
Director General
Indian Council of Agricultural
Research
New Delhi, India

June 2002

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Mruthyunjaya
Suresh Pal
Raka Saxena

EXECUTIVE SUMMARY

Modern science is a powerful stimulus to agricultural transformation and economic growth. Through improved technologies, it has been possible to increase food availability per person by almost 20 percent since the early 1960s. Nevertheless, hunger remains persistent in Asian countries. Further, the yield potential of the green revolution has apparently been exhausted. Given the urgency of averting hunger, new applications of modern science to food and agriculture through research and development (R&D) have to be sustained. New developments in biotechnology and information technology offer high potential. The NARS in some of the Asian countries are fairly well developed (e.g. India, Pakistan, Sri Lanka). Other countries have also specialized in some crops or resource use. All Asian countries can benefit from information exchange and collaboration in planning and organizing research activities. In South Asia, such collaboration has great potential because of the large contiguous agro-ecological tracks. Research priorities and funding applicable to one region or country could be of use to other regions or countries. Further, cropping pattern are dominated by rice and wheat for which generic research will be useful for large areas in different countries. The advances made in biotechnology, tissue culture, and plant/animal genetics in some of these countries can be made use of by others, rather than reinventing the wheel.

South Asian countries include Bangladesh, Bhutan, India, Maldives, Nepal, Pakistan and Sri Lanka. These countries, in general, have similar socio-political institutions and economic, agricultural and governance systems. However, these countries differ considerably in terms of their size of population, geographical area and economy. India is the largest country in the region with about one billion population and 442 billion US dollars of gross domestic product (GDP) in 1999. Population density in the region varies from 981persons/sq km in Bangladesh to 164 persons/sq km in Nepal. More than two-thirds of the population lives in rural areas, and a vast majority of them are illiterate. Exports constitute about 11-22 percent of GDP, except Sri Lanka where exports are 36 percent of her GDP. Foreign direct investment is also nominal in most of the countries, except India where it was US$ 2.6 billion in 1998. Furthermore, external debt as percentage of GDP varies from 20 percent in India to 41 percent in Pakistan and Sri Lanka. The World Bank has classified all the South Asian countries as low-income countries with per capita GNP of US$ 755 or less. Real per capita GDP in 1999 (1993 international dollars) varied from 1219 in Nepal to 3056 in Sri Lanka with India and Pakistan occupying a middle position. All these countries have improved their economic performance in 1990s; the average GDP growth rate during 1990s varied from 4 percent in Pakistan to 6.1 percent in India. However, much of this growth was negated by the growth in population, resulting in a moderate rate of growth in per capita income. The human development index is also very low in all the countries. The national poverty line indicates that more than 34 percent of the population lives below the poverty line. The incidence of poverty is more in rural areas. The international poverty estimate (percent of population below 1 dollar a day) varies from 6.6 percent in Sri Lanka to 44 percent in India. The international poverty line when measured as percentage of population with the expenditure below 2 dollars a day, indicates that more than three-fourths of the population was living below the poverty line, except in Sri Lanka where the poverty level was 45.4 percent. Alleviation of poverty and malnutrition therefore will continue to be a major challenge in South Asia.

In spite of high population pressure and limited or no expansion of arable land, the countries in South Asia have made tremendous progress in terms of achieving self-sufficiency in foodgrain production. Cereal production doubled in South Asia during the last three decades, reaching a level of 245 million tonnes in 1999. The production of pulses, however, varied from 12 to 15 million tonnes during the last four decades. Another remarkable achievement, albeit less discussed, is that milk production in the region increased more than three times during the last three decades. Most of these gains were negated by the growth in population. Consequently, annual per capita foodgrain production remained almost stagnant (around 180 kg) during 1960s to 1980s and increased moderately to 197 kg in 1990s. In spite of almost four-fold increase in milk production, the per capita production increased from 48 kg in 1961 to 80 kg in 1999. Nevertheless, there is marked decline in food imports and the region is self-sufficient in food production. Notwithstanding these significant achievements, crop yields are still low in the region—yields of rice (clean) and wheat are less than 3 tonnes/ha. The productivity of agricultural workers is also very low. Level of fertilizer consumption is moderate and barring few irrigated pockets, extent of farm mechanization is also low. Limited area under irrigation without any further scope of its expansion and declining per capita availability of arable land call for increase in land productivity.

South Asia can be divided into six broad agro-ecoregions, viz. (i) Hot Arid (HA); (ii) Semi-Arid (SA); (iii) Irrigated Sub-Humid (ISH); (iv) High Rainfall Humid (HRH); (v) Sub-Humid to Humid Coasts (SHC); and (vi) Sub-Humid to Cold Arid Mountains (SCAM). All these AERs are fairly uniform, except the rainfed humid and mountain regions where there is some variability in climate, soil type and irrigated area. The Semi-Arid, High Rainfall Humid, and Irrigated Sub-Humid AERs are quite large, occupying 38.1, 26.4 and 19 percent, respectively, of the total net sown area in South Asia. They contribute about one-fourth each to the total value of agricultural output. It may be noted here that the High Rainfall Humid AER largely practicing rice-based production system, is of greater significance as it has lot of potential for further growth, and a large proportion of poor people live in this region. The Irrigated Sub-Humid system practices rice-wheat, cotton-wheat and sugarcane-wheat cropping systems. Both canal and tubewell irrigation are intensively used, along with other modern inputs like fertilizers. Livestock is important in all the systems, but horticultural crops are widely grown in the Semi-Arid and the Coastal ecoregions. Another important characteristic is that except Arid and part of the Irrigated ecoregions, all other ecoregions receive significant amount of precipitation which can be conserved and used for agriculture. Most of the poor people are concentrated in the High Rainfall Humid, Semi Arid and Mountain agro-ecoregions. These systems are also characterized by low productivity and vulnerability of natural resources for degradation.

Modified congruence analysis is applied to arrive at the regional and commodity priorities, using the criteria of efficiency, sustainability and equity. ISH, SA and HRH are the three top priority AERs in South Asia. Efficiency objective can be better addressed on focusing on ISH and HRH, but for poverty alleviation HRH and SA are more important. Sustainability issues are equally important in these AERs, although factors affecting sustainability may vary. For example, it could be depletion of groundwater and soil nutrients in the ISH, whereas soil erosion due to water may be more important for the other two. Among the three smaller AERs, the SHC and SCAM are more important from the point of view of productivity and poverty.

Priority commodity groups (among 91 commodities) in South Asia are cereals, livestock, horticultural crops and plantation crops in that order. Cereals are more important in all the AERs, but their priority score is 41 and 51 in the ISH and HRH ecoregions, respectively. Livestock is important in all the AERs, but it gets very high priority score in the HA (41) and SCAM (29). Whereas fruits, cash crops and plantation crops are priority commodities for the SA, ISH and SHC systems, respectively.

In order to capture the effect of changes in the demand on commodity priorities, VOP of a commodity was adjusted with the expected growth in its demand in the region. Since research and extension lag is about 8-11 years, the growth was extrapolated over a period of 10 years. This adjustment in the VOP implies that the commodities with higher expected growth in the demand should get high priority. The adjusted VOP thus obtained along with the parameters of sustainability and equity was used for another iteration of the analysis. The results indicate that there is a noticeable increase in priority score of horticultural and livestock commodities, whereas cereals registered a significant decline in their priority score. Cash and plantation crops also showed moderate decrease in their priority score, while other commodities showed no significant change. It is important to mention here that these results are indicative in nature and some degree of scientific judgment is required to capture other external factors and opportunities (including chances of research success) in setting research priorities.

The overarching priorities common to all the stakeholders pertain to five important themes. *First*, assessment of poverty in the region is a matter of concern for all. Intensive efforts to study the poverty, its mapping and assessment of nature of interventions and investment priorities are to be made. *Second*, management and sustainable use of natural resources is another important priority area for all the agro-ecoregions. Efforts are needed to assess and map the nature and extent of degradation of these resources.

The study of technological and institutional interventions for sustainable use of natural resources is also important. Both of these research areas are of 'public good' nature and therefore public research organizations at national and international levels may have to pool their resources to address these research issues. *Third*, livestock, horticulture and fishery sectors, which have shown significant growth in the recent past, are yet to be fully developed. Concerted research efforts on these areas will diversify the sources of income and employment in the region, and can contribute to alleviation of poverty. It may be noted here that these sub-sectors are important in all the AERs, and therefore, a significant amount of economies of scale in research can be realized. Also, private sector can be a useful ally in the R&D in these areas. *Fourth*, studies on commercialization of agriculture and integration of markets would help the countries to compete in the world market. *Lastly*, a good amount of efforts are needed to study the institutional arrangements for improving farmers' access to technologies, seeds, credit, market, etc. Also, there is a need for assessing appropriate institutional arrangements for reducing the impact of risk. Involvement of private sector (profit as well as non-profit) for these purposes and its linkages with public organizations need to be considered under an institutional perspective.

The strategy should focus on accelerating agricultural development through proper mix of technology and organizational and policy reforms. Efficient organization of production systems and substitution of knowledge for capital should be guiding forces. Given the intensity of agricultural research in South Asia, it is indispensable to organize research efforts efficiently and realize potential synergies through inter-institutional collaboration based on the principle of comparative advantages. This also implies establishing effective working linkages with private R&D organizations. The CGIAR accords high priority to South Asia and stresses on regional integration of research efforts through research partnership. The CG Centres can act as facilitators, collaborators and advocates, and can bring together NARSs for partnership in strategic research areas. There are a number of research networks operating in the region. This approach needs to be strengthened and replicated. The NARS-NARS collaboration would be useful in a number of commodities like commercial and plantation crops, where international research efforts are negligible.

In terms of research methodology, there are significant scientific advancements which need to be harnessed for greater effectiveness and efficiency of research systems. Application of molecular biology tools for control of yield losses due to biotic and abiotic stresses, reduction in post-harvest losses, shortening R&D lag, maintaining animal health and improving product quality hold immense potential. Other promising advancements are IPM, IPNM, ICM, watershed management and precision farming, which are in early phase of their adoption. There is a need for tailoring these technologies to specific research target domains, as some of these technologies may involve commodity (in case of IPM and IPNM) or location (in watershed) specificity. Since these technologies are significantly different from the Green Revolution technologies (technologies embedded in seed, fertilizer and other inputs), institutional mechanisms for technology transfer need to be revamped. The dissemination of specialized information (such as soil fertility, resource management methods, etc.) should also be emphasized, besides transfer of technologies embedded in inputs, and imparting skills. In this regard, application of information communication technology (ICT) assumes greater significance.

1 INTRODUCTION

The Asia region even today has nearly two-thirds of the undernourished population of the world. South Asia alone is home of about one-third malnourished persons in the world; roughly one out of every five persons in the region is chronically undernourished. The percentage of underweight children below 5 years of age, in the total number of this age group, is as high as 67 in Bangladesh, 53 in India, and about 38 each in Pakistan and Sri Lanka. The FAO estimates indicate that even by 2010, Asia will have about one-half of the world's malnourished population, of which two-thirds will be in South Asia.

In the South Asian countries, nearly 75 per cent of the poor are concentrated in rural areas and depend on agriculture for their food, employment and income. The landless farm workers account for about 40 per cent of rural poverty in Bangladesh and 45 per cent in India. The rests are small and marginal cultivators and field tenants. Agricultural and rural development is central to a strategy aimed at alleviating poverty and food insecurity, apart from serving to fuel industrialization. The agricultural growth during the past three decades clearly supports this view. However, the recurring issues on population and problems of demographic transition and natural resource degradation and management are more pressing now than ever before. Likewise, new challenges are emerging from the global developments in trade. And, since these issues have important implications on agricultural development and household food security in the region, it is crucial that they are accorded the attention they deserve.

Modern science is a powerful stimulus to agricultural transformation and economic growth. Through improved technologies, it has been possible to increase the food availability per person by about 20 per cent since the early 1960s, but even then, hunger remains persistent in the Asian countries. Further, the yield potential of the green revolution appears to have been exhausted. The necessity of averting hunger calls for applications of modern science to food and agriculture through innovative research and development

(R&D) work. The developments in biotechnology and information technology have offered higher potentials. Public research investments should be more focussed in areas that are not expected to be privately funded but that offer convincing expectations of a positive social payoff. Besides directing research investments to high potential irrigated areas, it is necessary to accord importance to rainfed areas and fragile agro-ecoregions.

The agricultural research systems are fairly well developed in some of the Asian Countries namely India, Pakistan and Sri Lanka. Other countries too have specialized in some crops or resource use. The R&D results from these efforts could be utilized by all the Asian countries through information exchange and initiating joint collaborations in planning and organizing relevant research activities. In South Asia, such R&D collaborations have great potential because of the large contiguous agro-ecological tracks. In this region, the cropping patterns are dominated by rice and wheat, for which generic research would be useful for large areas in different countries. The advances made in areas like biotechnology, tissue culture, and plant/ animal genetics in some of these countries could be utilized by others, rather than 'reinventing the wheel'.

Socio-economic profile of the countries

South Asian countries include Bangladesh, Bhutan, India, Maldives, Nepal, Pakistan and Sri Lanka. These countries have more or less similar socio-political institutions. There are marked similarities in their economic, agricultural and management systems, as well as in their approach to education, health services and social welfare activities. However, these countries differ considerably in terms of size of population, geographical area and economy (Table 1). India is the largest country in the region with about one billion population and a gross domestic product (GDP) of 442 billion US dollars (1999). The population density in the region varies from 981 persons/sq km in Bangladesh to 164 persons/sq km in Nepal. More than two-thirds of the population lives in the rural areas and a vast majority of it is illiterate. Exports constitute about 11-22 per cent of GDP, except in Sri Lanka where it is 36 per cent. Foreign direct investment is also nominal in most of these countries, except in India where it was US$ 2.6 billion in 1998. The external debt as percentage of GDP varies from 20 per cent (in

India) to 41 per cent (in Pakistan and Sri Lanka). The World Bank has classified all the South Asian countries as 'low-income countries' with per capita GNP of US$ 755 or less. Real per capita GDP in 1999 (1993 international dollars) varied from 1219 in Nepal to 3056 in Sri Lanka with India and Pakistan occupying a middle position. All these countries have improved their economic performance during the 1990s; the average GDP growth rate during this period varied from 4 per cent in Pakistan to 6.1 per cent in India. However, much of this growth was negated by the rise in population, resulting in only a moderate growth rate in per capita income. The human development index is also very low in all these countries (Table 1).

Table 1. Basic socio-economic indicators of South Asian countries

Indicator	Bangladesh	India	Nepal	Pakistan	Sri Lanka
Human development index[a] (1998)	0.461 (146)	0.563 (128)	0.474 (144)	0.522 (135)	0.733 (84)
Adult illiteracy rate (%, 1998)					
- Males	49	33	43	42	6
- Females	71	57	78	71	12
Population (million, 1999)	128	998	23	135	19
Population density (people/sq km, 1999)	981	336	164	175	294
Urban population (%, 1999)	24	28	12	36	23
Gross national product (billion dollars, 1999)	47.0	442.2	5.1	64.0	15.7
Average annual GDP growth rate (%), 1990-99	4.8	6.1	4.8	4.0	5.3
Real per capita gross national product (1993 international dollars, 1999)	1,475	2,149	1,219	1,757	3,056
Exports of goods and services as percentage of GDP (1999)	14	11	22	15	36
Foreign direct investment (million dollars, 1998)	308	2,635	12	500	193
Share of agriculture in gross domestic product (%, 1999)	21	28	41	26	21
External debt as percentage of gross national product	22	20	31	41	41
Food production index (1989-91=100)					
- 1979-81	79.2	68.1	65.9	66.4	98.3
- 1996-98	110.8	119.9	117.2	136.2	109.1

[a] Number in parentheses is rank out of 174 countries.
Source: World Bank (2001), UNDP (2000)

The estimates of poverty in the region during the early 1990s indicate that a large proportion of population was living below the poverty line (Table 2). The national poverty line of different countries indicates that more than 34 per cent of the population lives below the poverty line. The incidence of poverty is higher in rural areas. For instance, the rural poverty in Nepal and Bangladesh was more than double of urban poverty. The urban-rural poverty difference was, however, comparatively small in India[1] . The international poverty line drawn on the basis of percentage of population having income below 1 US$ a day indicates a high concentration of poverty in the region. These estimates vary from 6.6 per cent in Sri Lanka to 44 per cent in India. The international poverty line, measured as a percentage of population with the expenditure below 2 dollars-a-day, indicates that more than three-fourths of the population was living below the poverty line, except in Sri Lanka where this level was slightly less at 45.4 percent. It has also been found that a vast majority of children below the age of 5 years is malnourished (Table 2). Alleviation of poverty and malnutrition therefore would continue to be a major challenge in South Asia.

Table 2. Incidence of poverty and malnutrition in South Asia

Indicator	Bangladesh	India	Nepal	Pakistan	Sri Lanka
National poverty line					
Survey year	1995/96	1994	1995/96	1991	1990/91
Percentage of population below poverty line					
- Rural	39.8	36.7	44.0	36.9	38.1
- Urban	14.3	30.5	23.0	28.0	28.4
- National	35.6	35.0	42.0	34.0	35.3
International poverty line					
Survey year	1998	1997	1995	1996	1995
Percentage of population below $1 a day	29.1	44.2	37.7	31.0	6.6
Percentage of population below $2 a day	77.8	86.2	82.5	84.7	45.4
Prevalence of child malnutrition					
Percentage of malnourished children under the age of 5 years (1992-98)	56	50	57	38	38

Source: World Bank (2001)

[1] The latest data (1999-2000) indicate a poverty level of 26.1 per cent in India. However, for the sake of comparison with other countries, 1994 data are indicated.

The foregoing discussion indicates that the progress in alleviating poverty in South Asia has been quite slow. This concern coupled with acceleration of agricultural growth for higher income, food and nutritional security and sustainable management as well as use of natural resources would continue to influence the investment priorities in the region. This paper discusses the development challenges in the region, in general and also specific to agricultural development. The paper comprises a brief description on the agricultural development scenario in the region followed by organization and intensity of agricultural research. The subsequent two sections are related to the characterization of major agro-ecoregions, and analysis of commodity priorities. This is followed by the identification of major production constraints, growth opportunities and research priorities for different agro-ecoregions. Finally, observations on research strategies for addressing the identified research priorities are presented.

2. AGRICULTURAL DEVELOPMENT SCENARIO

The agricultural scenario is dominated by small land holders in the South Asia region, with a few exceptions in some areas or sectors. The importance of agriculture, though central to the economic development, is declining over time in relative terms. The prime concern of all the countries in the region was to attain self-sufficiency in food, and a number of agriculture development programs were initiated to achieve this objective. All these countries introduced land reforms such as redistribution of surplus land, ceiling on land holdings, protection of agricultural tenancy, consolidation of land holdings, etc. to accelerate agricultural growth. The performance, however, differed from country to country and the impact was limited due to lack of supportive systems, like input supply, credit, marketing, etc. It is now widely acknowledged that due to non-availability of these supportive systems, the agricultural growth bypassed the resource-poor farmers and the regions. For instance, owing to the differences in supportive institutions, the rice productivity in eastern India is still far below that in the north-west India.

The most important sources of growth in agriculture, particularly in India and Pakistan, are non-price factors like technology, education etc. The research investments in surface irrigation and development and dissemination of improved technologies contributed largely to the agricultural growth, ushering the Green Revolution in the region. The HYV-technology along with a regular supply of fertilizers and water could lift the production frontier up during the 1960s and 1970s. This increase in the productivity attracted private investments in agriculture. In addition, incentives in the form of subsidized inputs and remunerative output prices also attracted private investments in agriculture[2] .

More recently, macro economic reforms, introduced in some countries including India during 1990s, have further accelerated the agricultural

[2] For detailed discussion on these issues in the Indian context, see Desai (1997).

growth. These reforms, on one hand, encouraged private investments (both domestic and foreign) in infrastructure and supportive system, on the other, improved the incentives in agriculture through better terms of trade, accelerating agricultural growth.

Although it is rather premature to establish direct impact of these reforms at this stage, it is believed that the reforms would create conducive environment for productivity led knowledge-intensive agriculture.

Resource use, productivity and availability of foodgrains

In spite of high population pressure and no or only a limited expansion of arable land, the countries in South Asia have made tremendous progress in terms of achieving self-sufficiency in foodgrain production. The production of cereals during the last three decades, has doubled reaching a level of 245 million tonnes in 1999 (Table 3). The production of pulses has varied from 12 to 15 million tonnes during the last four decades. Another remarkable achievement, albeit less discussed, is that milk production in the region has increased more than three times during this period. Most of these gains, however, were negated by the enormous growth in population. Consequently, the annual per capita foodgrain production remained almost stagnant (around 180 kg) during 1960s to 1980s and increased moderately to 197 kg during 1990s. Similarly, in spite of almost four-fold increase in milk production, the per capita production increased from 48 kg in 1961 to 80 kg in 1999. Nevertheless, there is a marked decline in the import of foodgrains and the region is becoming self-sufficient in food production.

Another significant achievement on food security front is the stabilization of production and prices of foodgrains in the region. It has been widely documented that year-to-year fluctuations in foodgrain production had registered a significant decline not only in favourable irrigated environment but also in rainfed regions (Pal et al., 1993 and Pandey et al., 2000). This had significant implications for food security of the region. In spite of floods, droughts and cyclones, there were few instances of starvation, large imports and food aids. This coupled with a better management of foodgrain stocks and the integration of domestic market, and assured availability of food. The prices of foodgrains decreased in real terms and remained more stable than the international prices.

Table 3. Agricultural Development Indicators

Indicator	Year	Bangladesh	India	Nepal	Pakistan	Sri Lanka
Percentage of land area under	1980	2.0	1.8	0.2	0.4	15.9
permanent crops	1997	2.5	2.7	0.5	0.7	15.8
Irrigated land as percentage	1979-81	17.1	22.8	22.5	72.7	28.3
of crop land	1995-97	43.4	32.4	38.2	80.8	30.7
Per capita arable land (ha)	1979-81	0.10	0.24	0.16	0.24	0.06
	1995-97	0.06	0.17	0.13	0.17	0.05
Number of tractors	1979-81	0	2	0	5	4
per thousand agricultural workers	1995-97	0	6	0	13	2
Fertilizer consumption (kg/ha)*	1998	132	93	26	91	116
Agricultural productivity	1979-81	212	275	162	394	649
(value added per agricultural worker (1995 dollars)	1996-98	276	406	189	626	726
Total cereal production (million tonnes)	1999	24.64	188	4.78	24.45	1.96
Total pulses production (thousand tonnes)	1999	513	13,550	214	1089	28
Total milk production (thousand tonnes)	1999	2,075	77,180	1,143	25,566	295
Paddy yield (tonne/ha)	1998	2.7	2.9	2.4	2.8	3.2
Wheat yield (tonne/ha)	1998	2.2	2.6	1.6	2.2	..

Source: World Bank (2001), FAO (1998)
* Computed from FAO data.

Notwithstanding these significant achievements, the crop yields are still low in the region—yields of rice (clean) and wheat are less than 3 tonnes/ ha. The productivity of agricultural workers is also very low. The level of fertilizer consumption is moderate and barring few irrigated pockets, extent of farm mechanization is also low. The limited area under irrigation with no scope of its further expansion and the declining per capita availability of arable land in the region call for increasing crop productivity (Table 4). In the hill and mountain regions, increasing the productivity of fruits and foresting in a sustainable manner, could be very important.

Trend in food demand

Two major changes have been observed in the trends in the food demand in South Asia: (i) there is noticeable decline in per capita consumption of

Table 4. Trends in foodgrain production and increase in population in South Asia

	Year	Bangladesh	Bhutan	India[a]	Nepal	Pakistan	Sri Lanka	South Asia
Total cereal production[c]	1961	10.24	0.09	69[b]	2.30	6.44	0.70	89
(million tonnes)	1970	11.48	0.11	97	2.24	10.91	1.07	119
	1980	15.13	0.14	119	3.19	15.45	1.50	149
	1990	19.17	0.10	162	2.84	19.39	1.76	202
	1999	24.64	0.14	188	4.78	24.45	1.96	245
Total pulses production	1961	253	0.8	12,700[b]	85	934	3.9	14977
(thousand tonnes)	1970	351	1.3	11,820	111	780	5.4	13069
	1980	632	2.3	10,630	139	676	42	12121
	1990	512	1.6	14,260	168	1072	54	14077
	1999	513	1.6	13,550	214	1089	28	15396
Total milk production	1961	915	18	20,375	546	5,998	104	27,957
(thousand tonnes)	1970	1,065	22	20,800	625	7,445	141	30,098
	1980	1,162	28	31,560	747	9,014	243	42,753
	1990	1,593	31	63,678	922	14,723	252	71,200
	1999	2,075	32	77,180	1,143	25,566	295	106,291
Total population	1961	53	0.9	452	9	51	10	577
(million)	1970	67	1.1	555	11	66	12	712
	1980	88	1.3	689	14	85	15	893
	1990	109	1.7	851	19	119	17	1,117
	1999	127	2.1	998	23	152	19	1,321
Per capita production of foodgrains[c]	1961	198	98	181	265	145	70	179
(kg)	1970	177	106	196	214	177	89	186
	1980	179	110	188	238	190	103	180
	1990	181	57	207	159	172	107	195
	1999	198	69	202	217	168	104	197
Per capita production of milk (kg)	1961	17	20	45	61	118	10	48
	1970	16	20	37	57	113	12	42
	1980	13	22	46	53	106	16	48
	1990	15	18	75	49	124	15	64
	1999	16	15	77	50	168	16	80

Source: FAO (2000); [a] Economic survey (various years); [b] data refers to 1960; [c] paddy data were converted into clean rice.

cereals, particularly coarse cereals, probably because of a decrease in the real prices of cereals and increase in real income; and (ii) consumption pattern has become more diversified because of increase in demand for high-value products like fruits, vegetables, milk and meat (Paroda and Kumar, 2000). These changes have important implications on food and nutritional security. These countries have not only to produce additional food but also diversify food production towards products of higher nutritional value.

The second concern of food security is that the demand for food would increase because of the rise in population, income of poor people and feed demand. It is estimated that the demand for foodgrains in South Asia would increase to about 360 million tonnes by 2030 AD, assuming a moderate to high rate of growth in income (3.5 to 5.5 per cent per annum). Depending upon the growth in income, demand for milk would be in the range of 192-232 million tonnes and that for fruits, 110-138 million tonnes. An increase of a similar magnitude is expected in the demand for vegetables, meat, fish and eggs (Table 5). It is important to note that for meeting such large increase

Fig. 1a: Required increase in yield to meet food demand in 2030 in South Asia

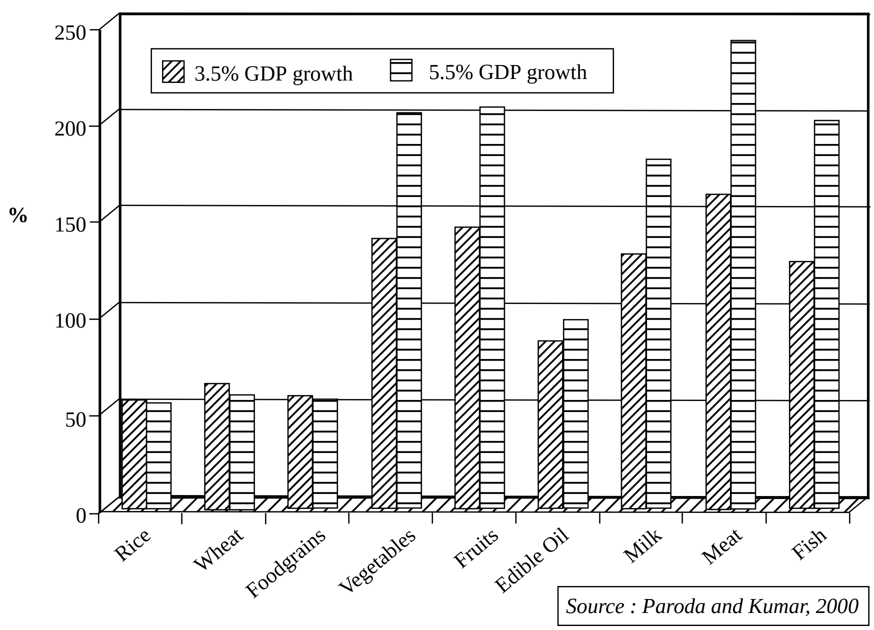


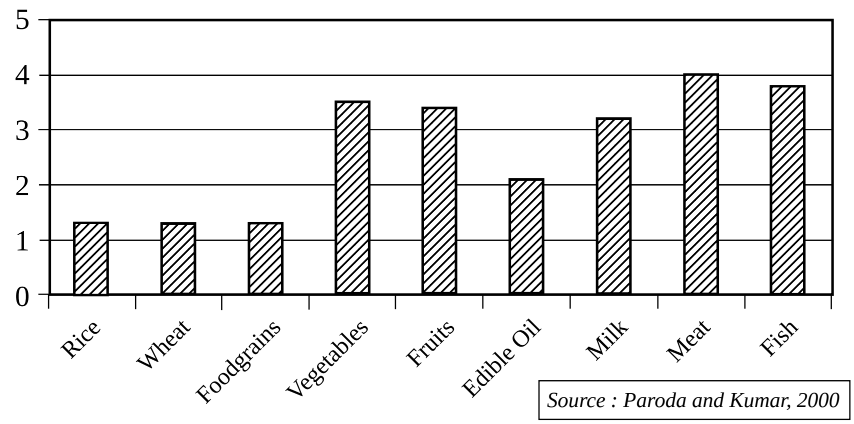
Table 5. Projection of food demand in South Asia in 2030

(million tonnes)

Food item	Assumption	Bangladesh	India	Nepal	Pakistan	Sri Lanka	South Asia
Rice	3.5% GDP growth	32	114	4.9	6	2.8	161
	5.5% GDP growth	31	114	4.9	6	2.7	160
Wheat	3.5% GDP growth	4	83	1.7	38	1.2	129
	5.5% GDP growth	4	80	1.6	37	1.2	124
Pulses	3.5% GDP growth	1.1	24	0.4	2.0	0.2	28
	5.5% GDP growth	1.1	26	0.5	2.1	0.2	30
Total foodgrains	3.5% GDP growth	38	264	10	50	4.3	366
	5.5% GDP growth	37	260	10	49	4.2	360
Edible oils	3.5% GDP growth	1.0	12	0.2	4.4	0.1	18
	5.5% GDP growth	1.1	13	0.2	4.6	0.1	19
Vegetables	3.5% GDP growth	2.8	151	3.6	9.4	1.4	168
	5.5% GDP growth	3.3	193	4.4	11.3	1.7	215
Fruits	3.5% GDP growth	3.6	84	1.6	18.8	1.4	110
	5.5% GDP growth	4.5	106	2.1	24	1.7	138
Milk	3.5% GDP growth	4.7	130	2.9	52	1.0	192
	5.5% GDP growth	5.7	158	3.6	63	1.3	232
Meat	3.5% GDP growth	0.9	10	0.6	5.1	0.1	17
	5.5% GDP growth	1.2	13	0.8	6.3	0.2	22
Eggs	3.5% GDP growth	0.3	3.5	0.1	0.8	0.1	5
	5.5% GDP growth	0.4	4.7	0.1	1.0	0.2	64
Fish	3.5% GDP growth	2.6	10	0.1	1.1	0.7	15
	5.5% GDP growth	3.4	14	0.1	1.3	0.9	20

Source: Paroda and Kumar (2000)

Fig. 1b: Expected growth (%) in food demand in South Asia, 2000-15



in demand, yields of foodgrains would have to be increased by about 50 per cent by 2030 AD. The required increase in yields of livestock and other high value commodities would be in the range of 100-200 per cent, depending upon the rate of income growth (Fig. 1a). These targets of yield increases are quite challenging.

Sustainability concerns

The concerns relating to sustainability of agricultural systems are becoming central to the development process. These concerns have been studied and explained by a number of researchers in various ways. A widely accepted measure is the agricultural total factor productivity (TFP)—productivity of a system by taking all outputs and inputs together. It is observed that there is a deceleration in the growth of TFP in the agriculturally developed (irrigated) regions (Evenson et al., 1998 and Kumar and Rosegrant, 1994). It is also observed that a number of constraints like buildup of pests, depleting soil fertility, weeds, etc. are emerging in the irrigated production systems (Fujisaka et al., 1994). The most important concern is related to the sustainable use of natural resources. It is being felt increasingly that natural resources—land and water—are depleting fast. Land degradation due to salinity, alkalinity, water-logging, overgrazing and erosion by water and wind is widespread and unabated. Intensification of land-use, NPK imbalance, less application of organic manure, and adverse effect of pesticides on microbial activities in soil, are fast eroding the productive capacity of land. These sustainability issues need to be addressed, whilst enhancing the productivity of agricultural systems.

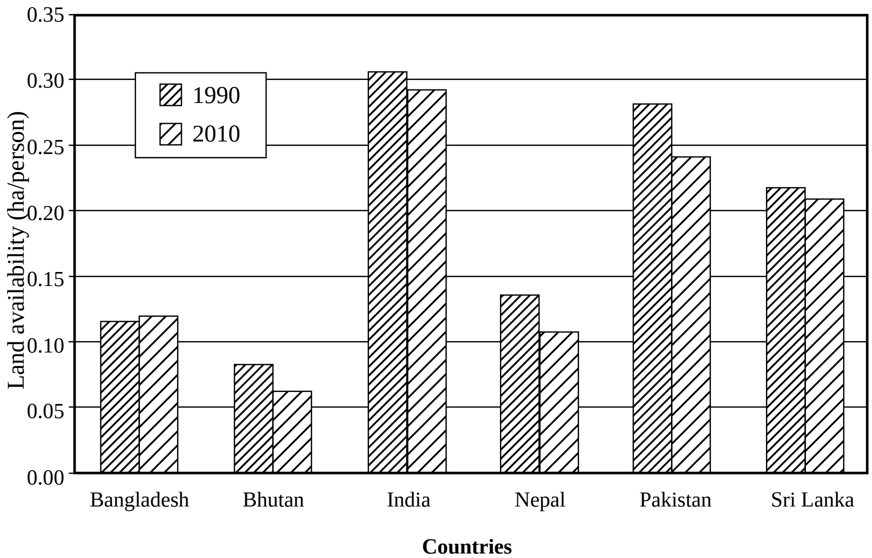
Several studies have also pointed out sustainability implications of rapidly dwindling groundwater resources in South Asia. In a recent study, Seckler et al. (1998) have examined the present status and future requirements of groundwater resources (Table 6). It has been indicated that most of the groundwater is used for irrigation purposes, and irrigation effectiveness is less than 50 per cent in South Asia. Further, with the current level of low irrigation effectiveness, withdrawals of groundwater would increase by 67 per cent in India and 134 per cent in Pakistan by 2025 AD, which could be brought down to 15 and 91 per cent, respectively, if irrigation effectiveness is increased to 70 per cent. With such a marked increase in irrigation effectiveness, India and Pakistan would still withdraw 29 and 71 per cent of their groundwater resources, respectively in 2025. It is important to note that these are the average figures for these two countries and the situation of groundwater-use is alarming even today in semi-arid and arid regions.

Table 6. Status and efficiency of groundwater-use in south Asia

Country	Bangladesh	India	Nepal	Pakistan	Sri Lanka
Annual water resources 1990 (km^3)	2357.0	2,085	170.0	418.3	43.2
Total withdrawals 1990 (km^3)	23.8	518	2.9	155.7	8.7
Per capita withdrawals 1990					
- Domestic (m^3)	7	18	6	26	10
- Industry (m^3)	2	24	2	26	10
- Irrigation (m^3)	211	569	143	1226	483
Irrigation effectiveness 1990 (%)	30	40	58	49	36
Percentage increase in the withdrawals in 2025 over 1990					
- With current level of irrigation effectiveness	89	67	122	134	51
- With 70% irrigation effectiveness	2	15	87	91	-4
2025 withdrawals (with 70% irrigation effectiveness) as percentage of annual water resources	1	29	3	71	19

Source: Seckler et al. (1998)

Fig. 2: Availability of land per person in agriculture in different countries of South Asia



Agricultural development issues

The development issues identified for the region based on the foregoing discussion, are:

Efficient growth. The acceleration of agricultural growth would continue to be a pressing need of the region. It is not only essential to enhance the rate of growth but also to achieve an efficient growth. Higher growth in agriculture is desirable for food and nutritional security, higher employment and income, whereas the improved efficiency of production systems is essential for making agriculture competitive in the wake of liberalization regime. Also, the growth should be diversified in terms of products base and widely spread regionally.

Poverty alleviation. It is now widely accepted that the growth in agriculture, led by the technological developments, made a significant impact on rural poverty alleviation. Given the level of absolute poverty and hunger in this region, the need for accelerating agricultural growth would exist for a long time. This growth needs to be equitable in terms of crops/commodities, regions and class of producers.

Sustainability. The issues relating to sustainability of agricultural systems are becoming increasingly important and visible. They primarily deal with the inter-generational equity in use of natural resources and protection of environment. It is necessary that the productivity level should be enhanced and sustained over time. At the same time, natural resources and environment should be protected for use by future generations. With the present widespread degradation of land, water, and genetic and other environmental resources, sustainability of agricultural system would be central to all developmental programs in the region.

In addition, there could be a number of other developmental issues, such as export promotion, gender equity, system diversification, self-reliance, etc. Agricultural research is expected to contribute to these developmental objectives in South Asia[3]. The agricultural research in fact, has a comparative advantage in contributing to the objectives of efficient growth and promoting sustainability of agricultural production system. It is because the development and dissemination of appropriate technologies not only provide a lasting contribution (unless replaced by a new technology) to these objectives, but their application on a large scale is cost neutral also. As regards the poverty alleviation, analysts believe that economic policy options are better placed to address this objective. We, however, believe that growth and income effects of agricultural technologies have significant impact on poverty reduction, and this impact could be enhanced using other policy measures.

Today, in the 21st century, we are to deal with a knowledge-based society. Science, however, holds the key for development. For the countries in the region, it is critical to utilize the benefits of the new science and technology for the socio-economic development, particularly in alleviating rural poverty. Many of the rural poor depend on agriculture for employment and income. Accelerated agricultural growth offers a potential source of poverty reduction. Agricultural research should therefore play a central role in this task.

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[3] All these concerns are explicitly considered by the NARSs in developing their research plans (PARC, ICAR (not dated); BARC, 2001)

Agricultural research

Intensity and organization of research. The intensity of agricultural research, measured as: the number of scientists with at least masters degree or expenditure on research as percentage of AgGDP, varied considerably. India has the largest agricultural research system in the region, employing about twenty-two thousand scientists (Box 1) and spending a slightly less than 0.5 per cent of AgGDP on agricultural research and education. Research intensity is much low in other countries, with a spending of less than 0.3 per cent of AgGDP on agricultural research and education[4] . This is much smaller than what is spent by the developing countries on an average (0.5 per cent) and certainly much smaller than that spent by the developed countries (2.5 per cent). Unlike in the developed countries, most of the agricultural research in this region is conducted by public research organizations.

The organization of agricultural research is almost similar in all the South Asian countries. There are central as well as provincial research organizations, particularly in the large countries like India and Pakistan. There are institutes dealing with research as well as agricultural universities for education and research. At the centre, there is a council to plan, coordinate and conduct agricultural research, education and frontline extension (transfer and refinement of new technologies). The Indian Council of Agricultural Research (ICAR) is the largest and the oldest organization in the region.

Box 1. Number of scientists in public agricultural research organizations in South Asia

Country	Number of scientists
Bangladesh	2,224
India	22,249
Nepal	236
Pakistan	3,461
Sri Lanka	484

Note: Data provided by the research council of the respective countries and include scientists with masters or higher degree.

[4] Source: Information provided by the research councils/organizations.

Major research thrusts. Over the years, the public research organizations have successfully addressed the research needs of their countries (Alston et al., 2000). As noted earlier, in the beginning, the main objective of the system was attainment of food self-sufficiency, which has now been expanded with the addition of such objectives as equitable growth, sustainability of production systems, diversification of product-mix, export promotion, etc. In terms of commodity coverage, focus has slowly expanded from research on crops to livestocks, horticulture, fisheries, forestry and natural resources. A similar expansion has taken place in the disciplines of agricultural sciences, and currently, the focus is on agricultural biotechnology.

Need for research prioritization. The need for prioritization of agricultural research arises because of three reasons: (i) There is a considerable expansion in the research agenda and making allocation of research resources is difficult for fund providers. The conventional approaches for resource allocation are inadequate, and therefore, use of a formal and systematic approach of research prioritization requiring detailed information, analysis and participation of stakeholders is warranted. The new approach objectively assesses the impacts of alternative research activities in terms of attainment of objectives. (ii) The research intensity is very low and therefore it is essential to use available resources judiciously for maximizing research benefits. Also, research prioritization would help improve the efficiency in the system. (iii) The fund facilitators can easily support research programmes if these have already been identified in a consultative, bottom-up approach. Keeping this objective in view, the remaining part of this paper has been developed.

3. AGRO-ECOREGIONS FOR RESEARCH PLANNING

Delineation and characterization

The agro-ecoregional basis of research planning is receiving increasing acceptance all over the globe, as it helps in targeting research efforts and achieves economies of scale through integration of research efforts. This approach requires identification and characterization of various ecoregions based on agro-climatic and socio-economic factors[5] . A number of studies have identified different agro-ecoregions (AERs) in the South Asia (Sehgal et al., 1992; ICRISAT, 1999). Recently, three councils, viz ICAR, PARC and NARC, have identified major AERs for their respective countries for identification of research investment priorities [PARC (not dated); Saxena et al., 2001; D. Joshy (NARC)[6]]. The Centres of the Consultative Group on International Agricultural Research (CGIAR) have also identified four broad regions (mountains, lower Indo-Gangetic Plains, upper Indo-Gangetic Plains and semi-arid regions) in South Asia for identification of research priorities (Lenne, 2001). We have used this information and our own evaluation to identify and characterize major AERs of South Asia. This has been done through refinements of broad zones considered by the CG centres, and integration of other exercises carried out by the NARSs. The zones so obtained were further refined with feedback from the stakeholders and experts. The identified AERs are: (i) Hot Arid (HA); (ii) Semi-Arid (SA); (iii) Irrigated Sub-Humid (ISH); (iv) High Rainfall Humid (HRH); (v) Sub-Humid to Humid Coasts (SHC); and (vi) Sub-Humid to Cold Arid Mountains (SCAM). The regional spread, soil type, climate, major cropping systems and economic significance of these AERs are given in Table 7. The geographical spread and cropping pattern of these AERs are shown in Map 1[7] and Map 2, respectively. All these AERs are fairly uniform, except the rainfed humid and mountain regions where there is some variability in climate, soil type and irrigated area. The Semi-Arid, High Rainfall Humid,

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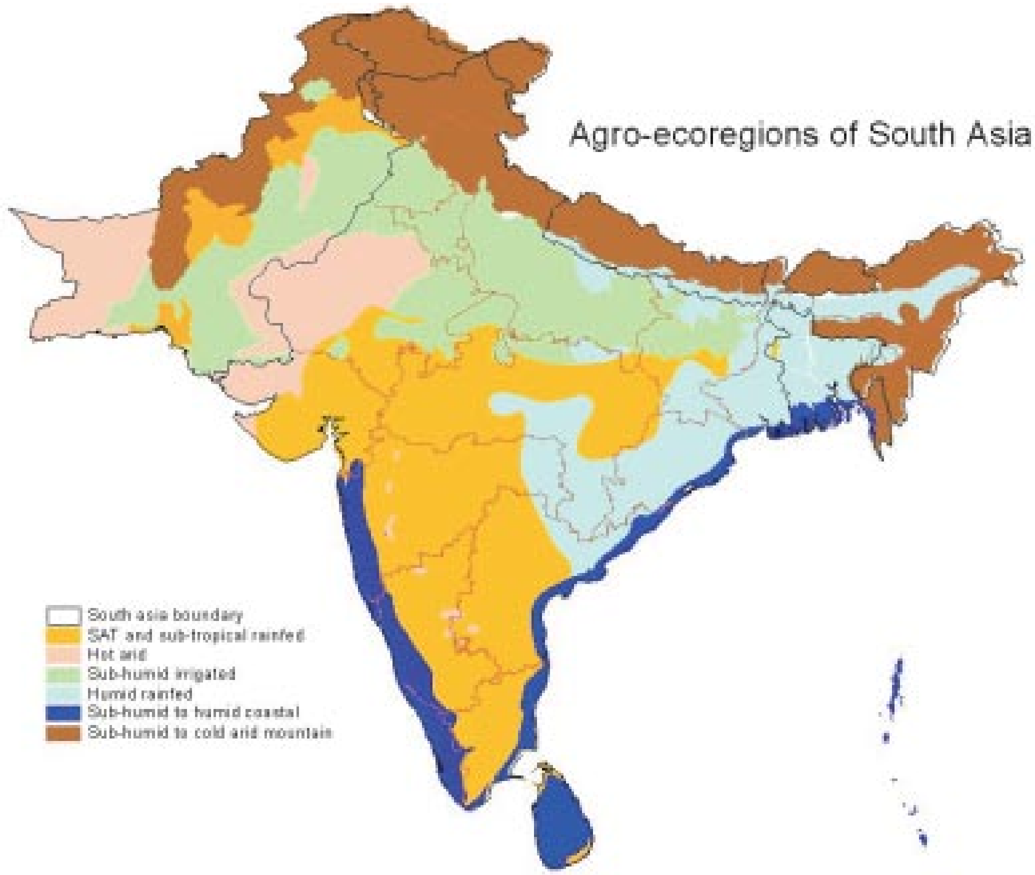
[5] The terms agro-ecoregions and eco-system have been used interchangeably in this paper.
[6]. Personal communication.
[7] Thanks are due to U. K. Deb (ICRISAT) for help in producing the maps.


Agro-ecoregions of South Asia
South asia boundary
SAT and sub-tropical rainfed
Hot arid
Sub-humid irrigated
Humid rainfed
Sub-humid to humid coastal
Sub-humid to cold arid mountain

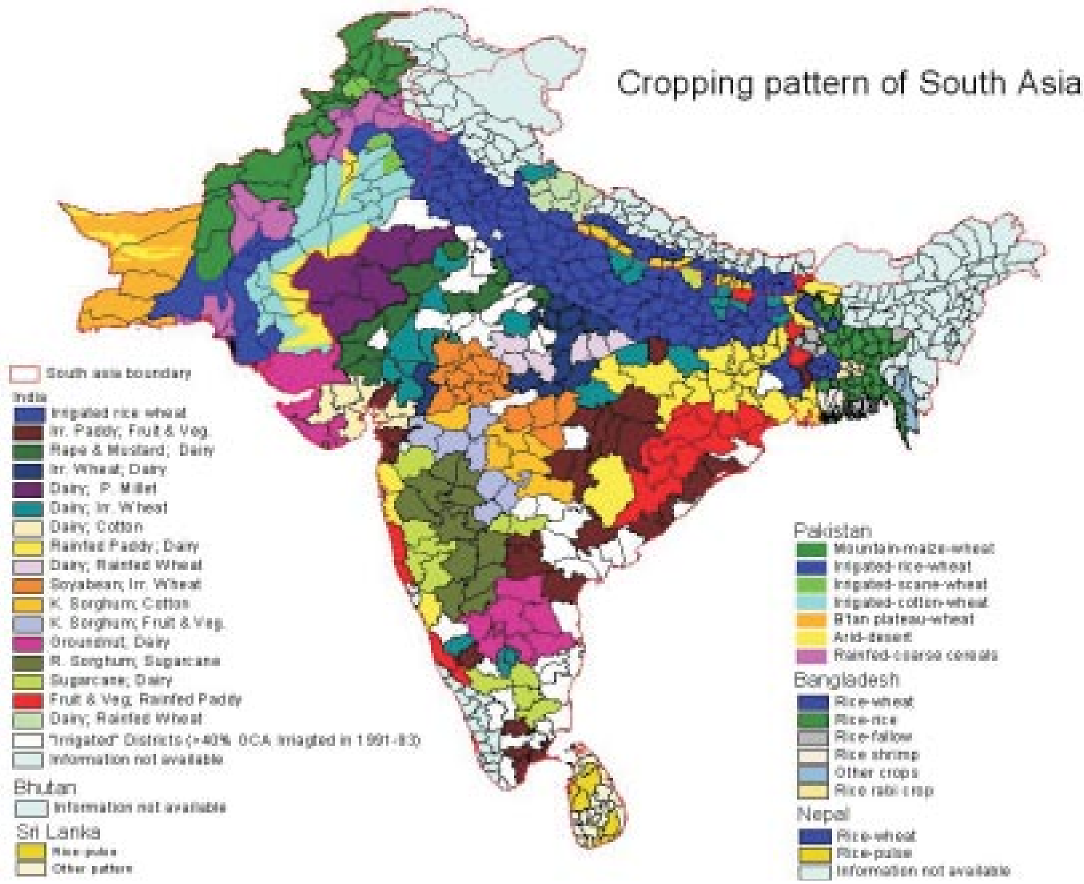

Cropping pattern of South Asia
South asia boundary
India
Irrigated rice wheat
Irr. Paddy; Fruit & Veg.
Rape & Mustard; Dairy
Irr. Wheat; Dairy
Dairy; P. Millet
Dairy; Irr. Wheat
Dairy; Cotton
Rainfed Paddy; Dairy
Dairy; Rainfed Wheat
Soyabean; Irr. Wheat
K. Sorghum; Cotton
K. Sorghum; Fruit & Veg.
Groundnut; Dairy
R. Sorghum; Sugarcane
Sugarcane; Dairy
Fruit & Veg; Rainfed Paddy
Dairy; Rainfed Wheat
"Irrigated" Districts (>40% GCA irriagted in 1991-93)
Information not available
Bhutan
Information not available
Sri Lanka
Rice-pulse
Other pattern
Pakistan
Mountain-maize-wheat
Irrigated-rice-wheat
Irrigated-scane-wheat
Irrigated-cotton-wheat
B'tan plateau-wheat
Arid-desert
Rainfed-coarse cereals
Bangladesh
Rice-wheat
Rice-rice
Rice-fallow
Rice shrimp
Other crops
Rice rabi crop
Nepal
Rice-wheat
Rice-pulse
Information not available

Table 7. Important agro-ecoregions of South Asia and their characteristics

Particular	Hot Arid Agro-ecoregion	Semi-Arid Agro-ecoregion	Irrigated Sub-Humid Agro-ecoregion	High Rainfall Humid Agro-ecoregion	Sub-Humid to Humid Coastal Agro-ecoregion	Sub-Humid to Cold Arid Mountain Agro-ecoregion
Regional coverage	Desert of India and Pakistan; arid and plateau region of Baluchistan in Pakistan	Rainfed peninsular and west India; rainfed region of Pakistan (Punjab and Sindh); part of Sri Lanka	Irrigated region of north-west India (upper Indo-Gangetic Plains) and irrigated region of Pakistan (Punjab and Sindh); part of *tarai* region of Nepal	Eastern India (irrigated or lower Indo-Gangetic region, and rainfed or eastern Plateau region); Bangladesh; part of *tarai* region of Nepal	Coastal regions of India and Bangladesh; part of Sri Lanka; Maldives	Hill and mountain region of India, Nepal and Pakistan; Bhutan
Dominant soil type	Desert soils; plateau	Loamy; black and red soils	Alluviam-derived soils	Alluviam-derived soils; red and yellow soils; lateritic soils	Loamy deltaic-alluvial, red and lateritic soils	Brown forest and podzolic soils; sandy to loamy skeletal soils
Climate	Hot arid	Hot semi-arid;	Hot-semi arid; hot sub-humid	Hot sub-humid to per-humid	Hot semi-arid to per humid	Cold arid; warm sub-humid to per-humid
Rainfall (mm)	< 300	500-1000	500-1200	1000-2000	900-3200	< 150-4000
Dominant cropping systems	Millets, pulses and oilseed-based	Coarse cereal-pulse-based; cotton-based; oilseed-based; rice and sugarcane-based in irrigated areas	Rice-wheat; sugarcane-wheat; cotton-wheat; maize-wheat	Rice-rice; rice-wheat; rainfed rice-based; rice-vegetables; rice-fish; fruits	Rice-coconut-based; plantation crops; fruits; brackishwater shrimp and fish	Millets and wheat in cold arid; rice, coarse cereals and wheat-based
Share in the total net sown area (%)	7.3	38.1	19.0	26.4	5.8	3.4
Share in total value of agricultural production (%)	2.91	25.40	28.59	26.63	10.36	6.11

Source: Based on information provided in Sehgal et al. (1992) and PARC (not dated).

and Irrigated Sub-Humid AERs are quite large, occupying 38.1, 26.4 and 19 per cent, respectively of the total net sown area in South Asia. They contribute about one-fourth each to the total value of output. It may be noted here that the High Rainfall Humid AER largely practising rice-based production systems, is of greater significance as it has enormous potential for further growth, and a large proportion of poor people live in this region (Evenson et al., 1996). The Irrigated Sub-Humid system practises rice-wheat, cotton-wheat and sugarcane-wheat cropping systems. Both canal and tubewell irrigation are intensively used along with other modern inputs like fertilizers. Livestock is important in all the systems, but horticultural crops are widely grown in the Semi-Arid and the Coastal ecoregions. Another important characteristic is that, all ecoregions except Arid and a part of the Irrigated ecoregions, receive significant amount of precipitation which can be conserved and used for agriculture. The estimates of poverty by agro-ecoregion are not readily available, but considering the administrative regions covered under various agro-ecoregions, it can easily be seen that most of the poor people are concentrated in the High Rainfall Humid, Semi Arid and Mountain agro-ecoregions. These systems are also characterized by low productivity and vulnerability to natural resources for degradation. These considerations have significant bearing on identification of research priorities.

4. AGRO-ECOREGION AND COMMODITY PRIORITIES

Methodology and data

Studies on research priority setting are generally carried out using five methods, singly or in combination. These are: congruence (weighted criteria) model, economic surplus model/benefit-cost analysis, mathematical programming, econometric models and simulation model. The scoring model can also be applied at micro-level for prioritization of research projects. The choice of the model is guided by the level of priority setting (macro or micro) and availability of data, analytical skills and resources. We have applied the modified congruence model because of the ease of its application under a situation where time and data are the binding constraints. In simple words, the congruence model allocates research resources in proportion to the relative value of production by region or commodity. It implicitly assumes that opportunities for research are equal across commodities, and that the research benefits are proportional to the value of output. The analysis is based on the present values and assumes constancy of relative shares. These restrictive assumptions imply that results of this exercise provide only a starting point in rationalizing research resource allocation. The CGIAR (1992) and the Indian agricultural research system (Jha et al., 1995) also applied this approach because of its simplicity, transparency and flexibility.

Prioritization of commodities and regions involves calculation of an initial baseline matrix consisting of the value of output from different commodities in different regions. A composite baseline is then developed using the value of output (efficiency), number of poor people (equity), and arable land (sustainability) indicators, using equal weights for these three parameters (Box 2).

These parameters capture extensity dimensions. Initial priority determination based on extensity parameters was modified using intensity parameters, viz. growth in AgGDP, per capita income, child malnutrition, extent of groundwater withdrawals, per capita water availability and number of

Box 2. Criteria for research prioritization		
Objective	Extensity parameter	Intensity parameter
Efficiency	Value of agricultural output	Growth in AgGDP
Sustainability	Arable land	Extent of groundwater withdrawal and per capita water availability
Equity	Number of poor people	Per capita income and child malnutrition

scientists in the national system (for details of concepts and methods, see Jha et al. 1995). The following are specific steps in arriving at the initial and final baselines, indicating relative priorities:

Construction of initial baseline

The construction of initial baseline (IBL) can be illustrated by the following steps:

1. Compute percentage distribution of each extensity parameter (P_{ij})

   $$P_{ij} = (A_{ij} / \sum_{i=1}^{n} A_{ij}) \text{ x } 100; \ i = 1, \ldots\ldots n; \ j = 1, \ldots\ldots k$$

   where, A_{ij} is value of j^{th} parameter in i^{th} agro-ecoregion, n is the number of ecoregions and k is the number of extensity parameters.

2. Assign weight (W_j) to each extensity parameter.

3. Compute initial baseline (B_i)

   $$B_i = (\sum_{j=1}^{k} W_j P_{ij}); \ i = 1, \ldots\ldots n$$

Modification of initial baseline

The initial base line does not fully consider the intensity dimensions of growth, equity and sustainability, and, therefore, appropriate intensity parameters or modifiers are used for modifying the baseline. The idea is that a higher priority should be given to that region where intensity of the problem is severe. For example, the agro-ecoregions with high groundwater exploitation should be accorded a high priority. Here, the direction of impact of modifier is positive. On the contrary, the agro-ecoregions with low per capita income (indicating intensity of inequality) should be accorded a high priority. In this case, the direction of impact is negative. Thus, the selection of modifiers becomes highly crucial at this stage. Having selected the modifiers, the next step is to decide the weight and sign to be attached to each modifier while quantifying its impact on the initial baseline. The sign of the modifiers should be appropriately considered to target the impact of the modifier in the desired direction while modifying the initial baseline. The following step is involved in quantifying the impact of modifiers:

$$\textit{Impact of modifiers (Cij)} = [1+\{M_{ij} / Max\ (M_{ij})\}\ x\ W_j]\ B_i$$

where, M_{ij} denotes the data for jth modifier for the i^{th} agro-ecoregion, Max (M_{ij}) denotes the maximum value of $_j$th modifier, and W_j is the weight for $_j$th modifier.

Modifiers may have positive as well as negative impact on initial baseline. Above formula holds true for the modifiers having positive impact. In case of modifiers carrying negative sign, the direction has to be reversed. This is done by subtracting the standardized value of modifier ($M_{ij} / Max\ (M_{ij})$) from 1 and then multiplying by weight and the initial base line. The impact of each modifier is aggregated to get the total impact of all the modifiers. Using this aggregate impact, the initial baseline is modified by using the following steps to get the final baseline.

$$\textit{Adjusted baseline (Di)} = B_i + \sum_{i=1}^{k} Cij$$

$$\textit{New priority distribution or final baseline (Ei)} = (Di / \sum_{i=1}^{n} Di)*100$$

Priority Setting by Commodity

The relative emphasis on different agro-ecoregions based on the final baseline varies considerably from the relative priority ranking based on value of production (VOP) alone. The shifts in relative emphasis among different regions have to be translated in terms of priorities of commodities in every agro-ecoregions. This is achieved by adjusting the VOP of each commodity in each agro-ecoregion. The factor for adjustment (for each agro-ecoregion) is the ratio of the final baseline and VOP. The adjusted VOP is used for arriving at commodity priorities in an agro-ecoregion or aggregate priorities for all the agro-ecoregions.

Since data for all the modifiers by agro-ecoregions were not available, the research prioritization amongst different agro-ecoregions was done using extensity parameters only. Although this is a limitation, one should not expect major changes in results, as the aggregate impact of all the modifiers (deviation between final and initial baselines) in the country-level analysis was less than 2 percentage points for a country. The parameters for prioritization and weighting schemes were decided on the basis of the information provided by the NARSs. The value of production was computed using international prices, with adjustments for freight charges. The freight charges were added to the international prices under importable hypothesis, and subtracted under exportable hypothesis. Transport cost within the region could not be considered because of non-availability of data. For internationally non-traded commodities, the domestic prices of larger-producing country(ies) were taken after converting them into US dollars. For this purpose, exchange rates reported by the International Monetary Fund were used. Necessary data for this exercise were taken from FAOSTAT and other published sources[8] for the period 1997 to 1999, and the analysis is based on the triennium average.

Agro-ecoregion and commodity priorities

The modified congruence model gives priorities by commodities and agro-ecoregions. This priority matrix can be used to arrive at different priority dimensions, such as AER priorities (sum over commodities by AERs), commodity priorities (sum over AERs by commodity) or commodity group priorities for the region (sum over commodities and AERs). In this exercise, AER priorities, and commodity priorities within and across AER have been

[8] Research Councils in the region also provided some information, which is acknowledged with thanks.

discussed here. For the benefit of national programs, commodity priorities by countries have also been presented. The ‘priority score’ is the share of a commodity/group or AER/country in 100 (per cent), and therefore, higher the score, higher is the priority. The national systems can use the priority matrix for allocation of resources across commodities or AERs. Fund facilitators can also use the priority matrix to track priority AER and commodity or *vice versa*. Since identification of research priorities was the major objective of this exercise, we have focussed on AER and commodity priorities.

The AER priorities in South Asia are shown in Table 8. As noted earlier, the ISH, SA and HRH are the three top priority AERs in South Asia. The efficiency objective can be better addressed by focusing on ISH and HRH, but for poverty alleviation, HRH and SA are more important. Sustainability issues are equally important in these AERs, although factors affecting sustainability may vary. For example, it could be depletion of groundwater and soil nutrients in the ISH, whereas soil erosion due to water may be more important for the other two regions. Amongst the three smaller AERs, the SHC and SCAM are more important from the points of view of productivity and poverty.

The priority commodity groups (among 91 commodities) in South Asia (Tables 9 and 10) were found as cereals, livestock, horticultural crops (fruits

Table 8. Agro-ecoregion priorities in South Asia

(Percentages)

Agro-ecoregion	Value of production	Distribution of poors	Arable land distribution	Initial baseline
Hot arid (HA)	2.91	2.4	7.4	4.2
Semi-arid (SA)	25.40	25.0	38.1	29.2
Irrigated sub-humid (ISH)	28.59	23.8	19.8	23.8
High rainfall humid (HRH)	26.63	38.8	25.7	30.1
Sub-humid to humid coasts (SHC)	10.36	4.7	5.7	6.9
Sub-humid to cold arid mountains (SCAM)	6.11	5.3	3.4	4.9
All agro-ecoregions	100	100	100	100

Table 9. Priority score of commodity groups by country in South Asia

Commodity group	Bangla-desh	Bhutan	India	Mal-dives	Nepal	Paki-stan	Sri Lanka	South Asia
Cereals	60.4 (10.9)	22.2 (0.1)	35.2 (77.8)	0.0 (0.0)	55.4 (2.7)	21.9 (8.1)	20.3 (0.5)	35.25 (100)
Roots & tubers	2.0 (5.3)	4.2 (0.2)	2.7 (87.2)	0.0 (0.0)	4.9 (3.5)	0.6 (3.3)	1.4 (0.5)	2.43 (100)
Pulses	2.0 (2.9)	0.0 (0.0)	5.1 (89.4)	0.0 (0.0)	3.3 (1.3)	2.2 (6.4)	0.2 (0.0)	4.45 (100)
Oilseeds	1.4 (1.8)	0.2 (0.0)	5.8 (95.3)	0.0 (0.0)	0.4 (0.1)	1.0 (2.7)	0.2 (0.0)	4.71 (100)
Vegetables	1.2 (1.5)	8.5 (0.2)	6.1 (91.0)	0.0 (0.0)	0.0 (0.0)	2.6 (6.6)	4.7 (0.7)	5.22 (100)
Fresh fruits	4.8 (3.3)	39.7 (0.5)	10.0 (83.9)	1.7 (0.0)	2.5 (0.5)	7.3 (10.3)	17.8 (1.6)	9.25 (100)
Dry fruits	0.0 (0.0)	0.0 (0.0)	0.1 (28.7)	0.0 (0.0)	0.0 (0.0)	1.9 (70.8)	0.2 (0.4)	0.35 (100)
Cash crops	5.1 (3.1)	0.4 (0.0)	9.9 (73.3)	0.0 (0.0)	2.4 (0.4)	18.7 (23.1)	1.1 (0.1)	10.53 (100)
Livestock	14.1 (4.4)	24.7 (0.1)	17.6 (67.2)	0.0 (0.0)	26.0 (2.2)	40.4 (25.8)	8.9 (0.4)	20.46 (100)
Plantation	3.0 (3.9)	0.0 (0.0)	5.2 (84.1)	0.0 (0.0)	1.2 (0.4)	1.8 (4.9)	39.5 (6.6)	4.82 (100)
Fish	5.8 (14.6)	0.2 (0.0)	2.3 (72.1)	98.3 (0.5)	3.9 (2.6)	1.6 (8.4)	5.6 (1.8)	2.54 (100)
All commodities	100 (6.3)	100 (0.1)	100 (78.0)	100 (0.0)	100 (1.7)	100 (13.0)	100 (0.8)	100 (100)

Note: Figures in parentheses are priorities of a commodity group across countries.

and vegetables), cash crops and plantation crops in that order. Cereals were more important in all the AERs, but their priority score was 41 in the ISH and 51 in the HRH ecoregions. Livestock has been found important in all the AERs, but it got very high priority score in the HA (41) and SCAM (29), whereas fruits, cash crops and plantation crops were priority commodities for the SA, ISH and SHC systems, respectively. These priority scores were obtained using importable hypothesis for foodgrains, cotton and sugar, as these were not regularly exported from South Asia. For commodities under regular exports, such as jute, rubber, tea, coffee, etc., exportable hypothesis was used. In the second scenario, exportable hypothesis was also considered for foodgrains, cotton and sugar. Results

Table 10. Priority score of commodity groups by agro-ecoregions in South Asia

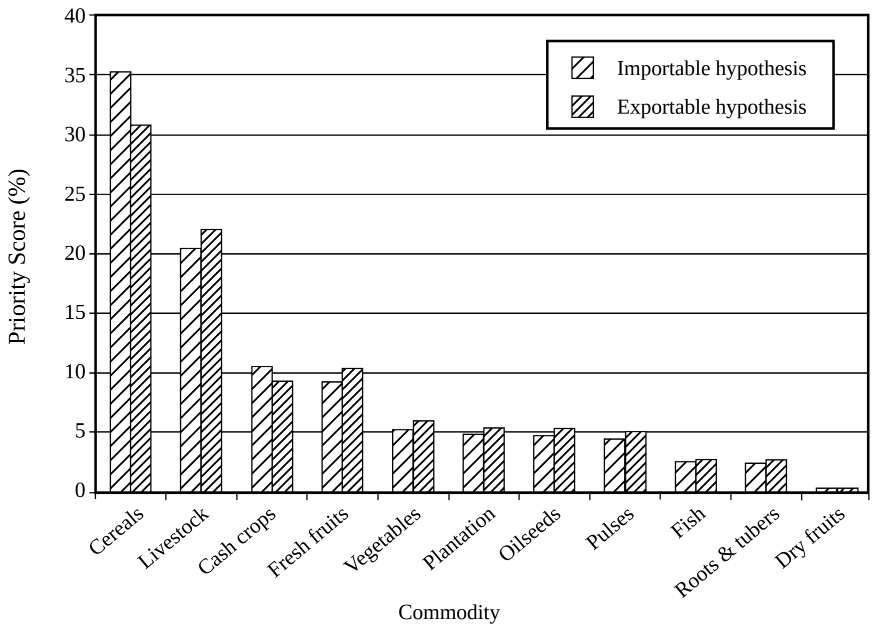
Commodity group	Hot Arid Agro-ecoregion	Semi-Arid Agro-ecoregion	Sub-Humid to Cold Arid Mountain Agro-ecoregion	Irrigated Sub-Humid Agro-ecoregion	High Rainfall Humid Agro-ecoregion	Sub-Humid to Humid Coastal Agro-ecoregion	South Asia
Cereals	18.3	20.0	24.6	41.1	50.7	25.9	35.05
	(1.5)	(14.5)	(4.3)	(33.5)	(38.5)	(7.6)	(100)
Roots & tubers	0.7	2.1	3.8	2.0	3.7	0.3	2.40
	(0.9)	(22.6)	(9.6)	(24.4)	(41.4)	(1.1)	(100)
Pulses	6.9	9.7	0.4	3.2	2.5	1.1	4.39
	(4.6)	(55.8)	(0.6)	(21.1)	(15.2)	(2.7)	(100)
Oilseeds	10.8	8.1	0.8	4.5	2.1	3.8	4.65
	(6.8)	(44.4)	(1.1)	(27.5)	(11.9)	(8.4)	(100)
Vegetables	4.2	4.8	4.4	3.7	7.2	5.7	5.19
	(2.3)	(23.5)	(5.2)	(20.5)	(37.1)	(11.4)	(100)
Fresh fruits	5.8	14.9	8.9	5.7	5.3	17.1	9.29
	(1.8)	(40.7)	(5.9)	(17.5)	(15.2)	(19.0)	(100)
Dry fruits	6.3	0.0	1.3	0.0	0.0	0.9	0.36
	(51.7)	(0.0)	(23.0)	(0.0)	(0.0)	(25.3)	(100)
Cash crops	1.5	12.7	1.5	18.2	5.5	4.6	10.51
	(0.4)	(30.7)	(0.9)	(49.5)	(14.0)	(4.5)	(100)
Livestock	40.7	21.7	29.2	19.3	19.5	12.0	20.44
	(5.8)	(27.0)	(8.7)	(27.0)	(25.4)	(6.1)	(100)
Plantation	0.4	4.3	24.2	1.2	1.1	18.4	5.11
	(0.2)	(21.3)	(29.0)	(6.7)	(5.5)	(37.3)	(100)
Fish	4.3	1.7	0.9	1.0	2.4	10.3	2.60
	(4.9)	(16.3)	(2.1)	(11.3)	(24.2)	(41.2)	(100)
All commodities	100	100	100	100	100	100	100

Note: Figures in parentheses are priorities of a commodity group across agro-ecoregions.

under both the scenarios (Fig. 3) showed only marginal differences in the priority scores. The priority score of cereals and cash crops decreased marginally under the exportable hypothesis, while it improved for livestock. But considering substantial increase in demand for food in South Asia and its implications on food insecurity (Pinstrup-Andersen et al., 1997; and Paroda and Kumar, 2000), we have subsequently discussed the results of the importable hypothesis also for these commodities.

The priority scores of individual commodities, as given by the modified congruence approach, were used to classify commodities into high, medium and low priority commodities individually for each AER (Table 11).

Fig. 3: Commodity priority score in South Asia



Commodities not covered in this table were of very low priority (score less than 2). As seen from Table 11, except for the HA, rice is a high priority commodity in all the AERs, while wheat is a high priority commodity in the HA and ISH, and of moderate priority in the SCAM and the HRH. Small ruminants, oilseeds and pulses are of high priority commodity in the HA and SA, whereas milch animals are of high priority in all the AERs, except in the SHC. All fruits, in general, are of low priority in all the AERs, except banana in the SA and SHC.

Futuristic Considerations: Sensitivity Analysis

The modified congruence analysis, which assumes constancy of relative shares of commodities or agro-ecoregions, can be a starting point for research prioritization. But the results need to be adjusted for expected changes arising from unfolding of growth opportunities, research capacity and challenges of globalization. But consideration of these changes requires additional data and detailed analysis. We have considered the growth opportunities by modification of baseline priorities with the growth in AgGDP. A similar modification of the baseline with the number of agricultural scientists has

Table 11. Priority status of commodities by agro-ecoregion in South Asia

Agro-ecoregion	High priority (priority score>7)	Medium priority (priority score between 4 and 7)	Low priority (priority score between 2 and 4)
Hot Arid Agro-ecoregion	Goat, wheat, millets, cattle, buffalo	Chickpea, rapeseed, dates, sheep	Rice, inland fish, poultry
Semi-Arid Agro-ecoregion	Banana, rice, cattle, buffalo	Chickpea, groundnut, cotton, sugarcane, tobacco	Sorghum, beans, orange, pulses, mango, poultry
Sub-Humid to Cold Arid Mountain Agro-ecoregion	Rice, tea, cattle	Wheat, maize, buffalo, sheep, goat	Potato, apple, tobacco, poultry
Irrigated Sub-Humid Agro-ecoregion	Rice, wheat, cotton, sugarcane, buffalo	Cattle	Rapeseed, potato, orange, goat
High Rainfall Humid Agro-ecoregion	Rice, cattle	Wheat	Potato, banana, sugarcane, jute, inland fish, buffalo, goat, poultry
Sub-Humid to Humid coastal Agro-ecoregion	Rice, banana, tea, marine fish	Coffee, rubber	Coconut, mango, sugarcane, buffalo, poultry, cattle
South Asia	Rice, wheat, cattle	Banana, cotton, sugarcane, buffalo	Tea, tobacco, potato, chickpea, poultry, goat

also been attempted to capture research capability of the NARSs[9] . However, some major changes are expected to emerge because of trade liberalization; these could be income and price impacts, affecting food demand, and effect on trade depending upon competitive advantage. These effects are of greater consequence and hence must be incorporated in the analysis and the results should be examined for their sensitivity. However, implications of competitive advantage on agricultural research can be best captured at micro-level (research programs and projects) research prioritization, and therefore, these have been considered in the next section. Incorporation of changes in demand for commodities at the macro-level (commodity or ecoregion) is important because ensuring food security is one of the main objectives of NARSs in the region.

[9] Please note that these modifications are done for the country-level analysis and not for the agro-ecoregion level.

Empirical studies have indicated significant changes in the demand for agricultural commodities (Pinstrup-Andersen et al., op cit.; Paroda and Kumar op cit). The demand projections for foodgrains include food as well feed demand. Expected changes in the demand are likely to affect prices and output of commodities and therefore this can be best captured by modification of the VOP. The VOP of a commodity was adjusted with the expected growth in its demand in the region (Figure 1b). Since research and extension lag is about 8-11 years (Davis et al., 1987), the growth was extrapolated over a period of 10 years[10]. This adjustment in the VOP implies that the commodities with higher expected growth in the demand should get high priority.

The adjusted VOP thus obtained along with the parameters of sustainability and equity was used for another iteration of the analysis. The results, given in Table 12, indicate that there was a noticeable increase in priority score of horticultural and livestock commodities, whereas cereals registered a significant decline in their priority score in South Asia. Cash crops and

Table 12. Sensitivity analysis of commodity priorities for South Asia

Commodity group	Base scenario	Priorities with VOP adjusted with growth in the demand
Cereals	35.25	31.67
Roots & tubers	2.43	2.39
Pulses	4.45	4.31
Oilseeds	4.71	4.61
Vegetables	5.22	5.84
Fresh fruits	9.25	10.24
Dry fruits	0.35	0.38
Cash crops	10.53	9.97
Livestock	20.46	23.10
Plantation	4.82	4.56
Fish	2.54	2.92

[10] $Y_0 (1+r)^t$ where Y_0 is VOP in the base year, r is expected growth in the demand and t is time period.

plantation crops also showed a moderate decrease in their priority scores, while other commodities showed no significant change. It may be noted here that in this sensitivity analysis we are making changes in the relevant parameter carrying one-third weight. Therefore, one should not expect drastic changes in the priority scores, unless weight are also changed significantly. It is important to mention here that these results on commodity priorities are only indicative in nature and some degree of scientific judgement need to be applied to capture other relevant external factors and opportunities (including chances of research success) in setting research priorities at the micro-level.

5. PRODUCTION CONSTRAINTS AND GROWTH OPPORTUNITIES[11]

Production constraints

Having identified the ecoregion and commodity priorities, the next logical step is to translate these commodity priorities into research programs. This needs identification and prioritization of production constraints (for priority commodities or production systems), and incorporation of growth opportunities and scientific feasibility. A survey of the available studies on the topic provides a fairly good understanding of the generic production constraints in the various AERs (Table 13). These production constraints are further classified into three categories: (a) natural resource-related constraints, (b) other technical constraints, and (c) socio-economic constraints (see Annexure). Inadequacy of data does not permit us to analyse relative importance of these three types of constraints, but as felt by participants of the expert consultation and reported in some studies, these constraints did cause significant production losses. For example, abiotic stresses like drought and submergence, caused significant production losses of rice in the eastern India (Evenson et al., 1996). Decreasing profits because of high capitalization of production systems and depletion of natural resources, particularly groundwater, are serious binding constraints in the ISH ecoregion (Fugisaka et al., 1994; and Roy and Datta, 2000). Production environment is becoming more hostile in the Arid and Semi-Arid ecoregions and opportunities for employment and income growth are less (Ryan and Spencer 2000). Diversity of production systems, low infrastructure development and technology penetration, lack of markets, labor migration, etc. are major constraints to development of hill and mountain agriculture. Livestock, which is important to smallholders and landless laborers for generation of employment and income in all the ecoregions, is constrained by a number of factors, such as poor nutrition due to non-availability of feed and fodder, high incidences of diseases and less developed markets and other infrastructure facilities (Devendra et al., 2000). Production losses

[11] This and the next section broadly summarize recommendations of the sub-groups formed during the expert consultations.

due to socio-economic constraints in all the ecoregions and sub-sectors of agriculture are also significant but difficult to estimate. A systematic strategy to address all these constraints successfully through harnessing scientific opportunities should guide further prioritization of research programs for various AERs.

Growth opportunities

Assessment of growth opportunities through application of science is a difficult task, but some judgement can be made using demand side considerations, clients' needs and scientific opportunities (Table 13). There are a number of areas having tremendous growth potential and filling technology gap in these areas would help tap this potential. The value addition in agricultural products through agro-processing has not received due attention in South Asia so far. Considering the extent of post-harvest losses, particularly in fruits, vegetables and other perishables, the scope for value addition, income supplementation, and employment generation is enormous. Their collective impact on poverty alleviation would be substantial. However, it requires a close collaboration with the private sector, large investments in infrastructure and detailed study of the market demand. Similarly, forestry and agro-forestry offer immense possibilities for growth with sustainable development. However due to paucity of information, it has not been possible to make a detailed quantitative analysis and articulate opportunities in this area in this document. Nevertheless, rehabilitation of forests, protection of biodiversity and environment, interactions between forestry and agriculture, market development for non-timber and minor forest products, agro-forestry development, etc. were considered to be high impact areas.

Another growth opportunity could be the management of rainwater in water deficit areas such as the arid and semiarid ecoregions. There is a need for further refinement and management of technologies and approaches for harvesting and use of water like watershed management. Adoption of these technologies requires group or community action and therefore, educating the community on this aspect would facilitate rapid adoption of these technologies. Diversification towards employment and income generating activities like livestock and horticulture requires adequate technological

Table 13. Major production systems, problems and opportunities by agro-ecoregion

	Hot Arid, and Semi-Arid Agro-ecoregions	Irrigated Sub-Humid Agro-ecoregion	High Rainfall Humid; and Sub-Humid to Humid Coastal Agro-ecoregions	Sub-Humid to Cold Arid Mountain Agro-ecoregion
Production Systems	Coarse cereals-based; cotton-based; oilseed (groundnut and soybean)-based; rice and sugarcane-based in irrigated areas; livestock; horticultural crops	Rice-wheat; cotton-wheat; sugarcane-wheat; maize-wheat; buffalo for home dairy; commercial meat and dairy	***Unfavourable, rainfed, flooded:*** Rice-pulses/oilseeds/minor grains; rice-jute; rice-fish/freshwater prawn; ***Favourable irrigated:*** Rice-rice; rice-wheat; rice-vegetables; rice-wheat; rice-vegetables; rice-fish; horticultural and plantation crops; brackishwater shrimp and fish; open water culture-based fishery; crop-livestock systems (Bengal goat)	***Low (3000-5000 feet) and mid (5000-8000 feet) heights:*** Rice-wheat; rice-potato; maize-potato; horticultural crops; trees (fodder and fuel); cattle, buffalo, sheep, goat, poultry Upper (>8000 feet) heights: Sheep, goat, horticulture, forestry, medicinal plants
Characteristics and constraints	• Risky environment • Erratic and scanty rainfall • Drought-prone • High incidence of poverty • Land degradation, salinization and deterioration of soil health • Low productivity and high yield losses • Lack of opportunities for income generation	• High productivity but low profitability of cereal systems • High and overcapitalized mechanization • High levels of input- use but low input-use efficiency • Relatively low levels of agro-ecoregion diversity • Salt-affected areas • Groundwater depletion, soil erosion and exhaustion of past sources of productivity growth (varieties, fertilizers)	• Low level of productivity and large yield gaps • Excess and deficit water regimes, and contamination of arsenic • Soil degradation and erosion • Biotic and abiotic stresses • Poor infrastructure and transfer of technology • Fragmented small holdings • Undeveloped markets, low industrialization • High incidence of poverty • Prone to natural disasters-drought, flood, cyclones, rise in sea level	• Diverse production systems because of differences in altitudes, slopes, soils, etc. • Poor infrastructure and low technology transfer • Water-excess and deficit • Soil erosion and loss of bio-diversity • Deforestation • High post-harvest losses • Jhum cultivation • High incidence of poverty and labor migration
Opportunities	• Diversification of systems • Soil and water management • Market integration • Biotechnology tools and integrated pest management (IPM) for control of biotic stresses	• Diversification of systems-livestock • Soil and water management- zero tillage • Precision farming • IPM • Market integration	• High rainfall, water management • Diversified systems • Dry season cereals (boro rice) • Aquatic system development • Market integration • Biotechnology tools and IPM for control of biotic stresses • Livestock development	• Post-harvest processing and value addition • Potential for off-season vegetables, fruits and plantation crops • Aquaculture, bee keeping, floriculture and seed production • Livestock • Ecoturism

Source: Based on and literature survey and discussion during the workshop and infrastructural support. In particular, their linkages with crop sector should be properly understood and exploited for complementarity. Advances in molecular biology and biotechnology can help in identification and utilization of tolerance to various abiotic and biotic stresses, besides making improvements in shelf-life and quality of products. Biotechnology can also play a significant role in organic farming. With the application of these tools it would be possible to reduce the time lag between research and technology development and the development of improved plant varieties and animal breeds. It would also increase chances of successful research. However, utilization of these frontier sciences and knowledge-intensive technologies needs higher capital investment, inter-institutional linkages, effective regulatory mechanism and delivery system. Diversification of production systems through promoting livestock, fishery, bee keeping and horticulture, and its integration with marketing system would offer novel opportunities in the region.

6. RESEARCH PRIORITIES AND STRATEGY

Research priorities

Currently, no formal research prioritization technique was applied to identify the system-specific research priorities because it has enormous cost, (time and resources) and data requirements. The priorities are simply 'consensus judgements' of the expert groups. These groups had, however, used the following systematic processes and objective criteria to arrive at these priorities: *Firstly*, the root cause analysis was carried out to find the major production constraints and the emerging research issues were examined along with research gaps and opportunities. *Secondly*, the emerging issues were further subjected to their likely impact on improving the efficiency and sustainability of production systems and alleviating the food insecurity and poverty. *Thirdly*, the comparative advantage of the region and chances of research success or scientific feasibility were considered.

The identified priorities for various agro-ecoregions in South Asia are given in Table 14. These priorities are broad-based and depending upon the specific requirement, one may further rework on these priorities and develop executable and locally relevant research programs. The fund facilitators may find these generic priority areas adequate to channel research grants, but individual organizations of the NARSs in the region may further fine tune these priorities for developing their own focussed research agenda.

The conservation of natural resources (land water and germplasm) is extremely important and the priority AERs are: the Arid, Semi-arid, and Irrigated sub-humid. Research issues relating to the rice-based production systems in the HRH region assume high priority because of their likely impact on poverty alleviation. Socio-economic research issues relating to efficient organization of production including agro-processing, sustainable use of resources, risk management, transfer of technologies and integration of markets, are extremely important for all the AERs.

Another way to look at these research priorities is to arrange them by sectors as depicted in Table 15.

Table 14. Agricultural research priorities by agro-ecoregion in South Asia

Hot Arid and Semi-Arid ecoregions of South Asia	High Rainfall Humid; and Sub-Humid to Humid Coastal Agro-ecoregions
1. Water management and water-use efficiency • Improved water harvesting and watershed management • Drought escape and resistant crops; short duration, water efficient crops • Improved water-use efficiency (sprinkler, fertigation) and pricing policy ***2. Diversification of income sources*** • Diversification of agriculture (crop, livestock, fishery, horticulture, agro-forestry) • Introduction of high value crops • Post-harvest processing and value addition • Dual purpose crops (food & quality fodder, feed) • Small scale mechanization • Solar and wind energy utilization for cost reduction ***3. Soil Health and Fertility*** • Incorporation of legumes in cropping systems • Breeding cultivars for efficient nutrient use • Integrated nutrient management including organic recycling ***4. Markets and Policy*** • Policies to promote access of poor small holders to markets • Role of private sector in marketing • Identify new markets for products • Market intelligence (information) • Risk management ***5. Low Productivity Needing Effective Technology Development and Dissemination*** • Seed and resource management technology delivery systems • Quality and value addition through genetic improvement • Biotechnology to reduce yield losses • Thrust on hybrid research • IPM systems for important crops ***6. Land-Use Planning*** • Land-use policy • Integrated planning for soil, water, crop-livestock management • Institutions for conflict management among land users • Develop and apply GIS techniques for land-use planning • Insurance and early warning systems	***1. Genetic Improvement*** • Conservation and utilization of biodiversity • Abiotic and biotic stress tolerance varieties • Nutrition improvement ***2. Diversification*** • Short-duration rice and wheat (to incorporate other crops) • Establishment of legumes and oilseeds in the system • Incorporation of coconuts and bananas in small farm systems • Vegetables, tubers, flowers and other horticultural crops • Farming systems involving crops and animals (cattle, buffalo, goat (black Bengal goat), poultry and fish) • Incorporating winter maize in the cropping system • Rice-based farming • Rice fallows to be used for pulses, groundnut, lentil, soybean ***3. Improving Competitiveness*** • Improving production, quality and processing efficiencies • Post-production management, drying, storage and marketing • Low energy input rural/community-based processing and storage technology • Establishment of cooperative village industries • Market development in the context of new trade regimes • Rural credit supply • Risk management ***4. Water Management*** • Promoting water users associations • Pricing – for efficient resource allocation • Water-use efficiency through crop management, efficiency of inputs in integrated farming and popularizing concepts of IPM, INM, IWM ***5. Soil Management*** • Zero tillage and small farm mechanization • Soil amendment • Coastal reforestation and mangrove rehabilitation/ restoration • Species and systems that promote natural resources management ***6. Aquaculture and Aquatic Systems Management: Inland*** • Polyculture (composite culture) of finfish in pond systems- genetic diversity and feeding and healthcare for more intensive culture of fish and crustaceans • Deepwater rice-fish/freshwater prawns • Integrated fish farming • Open water culture-based fishery ***7. Coastal aquaculture*** • Marine shrimp farming¾ sustainability improvement • Health management; feed and nutrition using farm-made, low-cost formulations; resource efficient hatchery and seed distribution systems; pond effluent management • Crab culture and ornamental fish

Note: Research themes and priority areas for the Hot Arid, Semi-Arid ecoregion of South Asia are in order of their priority ranking.

Table 14. contd...

Irrigated Sub-Humid Agro-ecoregions

1. Wate-use efficiency

- Water user associations to foster
  - ➢ Equitable use within systems
  - ➢ Canal maintenance
  - ➢ Pricing
- Practices for plot level water-use efficiency
  - ➢ Land levelling implements, training
  - ➢ Aerobic rice varieties for rice-wheat system
  - ➢ Alternative rice establishment practices
  - ➢ Wet-dry irrigation practices
  - ➢ Zero tillage in wheat
  - ➢ Drip and sprinkler irrigation

2. Control of soil degradation

- Reclamation of sodic lands
- More diverse crop rotations, including those with legumes, sugarcane, fodder crops to improve land quality
- Alternative household fuel sources to allow farm yard manure to be used for soil improvement
- Leaf color charts to improve nitrogen-use efficiency
- Zero tillage for timely sowing to improve nitrogen-use efficiency

3. Control of pests and weeds

- IPM in rice, cotton and sugarcane systems
- Host plant resistance for crop biotic stresses
- Zero tillage and bed system for integrated weed management strategies for *Phalaris* control in wheat systems
- More diverse agro-ecosystem for natural management of pests, diseases and weeds

4. Post-harvest management

- Varieties with high quality
- Straw treatment and management
- Improved threshing implements

5. Increasing crop yields

- Crop varieties for higher yield potential
- Improve input use efficiency, stress on precision farming

6. Diversification of the systems

- Incorporation of legumes in the rice-wheat system
- Focus on commercial livestock and horticulture sectors
- Small scale mechanization
- Mechanization of rice plantation

Sub-Humid to Cold Arid Mountain Agro-ecoregion

1. Common issues

- Conservation of soil and water
- Conservation and utilization of biodiversity
- Animal health and management
- Post-hervest processing and management
- Strengthening research system and capacity
- Issues relating to empowerment of women, labor migration and market integration
- Conservation and improvement of forestry
- Cold water fish culture
- Strengthening of seed system
- Ecoturism

2. Low height (3000-5000 feet)

- IPM in crops
- Off-season vegetables and mushroom production
- Small farm mechanization
- Promote agroforestry and bee keeping

3. Mid heights (5000-8000 feet)

- Improvement of horticulture and orchards-IPM, INM, root stock and plant propagation
- Improvement of medicinal and aromatic plants
- Promote agroforestry, bee keeping and tea plantation

4. Upper heights (>8000 feet)

- Conservation and use of medicinal plants
- Tropical fruits
- Improvement of horticulture and orchards-IPM, INM, root stock and plant propagation
- Packaging of fruits
- Develop sheep and rabbit farming

Source: Recommendations of the working groups made during the workshop.

Table 15. Agricultural research priorities by sector

Sector	Priority research themes
1. Crops	1. Crop varieties for ♦ tolerance to abiotic and biotic stresses ♦ Improving crop yield ceilings in irrigated areas ♦ Better product quality, nutrition and value addition ♦ Dual purpose (food and fodder) crops 2. Short duration varieties of rice and wheat to incorporate other crops, especially legumes in cropping systems 3. Diversifying the production systems 4. Improving input-use efficiency through ICM, IPM, INM, precision farming, etc. 5. Improving cropping systems for higher yields, pest management, natural resource conservation, and integration with livestock and trees 6. Sustainable seed and technology transfer systems 7. Small farm mechanization
2. Horticulture	1. Post-harvest handing, value addition through processing and storage 2. IPM and INM in orchards, vegetables and floriculture 3. Improving root stocks and rapid plant propagation ethods in fruit trees 4. Integrated management for off-season vegetables, flowers and peri-urban cultivation 5. Varieties for better quality, nutrition, shelf-life and suitable for processing 6. Protected cultivation of vegetables and flowers 7. Development of arid (hot and cold) horticulture
3. Livestock including poultry	1. Technological options for sustainable crop-livestock systems 2. Improving nutrition through ♦ Quality of crop residues and removing anti-nutritional factors ♦ Strategic supplementation ♦ Improved varieties of fodder crops and feed balance 3. Animal health ♦ Epidemiology, diagnosis and vaccine production of major diseases based on biotechnology ♦ Disease-nutrition interactions ♦ Genetic resistance to major diseases 4. Characterization and improvement of local breeds through selective breeding 5. Factors influencing adoption and impact of improved technologies 6. Market development, product processing and biosafety of products with focus on smallholders 7. Socio-economic and environmental impact of crop-livestock systems, including pastoral systems.

4. Fisheries	*Coastal* 1. Sustainable management of coastal systems and marine protected areas 2. Sustainable management of marine shrimp farming (feed, nutrition, health and seed distribution), including effluent management 3. Crab culture and ornamental fish *Inland* 4. Genetic improvement for growth enhancement and disease resistance 5. Fish health management, particularly for intensive culture of fish and crustaceans 6. Deepwater rice-fish/freshwater prawn 7. Integrated fish farming, and open water culture-based fishery 8. Cold fish water culture *General* 9. Post-harvest issues, and biosafety of seafood products 10. Socio-economic issues, environmental impact analysis and institutional issues of aquatic resources and aquaculture
5. Forestry	1. Sustainable management of second-growth forests 2. Inventorying, evaluation and development of forest resources 3. Tree and forest health management 4. Promotion and management of agro-forestry 5. Improvement of medicinal and aromatic plants 6. Market development for non-timber and minor forest products 7. Policy and institutional issues in management of forests 8. Ecoturism and landscape forestry
6. Natural resource management	1. Conservation of genetic (crop, livestock, fish, tree), water and land resources 2. Improving efficiency in distribution and use of irrigation water (policy, technology and institutional issues) 3. Technological and institutional options for harvesting and use of rainwater (e.g. watershed management) 4. Sustainable land-use, organic recycling and soil fertility management 5. Reclamation of degraded/sodic lands, control/management of saline and arsenic contaminated water
7. Socio-economics	1. Poverty mapping and investment priorities 2. Market integration and trade liberalization with focus on smallholders 3. Risk management 4. Empowerment of women and labor migration 5. Policy and institutional aspects of agricultural R&D

Source: Recommendations of working groups formed during the expert consultations.

The research areas, priority agro-ecoregion and partnership are given in Box 3. The broader priorities pertain to five important themes:

Box 3. Areas of common interest and partnership

Research area	Priority agro-ecoregion	Partnership
Poverty mapping and investment priorities	Semi-Arid; High Rainfall Humid; Sub-Humid to Cold Arid Mountains	NARS (public), IARCs
Improving water -use efficiency	All ecoregions of South Asia	NARS (public and non-profit private), IARCs
Reclamation/ management and use of saltaffected soils and saline water	Irrigated and coastal ecoregions of South Asia	NARS (public) and IARCs
System diversification	Hot Arid, Semi-Arid ecoregions	NARS (public and private), IARCs
Animal health and nutrition	All ecoregions of South Asia	NARS, IARCs, private
Commercialization and post-harvest processing	All ecoregions of South Asia	NARS (public and private), IARCs
Market integration and trade liberalization	All ecoregions of South Asia	NARS (public), private sector, IARCs
Sustainable seed and technology systems	All ecoregions of South Asia	NARS (public and private), IARCs
Risk management	Hot Arid; Semi-Arid; High Rainfall Humid; Humid Coastal	NARS (public), IARCs

(i) Assessment of poverty in the region is a matter of concern for all. Intensive efforts to study the poverty, its mapping and assessment of nature of interventions and investment priorities are to be made.

(ii) The management and sustainable use of natural resources (biodiversity, land and water) is another important priority area for all the agro-ecoregions. Efforts are needed to assess and map the nature and extent of degradation of these natural resources. The study of technological and institutional interventions for sustainable use of natural resources is also important. These research areas are of 'public good' nature and therefore public research organizations at the national and international levels may have to pool their resources and jointly make efforts to address these research issues.

(iii) The livestock, horticulture, fishery and forestry sectors, which have shown significant growth in the recent past, are yet to be developed fully. Concerted research efforts in these areas would diversify the sources of income and employment in the region, and can contribute to alleviation of poverty. It may be noted here that these sub-sectors are important in all the AERs, and therefore, a significant amount of economies of scale in research can be realized if attempted at global/ regional levels. Also, the private sector can be a useful ally in the R&D in these areas.

(iv) Studies on commercialization of agriculture and integration of markets would help the countries to compete in the world market.

(v) A good amount of efforts are needed to study the institutional arrangements for improving farmers' access to technologies, seeds, credit, market, etc. Also, there is a need to assess appropriate institutional arrangements for reducing the impact of risk. Involvement of private sector (profit as well as non-profit) for these purposes and its linkages with public organizations need to be considered under an institutional perspective.

Research strategy

The research strategy should focus on accelerating agricultural development through a proper mix of technology, organization and policy options. Efficient organization of production systems and needed substitution of knowledge for capital should be the governing forces. Given the intensity of agricultural research in South Asia, it is indispensable to organize research efforts efficiently and realize potential synergies through inter-institutional collaboration based on the principle of comparative advantages. This also implies fostering effective working linkages with private R&D organizations. The CGIAR accords high priority to South Asia and stresses on regional integration of research efforts through research collaboration. The CG Centres can act as facilitators, collaborators and promoters and can bring together NARSs for collaboration in research in strategic areas. There are a number of research networks like Cereals and Legumes Asia Network (CLAN), Network of Aquaculture Centers in Asia-Pacific (NACA), Tropical Asian Maize Network (TAMNET), Rice-Wheat Consortium, and Underutilized Tropical Fruits Asia Network (UTFANET), operating in the region. This approach needs to be strengthened and replicated. The NARS-NARS collaboration would be useful in a number of commodities like commercial and plantation crops, where international research efforts are negligible. The SAARC could also play an important role in this direction.

There is a need for change in research approach, particularly in the national research programs. The paradigm shift underscores interdisciplinary research in a system perspective. This may require change in research planning and implementation, as most of the research organizations in the NARSs are established, funded and managed on commodity/disciplinary basis. The research-extension-farmer linkages have been a perennial problem, in spite of introduction of several changes in the system. But these linkages are critical in research for management of natural resources. Fostering links with farmers is not only useful for articulating research needs, but also for assessment, refinement and transfer of technologies. Experiences gained from the farmers participatory plant breeding programs can be used to strengthen linkages with farmers. All such changes in research approach require greater inputs from social sciences, responsive research management and effective research evaluation mechanisms.

In terms of research methodology, there are some significant scientific advancements which need to be harnessed for greater effectiveness and efficiency of research systems. Application of the tools of molecular biology for control of yield losses due to biotic and abiotic stresses, reducing post-harvest losses, shortening R&D lag, maintaining animal health and improving product quality hold immense potential. Other promising advancements are: IPM, IPNM, ICM, watershed management and precision farming, which are in the early phases of their adoption. There is a need for tailoring these technologies to specific research target domains, as some of these technologies may involve commodity (in case of IPM and IPNM) or location (in watershed) specificity. Since these technologies are significantly different from the Green Revolution technologies (technologies embedded in seed, fertilizer and other inputs), institutional mechanisms for technology transfer need to be revamped. The dissemination of specialized information (such as soil fertility, resource management methods, etc.) should also be emphasized, besides transfer of technologies embedded in inputs and imparting skills. In this regard, application of information communication technology (ICT) assumes greater significance.

Engineering of NARSs including manpower planning, human resource development, decentralization and research¾extension¾farmer linkages, is central to improving research efficiency. Growth-oriented responsive management includes organization and management reforms relating to research infrastructure, research prioritization, monitoring and impact assessment, budgeting, resource generation, rationalization of investment pattern (allocation and expenditure components), manpower planning, career advancement, stakeholder management, service rules, administration, etc. International support for human resource development and infrastructure development is shrinking over time, and therefore, NARSs should allocate adequate resources for these critical activities.

7. SUMMING UP

This paper has examined the agro-ecoregion, commodity priorities in the South Asia. This is followed by a discussion on major production constraints and growth opportunities, which are subsequently used for identification of priority research themes for each of the agro-ecoregions. The results indicate the increasing importance of livestock and horticultural sector in the region, besides continuing emphasis on food crops—rice, wheat and pulses. Based on growth potential and likely impact of poverty, the humid ecoregion comprising eastern India and Bangladesh, should be accorded high priority. In terms of broad research themes, soil and water management, commercialization and diversification of production systems, market integration, livestock (including fisheries) health and nutrition, mapping of poverty, sustainable seed and technology systems are some of the high priority areas. These priority themes may also be of common interest to all the stakeholders (IARCs, NARSs, private sector, donors, etc). The NARSs can use these results for resource allocations. Similarly, IARCs and donors can use broad research areas for directing their resources and developing linkages with the NARSs. These priority areas could also be used to assess adequacy of research investments, needs for human resource development, information communication initiatives, collaboration and policy support. Of course, some refinement or modification of these research priorities at the local levels may be required according to the needs and goals of the research system.

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Annexure 1. Commodity Priorities by country

Commodity group	Bangla-desh	Bhutan	India	Mal-dives	Nepal	Paki-stan	Sri Lanka	South Asia
Wheat	2.79	1.03	9.67	0.00	8.47	14.15	0.00	9.78
Rice	57.57	12.71	21.90	0.00	36.00	6.56	20.09	22.13
Barley	0.01	0.95	0.25	0.00	0.33	0.14	0.00	0.22
Maize	0.00	6.49	1.18	0.00	8.99	0.80	0.16	1.17
Millets	0.07	1.01	0.96	0.00	1.61	0.12	0.02	0.78
Sorghum	0.00	0.00	1.22	0.00	0.00	0.18	0.00	0.95
Potato	1.56	4.24	2.06	0.00	4.92	0.61	0.15	1.85
Sweet potatoes	0.47	0.00	0.12	0.00	0.00	0.01	0.24	0.13
Cassava	0.00	0.00	0.53	0.00	0.00	0.00	1.05	0.42
Beans	0.35	0.00	1.39	0.00	0.49	0.23	0.24	1.12
Dry peas	0.06	0.00	0.25	0.00	0.00	0.16	0.00	0.21
Chickpeas	0.24	0.00	2.11	0.00	0.27	1.35	0.00	1.83
Lentil	0.70	0.00	0.33	0.00	2.56	0.08	0.00	0.35
Other pulses	0.68	0.00	1.04	0.00	0.00	0.35	0.00	0.89
Soybean	0.00	0.15	0.61	0.00	0.09	0.01	0.00	0.47
Groundnut in shell	0.12	0.00	2.02	0.00	0.00	0.16	0.07	1.57
Castor beans	0.00	0.00	0.23	0.00	0.00	0.01	0.00	0.18
Sunflower seed	0.00	0.00	0.42	0.00	0.00	0.23	0.00	0.36
Rapeseed	0.81	0.00	1.64	0.00	0.00	0.46	0.00	1.37
Sesame seed	0.25	0.00	0.29	0.00	0.00	0.10	0.13	0.25
Linseed	0.12	0.00	0.06	0.00	0.29	0.01	0.00	0.06
Safflower seed	0.00	0.00	0.15	0.00	0.00	0.00	0.00	0.12
Copra	0.08	0.00	0.32	0.00	0.00	0.00	0.00	0.25
Cabbage	0.11	0.00	0.36	0.00	0.00	0.03	0.17	0.29
Tomatoes	0.13	0.00	0.65	0.00	0.00	0.22	0.19	0.54
Cauliflower	0.08	0.00	0.43	0.00	0.00	0.09	0.00	0.35
Pumpkins, squash, Gourds	0.25	0.00	0.39	0.00	0.00	0.16	0.92	0.35
Cucumbers and Gherkins	0.03	0.00	0.02	0.00	0.00	0.01	0.18	0.02
Eggplants	0.00	0.00	0.59	0.00	0.00	0.04	0.38	0.46
Green chillies and Peppers	0.00	8.46	0.03	0.00	0.00	0.00	1.91	0.05
Dry onions	0.25	0.00	0.75	0.00	0.00	1.00	0.42	0.74
Garlic	0.18	0.00	0.19	0.00	0.00	0.18	0.00	0.18
Green beans	0.05	0.00	0.04	0.00	0.00	0.01	0.12	0.03
Green peas	0.00	0.00	0.18	0.00	0.00	0.04	0.00	0.15
Carrots	0.00	0.00	0.12	0.00	0.00	0.39	0.40	0.15
Watermelons	0.00	0.00	0.02	0.00	0.00	0.17	0.00	0.04
Cantaloups & Oth melons	0.14	0.00	0.08	0.00	0.00	0.29	0.00	0.12
Other vegetables	0.00	0.00	2.24	0.00	0.00	0.00	0.00	1.71
Grapes	0.00	0.00	0.24	0.00	0.00	0.14	0.00	0.20
Raisins	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Apples	0.00	1.15	0.17	0.00	0.00	0.44	0.00	0.20
Pears	0.00	0.00	0.02	0.00	0.00	0.03	0.00	0.02
Peaches	0.00	0.00	0.01	0.00	0.00	0.03	0.00	0.01
Plums	0.00	0.00	0.01	0.00	0.00	0.06	0.00	0.01
Oranges	0.04	38.51	0.91	0.00	0.00	3.70	0.06	1.28

Annexure 1. Contd....

Commodity group	Bangla-desh	Bhutan	India	Mal-dives	Nepal	Paki-stan	Sri Lanka	South Asia
Tang.mand	0.00	0.00	0.00	0.00	0.00	0.45	0.00	0.07
Lemons and limes	0.02	0.00	0.15	0.00	0.00	0.07	0.13	0.12
Grapefruit and pomelos	0.02	0.00	0.01	0.00	0.00	0.00	0.00	0.01
Citrus fruit nes	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.01
Apricot	0.00	0.00	0.00	0.00	0.00	0.14	0.00	0.02
Mangoes	0.33	0.00	1.84	0.00	0.00	0.80	0.64	1.55
Pineapples	0.22	0.00	0.14	0.00	0.00	0.00	0.37	0.13
Banana	3.61	0.00	5.50	0.00	0.00	0.27	0.00	4.46
Plantains	0.00	0.00	0.00	0.00	0.00	0.00	13.44	0.11
Papayas	0.06	0.00	0.06	0.00	0.00	0.01	0.00	0.05
Strawberry	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Almonds	0.00	0.00	0.00	0.00	0.00	0.47	0.00	0.07
Pistachios	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cashewnuts	0.00	0.00	0.11	0.00	0.00	0.00	0.18	0.09
Walnuts	0.00	0.00	0.01	0.00	0.00	0.06	0.00	0.02
Dates	0.00	0.00	0.00	0.00	0.00	1.36	0.00	0.20
Other fruits	0.45	0.00	0.89	1.75	2.53	1.15	3.17	0.95
Seed cotton	0.36	0.00	3.49	0.00	0.00	12.62	0.00	4.55
Sugarcane	1.80	0.41	5.89	0.00	2.17	6.00	1.07	5.54
Sugarbeets	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00
Green coffee	0.00	0.00	0.52	0.00	0.00	0.00	1.06	0.41
Cocoa beans	0.00	0.00	0.01	0.00	0.00	0.00	0.27	0.01
Tea	1.56	0.00	2.12	0.00	0.44	0.00	33.23	1.98
Tobacco leaves	1.41	0.00	2.12	0.00	0.74	1.82	1.40	2.00
Jute & jute-like fibres	2.99	0.00	0.52	0.00	0.23	0.00	0.00	0.59
Natural rubber	0.03	0.00	0.43	0.00	0.00	0.00	3.55	0.36
Beef and veal	3.46	15.66	2.50	0.00	4.84	3.80	2.03	2.80
Buffalo meat	0.01	0.00	0.29	0.00	1.35	0.68	0.04	0.34
Mutton and lamb	0.09	0.00	0.58	0.00	0.44	4.31	0.00	1.09
Goat meat	3.64	0.00	1.18	0.00	5.19	7.62	0.23	2.36
Pigmeat	0.00	0.46	0.15	0.00	0.23	0.00	0.03	0.12
Poultry meat	1.86	0.00	0.76	0.00	0.93	3.34	3.76	1.24
Cow milk, whole fresh	1.13	5.48	4.35	0.00	2.33	3.40	1.27	3.94
Buffalo milk	0.03	0.57	4.83	0.00	5.30	11.81	0.41	5.53
Sheep milk	0.07	0.00	0.00	0.00	0.22	0.09	0.00	0.02
Goat milk	1.93	0.00	0.41	0.00	0.42	0.59	0.04	0.53
Hen eggs	0.50	0.00	0.55	0.00	0.39	0.53	0.74	0.55
Wool, greasy	0.03	0.00	0.12	0.00	0.15	0.84	0.00	0.22
Cattle & buffalo hides	0.61	2.48	1.61	0.00	3.55	1.39	0.39	1.54
Sheepskins	0.02	0.00	0.09	0.00	0.10	0.67	0.00	0.17
Goat skins	0.75	0.00	0.22	0.00	0.58	1.33	0.00	0.42
Inland fish	5.03	0.24	1.20	0.54	0.68	0.53	0.65	1.34
Marine fish	0.81	0.00	1.15	97.71	3.18	1.09	4.99	1.19
Total	100	100	100	100	100	100	100	100

Annexure II. Major production constraints and growth opportunities in various agro-ecoregions of South Asia

Agro-ecoregion	**Major production constraints**			**Opportunities**
	Natural resources-related	**Technical constraints**	**Socio-economic constraints**	
Production Systems	Coarse cereals-based; cotton-based; oilseed (groundnut and soybean)-based; rice and	Rice-wheat; cotton-wheat; sugarcane-wheat; maize-wheat;	***Unfavourable, rainfed, flooded:*** Rice-pulses/oilseeds/minor grains;	***Low (3000-5000 feet) and mid (5000-8000 feet) heights:***
Hot Arid Agro-ecoregion	Desert soil, soil erosion by wind, very low rainfall, frequent droughts, acute shortage of groundwater	Saline and alkaline soil in coastal areas, shortage of fodder	High risk, resource poor farmers	Arid horticulture, livestock
Semi-Arid Agro-ecoregion	Deterioration of soil and groundwater resources, erratic rainfall, soil erosion due to water	Biotic stresses, moisture stress, low to poor soil fertility, low yields, limited use of crop products	High risk, resource poor farmers, threats from opening of markets, declining consumption of coarse cereals, high incidence of poverty, weakening of traditional institutions for management of natural resources	Diversification towards high value crops, scope for rainwater water harvesting and use
Sub-Humid to Cold Arid Mountain Agro-ecoregion	Diverse production environments, highly fragmented small holdings	High post-harvest losses, root stock susceptible to biotic and abiotic stresses	Resource poor farmers, poor infrastructure and institutional development, high incidence of poverty, labor migration	Rich biodiversity, value addition through processing, Horiculture and off-season vegetables, ecoturism
Irrigated Sub-Humid Agro-ecoregion	Deteriorating soil and water resources, salinity and water logging	Stagnant crop yields, late planting of crops, pest buildup, inefficiency in input/resource use, nutrient depletion, poor plant stand, low productive efficiency in livestock	Shortage of labour, high population pressure, unstable prices of commercial crops, deceleration in total factor productivity	Favorable production environment, developed infrastructure and institutions
High Rainfall Humid Agro-ecoregion	Adverse soils, soil erosion by water, submergence, drought and flood prone, Diverse production environment, Soil Salinity, arsenic contaminated groundwater	High incidence of biotic stresses, low soil fertility, and nutrient deficiency high mortality in livestock	High risk, low input use, poor infrastructure and institutional development, high incidence of poverty, low non-farm employment opportunities	High rainfall, scope for diversification, *boro* rice, rich biodiversity, inland aquaculture
Sub-Humid to Humid Coastal Agro-ecoregion	Deterioration of land and water resources, soil salinity, frequent cyclones	Low soil fertility, diseases in inland fisheries, biotic stresses	High risk, competitive export market of plantation crops	Expansion of inland aquaculture

Source: Compiled from various published and other sources.

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NATIONAL CENTRE FOR AGRICULTURAL ECONOMICS AND POLICY RESEARCH
(Indian Council of Agricultural Research)
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