Agricultural Research Prioritization

for South and West Asia

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Contents

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Acronyms and Abbreviations

AESs	Agro-ecosystems
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-ecosystem)
HRH	High Rainfall Humid (agro-ecosystem)
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-ecosystem)
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-ecosystem)
SCAM	Sub-Humid to Cold Arid Mountains (agro-ecosystem)
SHC	Sub-Humid to Humid Coasts (agro-ecosystem)
TAMNET	Tropical Asian Maize Network
TFP	Total factor productivity
UTFANET	Underutilized Tropical Fruits Asia Network
VOP	Value of production

Introduction

Asia region still accounts for nearly two-thirds of the chronically undernourished in the world. South Asia alone is home to about one-third malnourished persons in the world; about one out of every five persons in the region is chronically undernourished. Underweight children below 5 years old, expressed as a proportion of this age group, is as high as 67 percent for Bangladesh, 53 percent for India, and about 38 percent each for Pakistan and Sri Lanka. The FAO estimates indicate that, by 2010, Asia will still account for about one-half of the world's malnourished population, of which two-thirds will be from South Asia.

The main source of poverty in developing Asian countries remains the rural sector. Nearly three-fourths of the poor in these countries have their origin from rural areas and depend on agriculture for food, employment and income. The landless farm workers account for about 40 percent of rural poverty in Bangladesh, and 45 percent in India. The rest are small and marginal cultivators and tenants. Agricultural and rural development is seen as central to a strategy aimed at alleviating poverty and food insecurity, apart from serving to fuel industrialization. The past three decades of agricultural growth clearly supports this view.

However, recurring issues on population and problems with demographic transition and natural resource degradation and management appear to be more pressing now than ever before. New challenges are likewise emerging from global developments in trade. Because these have important implications for agricultural development and household food security in the region, it is crucial that they get 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 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 R&D have to be sustained. New developments in biotechnology and information technology offer higher potential. Public research investments should be more focussed in areas that would not be privately funded and that offer convincing expectations of a positive social payoff. Besides focusing research investments in high potential irrigated areas, giving importance to rainfed areas and fragile agro-ecosystems also assume critical significance.

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 relevant 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 part could be of use to other parts. Further, in South Asia, 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 reinvent the wheel.

Socio-economic profile of the countries

The South Asian countries include Bangladesh, Bhutan, India, Maldives, Nepal, Pakistan and Sri Lanka. These countries, in general, have common structures and socio-political institutions. There are marked similarities in their economic, agricultural and governance systems, as well as in their approach to education, health services and welfare activities. However, these countries differ considerably in terms of their size of population, geographical area and economy (Table 1). 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 live in rural areas and a vast majority of them are illiterate. Exports constitute about 11-22 percent of the 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 2.6 billion dollars 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 755 US dollars 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 (Table 1).

Most of the poor people live in South Asia. The estimate of poverty in the region during the early 1990s indicates that a large proportion of population is living below the poverty line (Table 2). 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. For instance, rural poverty in Nepal and Bangladesh was more than double of urban poverty. However, the urban-rural poverty difference was comparatively small in India[1]. The international poverty line (percent of population below 1 dollar a day) for the corresponding period indicates a high concentration of poverty in the region. The estimate 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 poverty level was 45.4 percent. Table 2 also indicates that a vast majority of children under age 5 is malnourished. The alleviation of poverty and malnutrition therefore will continue to be a major challenge in South Asia.

Economic situation in the West Asia is comparatively better than the South Asia. For example, in Iran, real per capita GDP in 1999 (1993 international dollars) was 5163 and external debt as percentage of GDP was only 12 percent. The population density and the proportion of illiterate people are also low (Table 1).

The foregoing discussion indicates that though the countries in the South Asia region have done reasonably well in general, their progress is quite slow in alleviating poverty. This concern coupled with acceleration of agricultural growth for higher income and food and nutrition security and sustainable management and use of natural resources will continue to influence investment priorities in the region. This paper examines the main development challenges in the region in general and those related with agricultural development in particular. The paper also outlines the role of agricultural research in meeting these

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

challenges. The paper is organised as follows. Next section discusses in brief the agricultural development scenario, followed by organization and intensity of agricultural research in the region. The subsequent two sections deal with major agro-ecosystems in the region and commodity priorities. This is followed by identification of major production constraints and growth opportunities in different agro-ecosystems. Finally, the paper concludes with some observations about research strategies for addressing the identified research priorities.

Agricultural Development Scenario

Small holders dominate the agriculture in South Asia. There may be exceptions in some regions or sectors where large holdings dominate, e.g., large estate in plantation sector. Importance of agriculture, though central to economic development, is declining over time. Prime concern of all the countries in the region was to attain food self-sufficiency, and a number of agricultural development programmes were initiated to achieve this objective. All the countries introduced land reforms such as redistribution of surplus land, ceiling on holdings, protection of tenants, consolidation of holdings, etc. to accelerate the growth in agriculture. The performance was, however, variable, and the impact was limited by lack of supportive systems like input supply, credit, markets, etc. It is now widely known that because of lack of these supportive systems the growth process bypassed resource-poor farmers and regions. For instance, rice productivity in eastern India is still far below than that in north-west India, owing to differences in supportive institutions.

The most important sources of growth in agriculture are non-price factors. Public investments in surface irrigation and development and dissemination of improved technologies contributed largely to the growth in agriculture sector, ushering the Green Revolution in the region. HYV technology along with assured supply of fertilizers and water really shifted the production frontier during the 1960s and 1970s. Increase in the productivity because of improved technologies and massive public investment in rural infrastructure, including, irrigation, encouraged private investment in agriculture. In addition, price incentives in the form of subsidized inputs and remunerative output prices also attracted private investment in agriculture.

More recently, macro economic reforms introduced in some countries like India during 1990s have further accelerated agricultural growth. On the one hand, these reforms encouraged private investment (both domestic and foreign) in infrastructure and supportive system for the provision of inputs (like seed) and other services. On the other hand, the reform process improved 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 will create conducive environment for input and knowledge-intensive agriculture.

Resource use, productivity and availability of foodgrains

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. As shown in Table 4, the production of cereals 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. As noted earlier, 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 total 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.

Another significant achievement on food security front is stabilization of production and prices of food grains in the region. It is widely documented that year-to-year fluctuations in foodgrain production have 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 has significant implications for food security of the region. In spite of floods, droughts and cyclones, there were few instances of starvation, large imports or food aids. This coupled with better management of food stocks and integration of domestic markets assured availability of food. Foodgrain prices deccreased in real terms as well as remained much more stable than the world prices.

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 of the region, 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 increasing productivity in the region (Table 3).

West Asia also has more or less similar agricultural development scenario, except that it is favourably placed in respect of population pressure. Rice yield is comparable with that in South Asia, but wheat yield is slightly lower. In this region agriculture is dominated by livestock, wheat and horticultural crops. The per capita production of foodgrains, which was increasing steadily until 1980s, has decreased slightly in 1990s. On the contrary, per capita milk production increased to 82 kg in 1999 after stagnating at 72 kg during 1961-1990.

Trend in demand for food

There are two major changes in the demand for food products. First, there is noticeable decline in per capita consumption of cereals, particularly coarse cereals, because of increase in real income caused by decrease in real prices of foodgrains. Second, consumption pattern has become more diversified because of increase in demand for high vale products like fruits, vegetables, milk and meat (Paroda and Kumar 2000). These changes have important implications for food and nutritional security. We have to not only produce additional food but also diversify food products with higher nutrition value.

Second concern of food security is that the demand for food will increase because of increase in population, income of poor people and feed demand. It is estimated that the demand for foodgrains in South Asia will increase to about 360 million tonnes in 2030, assuming a moderate to high rate of growth in income (3.5 to 5.5 percent). Depending upon the growth in income, the demand for milk will be in the range of 192-232 million tonnes and 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 in order to meet this increase in demand, yields of foodgrains should be increased by 50 percent by 2030. The required increase in yields of other high value commodities and livestock will be in the rage of 100-200 percent depending upon the growth in income (Fig. 1). 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 are studied and explained by a number of researchers in various ways. A widely accepted measure is 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 developed 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 relating to sustainable use of natural resources. It is increasingly felt that natural resources—land and water, are depleting fast. Land degradation due to salinity, alkalinity, water-logging, overgrazing and water and wind erosion is unabated and widespread. Intensification of land use, imbalanced used of NPK, less application of organic manure, and adverse effect of pesticides on microbial activities in soil, are fast eroding productive capacity of land. These issues need to be addressed, whilst promoting productivity of agriculture systems.

Several studies have pointed out sustainability implications of groundwater resources which are dwindling rapidly in South Asia. In a recent study, Seckler (1998) examined current use and future requirement of groundwater resources (Table 6). It is indicated that most of groundwater is used for irrigation purposes, and irrigation effectiveness is less than 50 percent in South Asia. Further, with current level of irrigation effectiveness, withdrawals of groundwater will increase by 67 percent in India and 134 percent in Pakistan in 2025. The withdrawal level can be reduced to 15 and 91 percent, respectively, if irrigation effectiveness is increased to 70 percent. With such a marked increase in irrigation effectiveness, India and Pakistan are expected to withdraw 29 and 71 percent of their groundwater resources in 2025 respectively. It is important to note that these are average figures for these two countries and situation of groundwater use is alarming even today in semi-arid and arid regions. The situation is equally alarming in the west Asia region. For example, Iran is expected to use 93 percent of her water resources in 2025 with an irrigation effectiveness of 70 percent, which is 5 percent higher than the existing level.

Agricultural development issues

Based on the foregoing discussion, the following development issues can be identified for the region:

Efficient growth: Acceleration of growth in agriculture will continue to be pressing need of the region. It is not only essential to accelerate 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. Efficient growth is required for making agriculture competitive in the wake of liberalization of trade regime. Also, the growth should be diversified in terms of products and regional base.

Poverty alleviation: It is now widely accepted that the growth in agriculture, led by technological developments, made significant impact on rural poverty. Given the level of absolute poverty, need for accelerating agricultural growth will always be there. The growth should be equitable in terms of crops/commodities, regions and class of producers.

Sustainability: The concerns relating to sustainability of agricultural systems are becoming increasingly important, which primarily deals with inter-generational equity. It is necessary that productivity level should be enhanced and sustained over time. At the same time, natural resources and environment should be protected for their sustainable use by future generations. Given the widespread degradation of land, water, and genetic and other environmental resources, sustainability of agricultural system will be central to all development programmes 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 will be expected to contribute to these development objectives in South Asia[2]. In West Asia, however, focus will be more on sustainable use of natural resources, besides agricultural growth.

As we entered into 21st century, we are dealing with a knowledge society. Science 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 alleviating rural poverty. Many of the rural poor depend on agriculture for employment and income.

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

Accelerated agricultural growth offers a potential source of poverty reduction. Agricultural research should therefore play a central role in this task.

Agricultural Research

Intensity and organization of research efforts

The intensity of agricultural research effort, measured as number of scientists with at least master degree or research expenditure as percentage of AgGDP varied considerably. The Indian agricultural research system is the largest employing about twenty-two thousand scientists (Box 1) and spending slightly less than 0.5 percent of AgGDP on agricultural research[3]. The intensity of research efforts is further low in other countries, spending less than 0.3 percent of AgGDP on agricultural research. This is much smaller than what is spent by all the developing countries (0.5 percent) and certainly much smaller than that spent by the developed countries (2.5 percent). Unlike the developed countries, most of agricultural research in this region is conducted by public research organizations.

The organization of agricultural research is quite similar in all the South Asian Countries. There are central as well as provincial research organizations, particularly in 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 front-line extension. The Indian Council of Agricultural Research (ICAR) is the largest and eldest organization in the region.

Major research … ve successfully
addressed researc… e beginning the
main concern of … objectives have
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production syster… c. In terms of
commodity cove… n to livestock,
horticulture, fishe… observed in the
disciplines of agri… iotechnology.

Box 1. Number of scientists in public agricultural research organizations

Country	Number of scientists
South Asia	
Bangladesh	2224
India	22,249
Nepal	236
Pakistan	3461
Sri Lanka	484
West Asia	
Iran	2997

Note: Data provided by research council of respective countries and include scientists with master degree or above.

[3] Personal Communication

Need for research prioritization

The need for prioritization of agricultural research arises because of three reasons. First, there is considerable expansion of research objectives, institutions, research programmes, etc. which may be rather difficult to comprehend for allocation of research resources. This requires a formal and systematic approach for research prioritization, so that cost and benefits of alternative research activities are clearly assessed in terms of attainment of research objectives. Secondly, the intensity of efforts is very low and therefore it is essential to use available resources judiciously for maximizing research benefits. It is also often mentioned that research systems in developing countries are effective but not efficient. Research prioritization also help improve research efficiency. Lastly, international donors can easily support research programmes if these are identified in a consultative bottom up approach. Keeping this objective in view, subsequent part of this paper is developed.

Agro-ecosystems for Research Planning

Delineation and Characterization

South Asia: Agro-ecoregional basis of research planning is getting increasing acceptance all over the globe, as it helps target research efforts and achieve 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[4]. A number of studies have identified agro-ecosystems (AESs) in the south Asia region (Sehgal et al., 1992; ICRISAT, 1999). More recently, ICAR, PARC and NARC have identified major AESs for their respective countries for better identification of research investment priorities (PARC (not dated); Saxena et al., 2001; D. Joshy (NARC)[5]). 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) for identification of research priorities (Lenne, 2001). We used this information and our own judgement to identify and characterize major AESs in South Asia. The identified AESs are: (i) Hot Arid (HA); (ii) Semi-Arid Tropics and Sub-Tropics (SAT); (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). Regional spread, soil type, climate, major cropping systems and economic significance of these AESs are given in Table 7.

[4] The terms of agro-ecoregion and agro-ecosystem are used interchangeably in this paper.
[5] Personal communication.

Geographical spread of these AESs is shown in Map 1[6]. All these AESs are fairly uniform, except the rainfed humid and mountains where there is some variability in climate, soil type and irrigated area. The Semi-Arid, High Rainfall Humid, and Irrigated Sub-Humid AESs 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 output. It may be noted here that the High Rainfall Humid AES largely practicing rice-based production systems, 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 the cropping systems of rice-wheat, cotton-wheat and sugarcane-wheat. Both canal and tubewell irrigation are intensively used, along with other factors of production like fertilizers. Livestock is important in all the systems, but horticultural crops are widely grown in the SAT and the Coastal systems. Another important characteristic is that except Arid and part of the Irrigated systems, all the systems receive significant amount of precipitation which can be conserved and used for agriculture. The estimates of poverty by agro-ecosystem are not readily available, but considering the administrative regions covered under various agro-ecosystems it can easily be seen that most of the poor people are concentrated in the High Rainfall Humid, SAT and Mountain agro-ecosystems. These systems are also characterized by low productivity and vulnerability of natural resources for degradation. These considerations may influence research priorities to a large extent.

[6] Thanks are due to U.K. Deb (ICRISAT) for help in producing the map.

West Asia: The paucity of data does not permit for a precise delineation and characterization of agro-ecosystems in West Asia. However, it can be generalized that a large part of the region falls under arid and semi-arid conditions. Owing to variations in altitude, rainfall, temperature and irrigation conditions, the region can be classified into irrigated, dryland, rangeland and desert agro-ecosystems. The irrigated and dryland systems cover only a small proportion of the area, but contribute significantly to the total agricultural production. For example, in Iran, irrigated system covers only 7.8 million ha area, as against 10.7 million ha under dryland and 90 million ha under pastures or rangelands. But most of the production of cereals, commercial crops and horticultural crops is contributed by the irrigated system. Rangelands largely support livestock of nomads and rural people (Keshavarz, 2001).

Regional and Commodity Priorities

Methodology and data

Studies on research priority setting have used five approaches, singly, or in combination. These are congruence (weighted criteria) approach, 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 influenced by the level of priority setting (macro or micro) and availability of data, analytical skills and resources. We have applied the modified congruence approach because of its ease of application in the situation of time and data constraints. Stated simply, 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 value of new knowledge generated by research is proportional to the value of output. The analysis is based on 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.

The identification of priorities by commodities and regions involves calculation of an initial baseline matrix consisting of value of output from different commodities in different regions. A composite baseline is then developed using value of output (efficiency), number of poor people (equity), 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 by using intensity parameters, viz. growth in AgGDP, per capita income, extent of groundwater withdrawals and number of scientists in the national system (for detailed methodology, see Jha et al. op cit. and CGIAR op cit.). Since data for these modifiers by agro-ecosystems are not available, research prioritization between agro-ecosystems was done using extensity parameters only. We have used our judgement to identify and specify the parameters for prioritization and weighting schemes, on the basis of information provided by the NARSs. The value of production was computed using international prices adjusted for transportation costs. Transportation cost was added to the p ... xportable hypothesis. Si ... was not considered. Fo ... roducing country(ies) w ... ge rates reported by the ... ise were taken from FA ... analysis is based on the triennium average.

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
Equity	Number of poor	Per capita income

Agro-ecosystem and commodity priorities

The modified congruence approach gives commodity by agro-ecosystem priority matrix. This priority matrix can be used to arrive at different priority dimensions, such as AESs priorities (sum over commodities by AES), commodity priorities (sum over AESs by commodity) or commodity group priorities for the region (sum over commodities and AESs). In this exercise, AES priorities and commodity priorities within and across AES are discussed. For the benefit of national programs, commodity priorities by countries are also presented. Priority score is the share of a commodity/group or AES/country in 100 (percent), and therefore, a higher score indicates high priority. The national systems can use the priority matrix for allocation of resources across commodities or AESs. Donors can also use the priority matrix to track priority AES and commodities or *vice versa*. Since identification of research priorities is the major objective of this exercise, we shall focus on AES and commodity priorities.

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

Fig. 3 shows the AES priorities in South Asia. As noted earlier, the ISH, SAT and HRH are the three top priority AESs in South Asia. Efficiency objective can be better addressed on focusing on ISH and HRH, but for poverty alleviation HRH and SAT are more important. Sustainability issues are equally important in these AESs, 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 AESs, 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 (Tables 8 and 9) are cereals, livestock, horticultural crops and plantation crops in that order. Cereals are more important in all the AES, but their priority score is 41 and 51 in the ISH and HRH AES, respectively. Livestock is important in all the AESs, 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 SAT, ISH and SHC systems, respectively. These priority scores are obtained using importable hypothesis for foodgrains, cotton and sugar, as these are not regularly exported from South Asia. For the commodities with 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 of both the scenarios (Fig. 4) show only marginal change 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; Paroda and Kumar, 2000), we subsequently discuss results of the importable hypothesis for these commodities.

Priority scores of individual commodities as given by the modified congruence approach were used to classify commodities into high, medium and low priority commodities separately for each of the AESs (Table 10). Commodities not covered in this table are of very low priority (score less than 2). As seen from Table 10, except the HA, rice is a high priority commodity in all the AESs, 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 in the HA and SAT, whereas milch animals are of high priority in all the AESs, except the SHC. Except banana in the SAT and SHC, all fruits, in general, are of low priority in all the AESs.

Table 11 gives commodity priorities for West Asia, which are similar to those obtained for the HA system of South Asia. Livestock ranked first with a priority score of 51, followed by cereals (19), fruits (13) and vegetables (12). Among individual commodities, priority commodities are wheat, barley, tomato, grapes, poultry, small ruminants and cow milk. Besides these commodities, orange, pistachio, rice and dates are also priority commodities for Iran perhaps because of diversity of production systems and availability of irrigation in some parts. Orange is a priority commodity for Iran, Iraq and Syria. Cotton is widely grown in Syria and therefore gets high priority score (14).

Futuristic Considerations: Sensitivity Analysis

The modified congruence analysis, which assumes constancy of relative shares of commodities or agro-ecosystems, 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 trade opportunities and challenges. But consideration of these changes requires additional data and analysis. We have considered the growth opportunities by modification of baseline priorities with the growth in AgGDP. A similar modification of the baseline with number of agricultural scientists is also attempted to capture research capability of the NARSs[8]. However, major changes are expected to arise because of trade liberalization; these could be income and price effects 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 result 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 are 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.

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

Empirical studies indicate 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 effect prices and output of commodities and therefore this can be best captured by modification of the value of production (VOP). The VOP of a commodity was adjusted with the expected growth in its demand in the region (Fig. 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[9]. 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 is a noticeable increase in priority score of horticultural and livestock commodities, whereas cereals registered a significant decline in their priority score in South Asia[10]. 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 judgement is required to capture other external factors and opportunities (including chances of research success) in setting research priorities.

Production Constraints and Growth Opportunities[11]

Production constraints

Having identified the AES and commodity priorities, 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 growth opportunities. The survey of available studies on the topic gives a fairly good understanding of generic production constraints in the various AESs (Table 13). These production constraints are classified into three categories: (a) natural resource-related constraints, (b) other technical constraints, and (c) socio-economic constraints (Annex). Absence of detailed data does not permit us to analyse relative importance of these three types of constraints, but

[9] $Y_0 (1+r)^t$ where Y_0 is VOP in the base year, r is expected growth in the demand and t is time period.
[10] Sensitivity analysis could not be done for West Asia because of non-availability of information on expected changes in the demand for agricultural commodities.
[11] This and the next section broadly summarize recommendations of the sub-groups formed during the meeting.

as felt by experts and others present in the meeting, these are causing significant production losses. For example, abiotic stresses like drought and submergence caused significant production losses in rice in eastern India (Evenson et al., 1996). Production losses due to socio-economic constraints are also significant but difficult to estimate. Proper definition of these constraints, strategy for addressing them successfully through harnessing opportunities and expected net benefits should guide further prioritization of research programs in the AESs of different NARSs.

Growth opportunities

Assessment of growth opportunities through application of science is a difficult task, but some judgement can be made using demand side considerations and scientific opportunities (Table 13). Focus on value addition through agro-processing has not received due attention in South Asia. Given the extent of post-harvest losses of fruits and vegetables and other perishables, the scope for value addition, income and employment generation and poverty alleviation would be substantial. However, this requires close collaboration with private sector, investment in infrastructure and an understanding of consumer preferences. Similarly, forestry and agro-forestry offers immense possibilities for growth with sustainable development. On account of paucity of information, it was difficult to make detailed analysis and articulate opportunities in this area in this document. Another growth opportunity could be management of rainwater in water deficit areas such as SAT and HA. There is a need for further refinement and management of technologies for harvesting and use of water. These technologies require group or community action and therefore better understanding of community action will facilitate rapid adoption of these technologies. Advances in molecular biology and biotechnology can help in identification and utilization of tolerance to various abiotic and biotic stresses, besides improvements in shelf life and quality of products. Biotechnology can also play a significant role in organic farming. Also, with application of these tools it is possible to reduce research and technology development lag in the development of improved varieties and breeds, as well as to increase chances of research success. However, utilization of these frontier sciences and information intensive technologies needs higher capital investment, inter-institutional linkages, effective regulatory mechanism and delivery system. Diversification of systems through livestock, fishery, bee keeping and horticulture, ably integrated with marketing system will offer uncommon opportunities in the region.

Research Priorities and Strategies

At this stage, no formal research prioritization technique was applied to identify the system-specific research priorities. The priorities are consensus judgements of the expert groups. The groups have, however, used systematic process and objective criteria to arrive at these priorities. Root cause analysis was done for major production constraints and emerging research issues were examined along with research gaps and opportunities. The emerging issues were further subjected to their likely impact on improving efficiency and sustainability of production systems and alleviating food insecurity and poverty. In addition, issues of comparative advantage of the region and chances of research success were also considered to arrive at the priority research themes for various AESs.

The identified priorities for various agro-ecosystems in South and West Asia are given in Table 14. These are very broad and depending upon the specific requirement, one may further rework on these priorities and develop executable and locally relevant research programmes. In other words, donors may find these generic priority areas adequate to channel research grants, but individual organizations of the NARSs in the region may further finetune them for developing their own focussed research agenda. It is clear from these priorities that research agenda is much more complex and broadened now. Conservation of natural resources (land water and germplasm) is extremely important and the priority AESs are SAT, HA and ISH. Research issues relating to the rice-based production systems in the HRH region assumes high priority because of its 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 AESs.

Box 3 summarizes the overarching priorities common to all the stakeholders. The broader priorities 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 (biodiversity, land and water) is another important priority area for all the agro-ecosystems. 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 AESs, and therefore, a significant amount of economies of scale in research can be realized. Moreover, 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 marke ... gements for impro ... s a need for assess ... nvolvement of pri ... with public organi ...

Box 3. Areas of common interest and partnership

Research area	Priority agro-ecosystem	Partnership
Poverty mapping and investment priorities	Semi-Arid Tropics; High Rainfall Humid; Sub-Humid to Cold Arid Mountains	NARS (Public), IARCs
Soil and water management	All Agro-ecosystems	NARS (Public and non-profit private), IARCs
System Diversification	Hot Arid, Semi-Arid Tropics	NARS (Public and private), IARCs
Commercialization and post-harvest processing	All Agro-ecosystems	NARS (Public and private), IARCs
Market integration and trade liberalization	All Agro-ecosystems	NARS (Public), private sector, IARCs
Sustainable seed and technology transfer systems	All Agro-ecosystems	NARS (Public and private), IARCs
Risk management	Hot Arid; Semi-Arid Tropics; High Rainfall Humid; Humid Coastal	NARS (Public), IARCs

Resea ... technology, organi ... emphasis. Given ... pensable to organ ... nstitutional collab ... g effective worki ... th Asia and stress ... p. 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 like Cereals and Legumes Asia Network (CLAN), Network of Aquaculture Centres in Asia-Pacific (NACA) and 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 useful in a number of commodities like commercial and plantation crops, where international research efforts are negligible.

There is also a need for change in research approach, particularly in 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 basis. Research-extension-farmer linkages have always been a problem, in spite of several changes introduced 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 farmer 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 significant scientific advancements which needs 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, animal health and improvement of product quality holds immense potential. Other promising advancements are IPM, IPNM, 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.

Engineering of NARSs including manpower planning, human resource development, decentralization and research-extension-farmer 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, investment pattern, staff planning, career advancement, stakeholder management, service rules, administration, etc. should be put in place. International support for human resource development and infrastructure development shrinking over time, and therefore, NARSs should allocate adequate resources for these critical activities.

Summing Up

This paper has examined the agro-ecosystem, production system and commodity priorities in South and West Asia. This is followed by a discussion on major production constraints and growth opportunities. These are subsequently used for identification of priority research areas for each of the agro-ecosystems. The results indicate 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 HRH system comprising eastern India and Bangladesh should get high priority. In terms of broad research themes, soil and water management, commercialization and diversification of production systems, market integration, mapping of poverty and degradation of natural resources and sustainable seed and technology systems are of high priority, as well as 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, partnership and enabling policy support. Of course, some refinement or modification of these research priorities may be required according to needs and goals of the research system.

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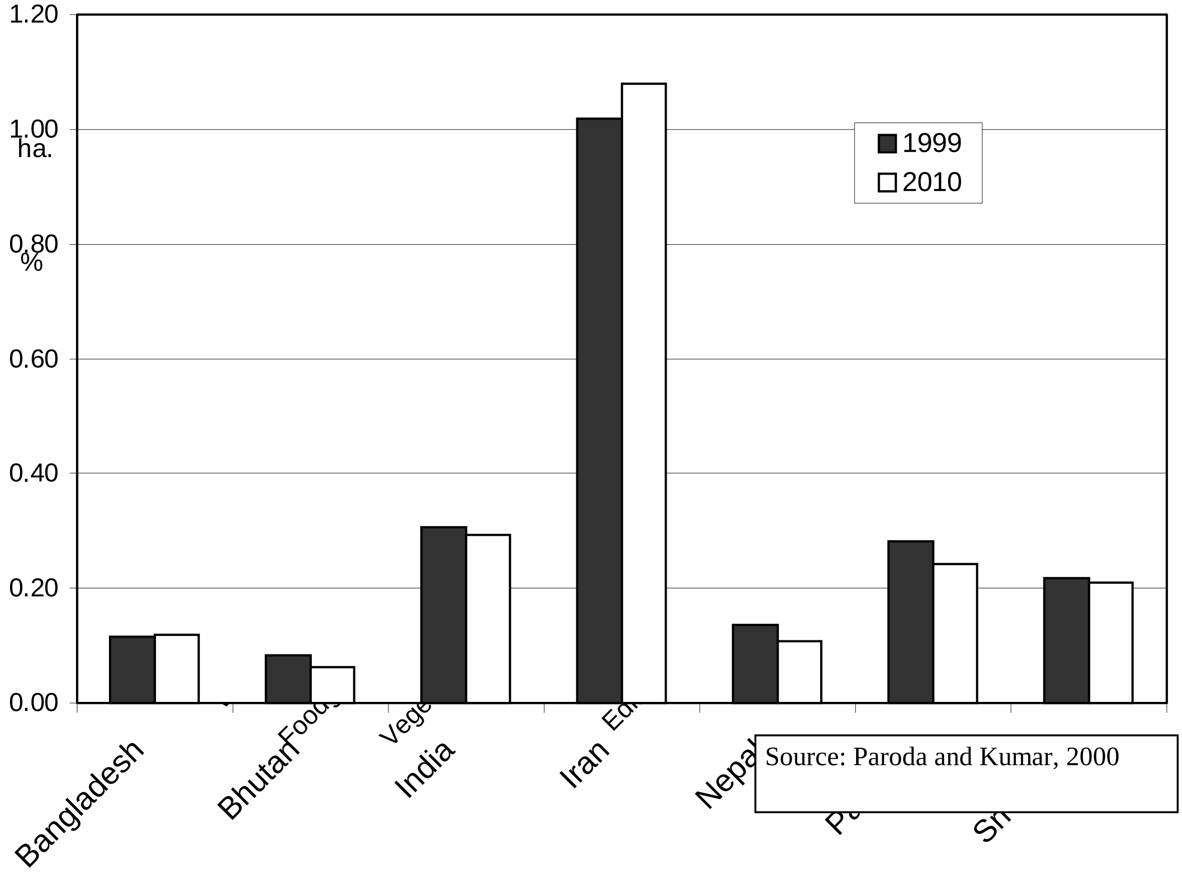
Fig. 1a: Required increase in yield to meet food demand in 2030 in south Asia



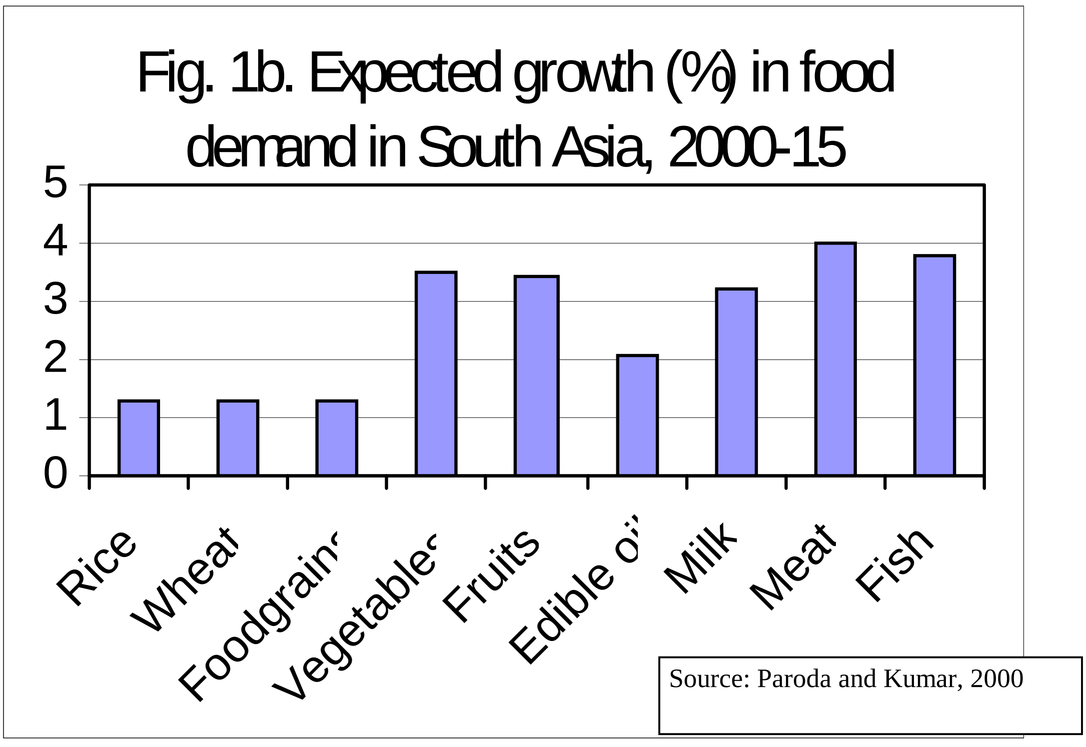


Figure 4.Commodity priority score in South Asia

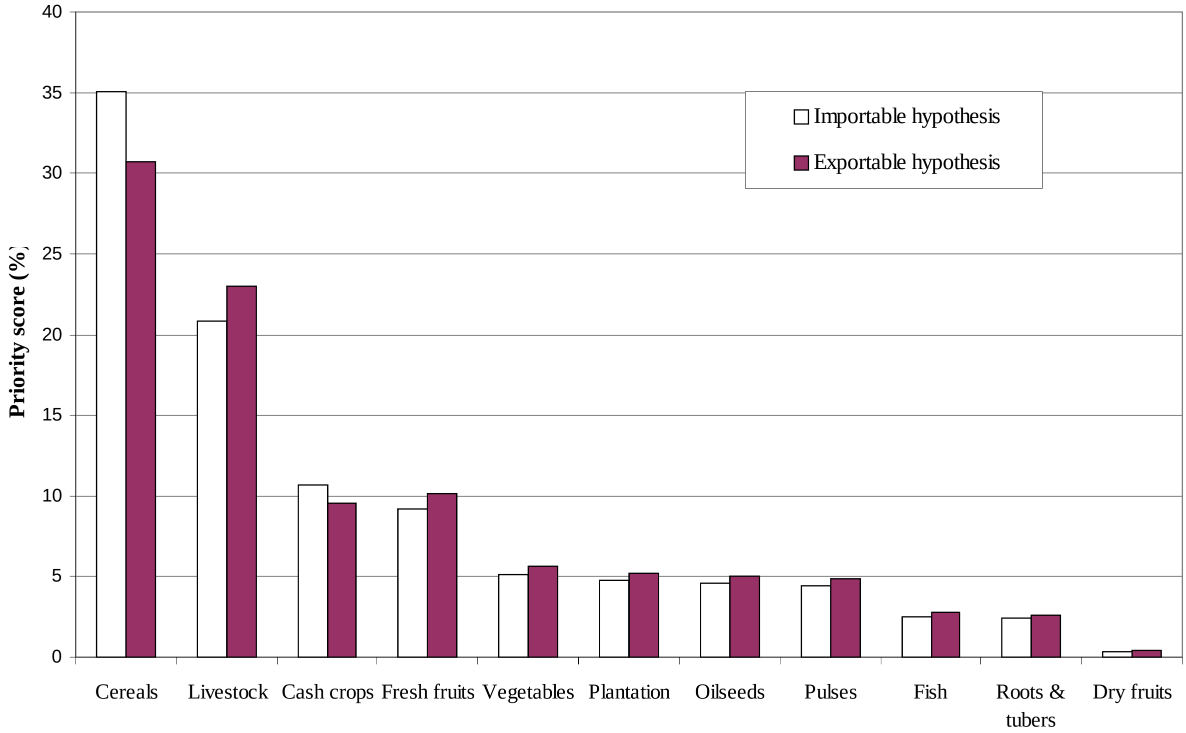


Fig. 3. Agro-ecosystem priorities in south Asia

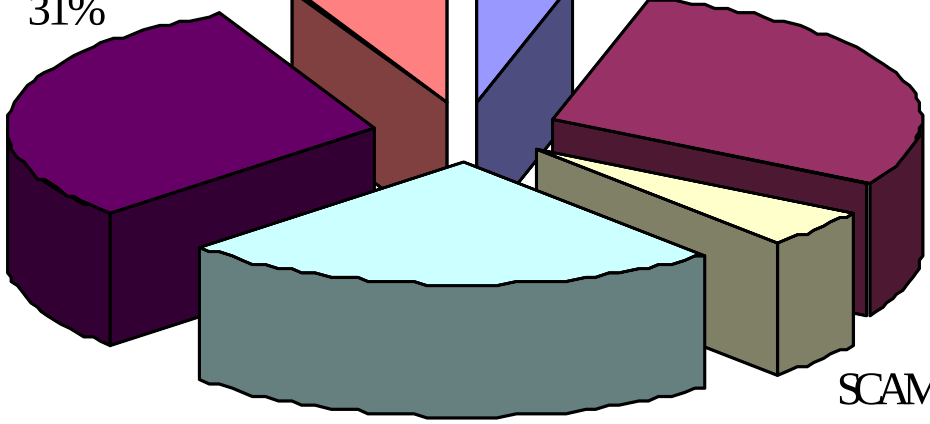


Table 1. Basic socio-economic indicators of south and west Asian countries

Indicator	Bangladesh	India	Nepal	Pakistan	Sri Lanka	Iran
Human development index[a] (1998)	0.461 (146)	0.563 (128)	0.474 (144)	0.522 (135)	0.733 (84)	0.709 (97)
Adult illiteracy rate (%, 1998)						
- Males	49	33	43	42	6	18
- Females	71	57	78	71	12	33
Population (million, 1999)	128	998	23	135	19	63
Population density (people/sq. km, 1999)	981	336	164	175	294	39
Urban population (%, 1999)	24	28	12	36	23	61
Gross national product (billion dollars, 1999)	47.0	442.2	5.1	64.0	15.7	110.5
Average annual GDP growth rate (%), 1990-99	4.8	6.1	4.8	4.0	5.3	3.4
Real per capita gross national product (1993 international dollars, 1999)	1,475	2,149	1,219	1,757	3,056	5,163
Exports of goods and services as percentage of GDP (1999)	14	11	22	15	36	14
Foreign direct investment (million dollars, 1998)	308	2,635	12	500	193	24
Share of agriculture in gross domestic product (%, 1999)	21	28	41	26	21	na
External debt as percentage of gross national product	22	20	31	41	41	12
Food production index (1989-91=100)						
- 1979-81	79.2	68.1	65.9	66.4	98.3	61.1
- 1996-98	110.8	119.9	117.2	136.2	109.1	144.7

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

Table 2. Incidence of poverty and malnutrition in south Asia

	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 age 5 (1992-98)	56	50	57	38	38

Source: World Bank (2001)

Table 3. Agricultural development indicators

Indicator		Bangladesh	India	Nepal	Pakistan	Sri Lanka	Iran
Percent of land area under permanent crops	1980 1997	2.0 2.5	1.8 2.7	0.2 0.5	0.4 0.7	15.9 15.8	0.5 1.0
Irrigated land as percentage of crop land	1979-81 1995-97	17.1 43.4	22.8 32.4	22.5 38.2	72.7 80.8	28.3 30.7	35.5 37.7
Per capita arable land (ha)	1979-81 1995-97	0.10 0.06	0.24 0.17	0.16 0.13	0.24 0.17	0.06 0.05	0.36 0.29
Tractors per thousand agricultural workers	1979-81 1995-97	0 0	2 6	0 0	5 13	4 2	17 40
Fertilizer consumption (kg/ha)*	1998	132	93	26	91	116	20
Agricultural productivity (value added per agricultural worker (1995 dollars)	1979-81 1996-98	212 276	275 406	162 189	394 626	649 726	2,570 4,089
Total cereal production (million tonnes)	1999	24.64	188	4.78	24.45	1.96	13.23
Total pulses production (thousand tonnes)	1999	513	13,550	214	1089	28	489
Total milk production (thousand tonnes)	1999	2,075	77,180	1,143	25,566	295	5,524
Paddy yield (tonne/ha)	1998	2.7	2.9	2.4	2.8	3.2	4.3
Wheat yield (tonne/ha)	1998	2.2	2.6	1.6	2.2	..	1.7

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

Table 4. Trends in foodgrain production and population in South Asia and West Asia (Iran)

		Bangladesh	Bhutan	India[a]	Nepal	Pakistan	Sri Lanka	South Asia	Iran
Total cereal production[c] (million tonnes)	1961	10.24	0.09	69[b]	2.30	6.44	0.70	89	3.8
	1970	11.48	0.11	97	2.24	10.91	1.07	119	5.65
	1980	15.13	0.14	119	3.19	15.45	1.50	149	8.57
	1990	19.17	0.10	162	2.84	19.39	1.76	202	12.35
	1999	24.64	0.14	188	4.78	24.45	1.96	245	13.23
Total pulses production (thousand tonnes)	1961	253	0.8	12,700 [b]	85	934	3.9	14977	160
	1970	351	1.3	11,820	111	780	5.4	13069	191
	1980	632	2.3	10,630	139	676	42	12121	225
	1990	512	1.6	14,260	168	1072	54	14077	355
	1999	513	1.6	13,550	214	1089	28	15396	489
Total milk production (thousand tonnes)	1961	915	18	20,375	546	5,998	104	27,957	1,581
	1970	1,065	22	20,800	625	7,445	141	30,098	2,000
	1980	1,162	28	31,560	747	9,014	243	42,753	2,800
	1990	1,593	31	63,678	922	14,723	252	71,200	3,900
	1999	2,075	32	77,180	1,143	25,566	295	106,291	5,525
Total population (million)	1961	53	0.9	452	9	51	10	577	22
	1970	67	1.1	555	11	66	12	712	28
	1980	88	1.3	689	14	85	15	893	39
	1990	109	1.7	851	19	119	17	1,117	56
	1999	127	2.1	998	23	152	19	1,321	67
Per capita production of foodgrains[c] (kg)	1961	198	98	181	265	145	70	179	180
	1970	177	106	196	214	177	89	186	209
	1980	179	110	188	238	190	103	180	225
	1990	181	57	207	159	172	107	195	2227
	1999	198	69	202	217	168	104	197	205

Per capita production of milk (kg)	1961	17	20	45	61	118	10	48	72
	1970	16	20	37	57	113	12	42	71
	1980	13	22	46	53	106	16	48	72
	1990	15	18	75	49	124	15	64	70
	1999	16	15	77	50	168	16	80	82

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

Table 5. Projection of food demand (million tonnes) in south Asia in 2030

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)

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

Country	Bangladesh	India	Nepal	Pakistan	Sri Lanka	Iran
Annual water resources 1990 (km^3)	2357.0	2,085	170.0	418.3	43.2	137.5
Total withdrawals 1990 (km^3)	23.8	518	2.9	155.7	8.7	64.3
Per capita withdrawals 1990						
- Domestic (m^3)	7	18	6	26	10	65
- Industry (m^3)	2	24	2	26	10	22
- Irrigation (m^3)	211	569	143	1226	483	1004
Irrigation effectiveness 1990 (%)	30	40	58	49	36	65
Percentage increase in the withdrawals in 2025 over 1990						
- with current level of irrigation effectiveness	89	67	122	134	51	112
- With 70% irrigation effectiveness	2	15	87	91	-4	100
2025 withdrawals (with 70% irrigation effectiveness) as percentage of annual water resources	1	29	3	71	19	93

Source: Seckler (1998)

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

Particular	Hot Arid Agro-ecosystem	Semi-Arid Tropical and Sub-Tropical Agro-ecosystem	Irrigated Sub-Humid Agro-ecosystem	High Rainfall Humid Agro-ecosystem	Sub-Humid to Humid Coastal Agro-ecosystem	Sub-Humid to Cold Arid Mountain Agro-ecosystem
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).

Table 8. Priority score of commodity groups in South Asia

	Bangladesh	Bhutan	India	Maldives	Nepal	Pakistan	Sri Lanka	South Asia
Cereals	60.4	22.2	35.2	0.0	55.4	21.9	20.3	35.04
	(11.1)	(0.1)	(76.4)	(0.0)	(2.7)	(9.3)	(0.5)	(100)
Roots &	2.0	4.2	2.7	0.0	4.9	0.6	1.4	2.39
tubers	(5.5)	(0.2)	(86.6)	(0.0)	(3.5)	(3.8)	(0.5)	(100)
Pulses	2.0	0.0	5.1	0.0	3.3	2.2	0.2	4.40
	(3.0)	(0.0)	(88.4)	(0.0)	(1.3)	(7.3)	(0.0)	(100)
Oilseeds	1.4	0.2	5.8	0.0	0.4	1.0	0.2	4.63
	(1.9)	(0.0)	(94.8)	(0.0)	(0.1)	(3.1)	(0.0)	(100)
Vegetables	1.2	8.5	6.1	0.0	0.0	2.6	4.7	5.15
	(1.5)	(0.2)	(90.0)	(0.0)	(0.0)	(7.6)	(0.7)	(100)
Fresh fruits	4.8	39.7	10.0	1.7	2.5	7.3	17.8	9.19
	(3.3)	(0.5)	(82.4)	(0.0)	(0.5)	(11.8)	(1.5)	(100)
Dry fruits	0.0	0.0	0.1	0.0	0.0	1.9	0.2	0.38
	(0.0)	(0.0)	(25.7)	(0.0)	(0.0)	(73.9)	(0.4)	(100)
Cash crops	5.1	0.4	9.9	0.0	2.4	18.7	1.1	10.68
	(3.1)	(0.0)	(70.5)	(0.0)	(0.4)	(25.9)	(0.1)	(100)
Livestock	14.1	24.7	17.6	0.0	26.0	40.4	8.9	20.86
	(4.4)	(0.1)	(64.3)	(0.0)	(2.1)	(28.7)	(0.3)	(100)
Plantation	3.0	0.0	5.2	0.0	1.2	1.8	39.5	4.75
	(4.1)	(0.0)	(83.3)	(0.0)	(0.4)	(5.7)	(6.5)	(100)
Fish	5.8	0.2	2.3	98.3	3.9	1.6	5.6	2.53
	(14.9)	(0.0)	(70.7)	(0.5)	(2.6)	(9.5)	(1.8)	(100)
All	100	100	100	100	100	100	100	100
commodities	(6.4)	(0.1)	(76.1)	(0.0)	(1.7)	(14.8)	(0.8)	(100)

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

Table 9. Priority score of commodities by agro-ecosystems in south Asia

Commodity group	Hot Arid Agro-ecosystem	Semi-Arid Tropical and Sub-Tropical Agro-ecosystem	Sub-Humid to Cold Arid Mountain Agro-ecosystem	Irrigated Sub-Humid Agro-ecosystem	High Rainfall Humid Agro-ecosystem	Sub-Humid to Humid Coastal Agro-ecosystem	South Asia
Cereals	18.3	20.0	24.6	41.1	50.7	25.9	35.05
	(1.52)	(14.52)	(4.29)	(33.52)	(38.52)	(7.64)	(100)
Roots & tubers	0.7	2.1	3.8	2.0	3.7	0.3	2.40
	(0.89)	(22.55)	(9.62)	(24.39)	(41.41)	(1.13)	(100)
Pulses	6.9	9.7	0.4	3.2	2.5	1.1	4.39
	(4.56)	(55.84)	(0.57)	(21.09)	(15.24)	(2.70)	(100)
Oilseeds	10.8	8.1	0.8	4.5	2.1	3.8	4.65
	(6.78)	(44.37)	(1.06)	(27.48)	(11.94	(8.37)	(100)
Vegetables	4.2	4.8	4.4	3.7	7.2	5.7	5.19
	(2.32)	(23.45)	(5.21)	(20.52)	(37.09)	(11.40)	(100)
Fresh fruits	5.8	14.9	8.9	5.7	5.3	17.1	9.29
	(1.82)	(40.65)	(5.87)	(17.48)	(15.16)	(19.02)	(100)
Dry fruits	6.3	0.0	1.3	0.0	0.0	0.9	0.36
	(51.71)	(0.00)	(22.97)	(0.04)	(0.00)	(25.27)	(100)
Cash crops	1.5	12.7	1.5	18.2	5.5	4.6	10.51
	(0.40)	(30.70	(0.85)	(49.50)	(14.04)	(4.51)	(100)
Livestock	40.7	21.7	29.2	19.3	19.5	12.0	20.44
	(5.78)	(26.99)	(8.73)	(27.02)	(25.39)	(6.09)	(100)
Plantation	0.4	4.3	24.2	1.2	1.1	18.4	5.11
	(0.24)	(21.28)	(28.96)	(6.73)	(5.49)	(37.30)	(100)
Fish	4.3	1.7	0.9	1.0	2.4	10.3	2.60
	(4.86)	(16.34)	(2.14)	(11.29)	(24.18)	(41.19)	(100)
	100	100	100	100	100	100	100

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

Table 10. Priority status of commodities by agro-ecosystem in south Asia

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

Table 11. Priority score of commodity groups in West Asia

Commodity group	Iran	Afghanistan	Iraq	Saudi Arabia	Syria	West Asia
Cereals	18.2 (13.7)	35.1 (11.0)	21.6 (4.3)	17.9 (66.5)	18.7 (4.5)	19.2 (100)
Roots & tubers	2.2 (20.5)	1.3 (4.9)	2.3 (5.6)	1.5 (66.5)	0.9 (2.6)	1.6 (100)
Pulses	1.4 (43.9)	0.7 (9.1)	0.8 (6.8)	0.1 (19.9)	2.1 (20.3)	0.5 (100)
Oilseeds	0.3 (16.3)	1.2 (25.8	1.9 (25.9)	0.1 (25.3)	0.4 (6.7)	0.3 (100)
Vegetables	8.4 (10.3)	2.8 (1.4)	23.0 (7.3)	13.0 (78.5)	6.3 (2.5)	11.8 (100)
Fresh fruits	20.2 (26.9)	9.9 (5.5)	23.6 (8.2)	8.2 (53.8)	13.2 (5.6)	10.8 (100)
Dry fruits	12.7 (80.0)	1.7 (4.6)	0.2 (0.3)	0.0 (0.0)	7.5 (15.1)	2.3 (100)
Cash crops	3.2 (35.1)	2.1 (9.6)	1.0 (3.0)	0.0 (0.0)	14.7 (52.2)	1.3 (100)
Livestock	30.4 (8.6)	45.1 (5.3)	24.0 (1.8)	58.0 (81.1)	34.1 (3.1)	50.8 (100)
Plantation	1.9 (71.4)	0.0 (0.0)	0.6 (5.9)	0.0 (0.0)	1.9 (22.7)	0.4 (100)
Fish	1.2 (15.9)	0.0 (0.2)	1.0 (3.5)	1.2 (79.5)	0.2 (0.9)	1.0 (100)
All commodities	100 (14.4)	100 (6.0)	100 (3.8)	100 (71.1)	100 (4.6)	100 (100)

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

Table 12. Sensitivity analysis of commodity priorities for South Asia

Commodity group	Base Scenario	Priorities with VOP adjusted with growth in the demand
Cereals	35.05	31.56
Roots & tubers	2.40	2.36
Pulses	4.39	4.25
Oilseeds	4.65	4.52
Vegetables	5.19	6.76
Fresh fruits	9.29	10.17
Dry fruits	0.36	0.41
Cash crops	10.51	10.08
Livestock	20.44	23.48
Plantation	5.11	4.60
Fish	2.60	2.91

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

	Hot Arid, SAT and West Asia Agro-ecosystems	Irrigated Sub-Humid Agro-ecosystem	High Rainfall Humid; and Sub-Humid to Humid Coastal Agro-ecosystems	Sub-Humid to Cold Arid Mountain Agro-ecosystem
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-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-ecosystem 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 altitude, slope, soil, 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

Table 14. Agricultural research priorities by agro-ecosystem in South and West Asia

Hot Arid; Semi-Arid Tropics; and West Asia Agro-ecosystems	High Rainfall Humid; and Sub-Humid to Humid Coastal Agro-ecosystems
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*** • Diversified agriculture (crop, livestock, fishery, horticulture, agro-forestry) • Higher value crops, e.g. • Post-harvest processing and value addition • Dual purpose crops (food & quality fodder, feed) • Rural enterprise development (vocational training) • Small scale mechanization • Solar and wind energy utilization ***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 • Identify new markets • Market intelligence and information • Risk management ***5. Low Productivity Needing Effective Technology Development and Dissemination*** • Seed and resource management technology delivery systems • Crop-tree-livestock options • Quality and value addition through genetic improvement • Biotechnology • 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 • 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 health care for more intensive culture of fish and crustaceans • Deepwater rice-fish/freshwater prawns • Integrated fish farming • Open water culture-based fishery ***Coastal aquaculture*** • Marine shrimp farming – 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 Tropics, and West Asia Agro-ecosystems are in order of their priority ranking.

Table 14. contd..

Irrigated Sub-Humid Agro-ecosystem	Sub-Humid to Cold Arid Mountain Agro-ecosystem

1. Water use efficiency
• Water user associations to foster
    • Equitable use within systems
    • Canal maintenance
    • Pricing
• Practices for plot level water use efficiency
    • Land level implements, training
    • Aerobic rice varieties for rice-wheat system
    • Alternative rice establishment practices
    • Wet-dry irrigation practices
    • Zero tillage in wheat
    • Drip irrigation, etc.
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 within 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
• High quality varieties
• Straw treatment and management
• Improved threshing implements
• Private investment in drying and storage
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
	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
	• Empowerment of women, 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.

Annex. Major production constraints and growth opportunities in various agro-ecosystems

Agro-ecosystem	**Major production constraints**			**Opportunities**
	Natural resources-related	***Technical constraints***	***Socio-economic constraints***	
South Asia				
Hot Arid Agro-ecosystem	Desert soil, soil erosion by wind, very low rainfall, frequent droughts, acute shortage of groundwater	Saline and alkaline soil in coastal area, shortage of fodder	High risk, resource poor farmers	Arid horticulture, livestock
Semi-Arid Tropical and Sub-Tropical Agro-ecosystem	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-ecosystem	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-ecosystem	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	Favourable production environment, developed infrastructure and institutions
High Rainfall Humid Agro-ecosystem	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 mentality 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-ecosystem	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
West Asia	Hersh production environment (drought, cold, heat and salinity), very low rainfall, acute shortage of groundwater, soil erosion	Poor soil fertility, shortage of fodder, biotic stress, over grazing of pastures	Inadequate input and technology delivery system, dependence on food imports	High value commodities

Source: Compiled from various published and other sources.