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Food Security, Research Priorities and Resource Allocation in South Asia

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Abstract

The study conduced on South Asian countries is focused on three issues, viz. (a) research priorities in agriculture, (b) level of research investment, and (c) focus of research investments to attain food-secured South Asia. The results of this empirical exercise have suggested that (a) cereals, horticulture, livestock and fisheries in commodity groups and rice and milk as commodities should receive greater attention in resource allocation at South Asia level with certain minor variations across the countries, (b) prioritization exercises need to explicitly target poor as otherwise their needs will continue to remain under-funded, and at least 2-3 times increase (if the AgGDP growth is assumed at 2.1%) and 3-4 times increase (if the AgGDP growth is assumed at 4%) is needed in funding support to these countries in agricultural research and education to attain food and nutritional security.

Introduction

The counties of South Asia have benefited significantly from investment in agricultural research. The green revolution during 1960s and 1970s consisting of use of high-yielding crop verities, fertilizers, irrigation and plant protection measures increased production of major agricultural commodities such as foodgrains, vegetables, fruits, milk, eggs and fish several fold. As a result, the per capita availability of important food commodities has increased substantially, despite increase in population. The increase in domestic agricultural production has also made a visible impact on the national food and nutritional security. However, poverty and malnutrition still continue to afflict more than one-fifth of South Asian population.

South Asian agriculture has dominance of small and marginal farmers. The ratio of agricultural land to agricultural population is about 0.38 ha/person in South Asia as compared to over 11 ha/person in the developed countries. With a global share of 6.3 per cent land, and 25 per cent population, the per capita availability of resources is 4-6 times less in South Asia than the world average. The pressure on land and water is rising further with diversion of agricultural land and water towards industrial, urban and other non-agricultural uses. Further, impact of environmental degradation on agriculture is getting severe in some regions and situations. Total factor productivity in agriculture, which brings sustainable growth, is either rising very slowly or has ceased to increase. While supply side picture is marred with several challenges, demand for food is rising rapidly due to unchecked growth in population and rise in income levels. The increase in food production to meet the requirement has to be achieved from the limited, diminishing and degrading resources.

The counties of South Asia have benefited significantly from investment in agricultural research in the past. However, all over the globe including countries in South Asia, the public resources in agricultural research are becoming inadequate in meeting the expanding research objectives and complex agenda for agricultural research. Though investment intensity of research rose from 0.20 per cent during early-1960s to about 0.50 per cent in 2008, this remains a way below the average for all the developing countries. Since most of the agricultural R&D is in the public domain, it is necessary that each research dollar

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is spent efficiently. Thus, there is a need to optimally allocate the available scarce resources.

Several research prioritization studies were made in India, mostly using modified congruence approach providing normative-relative research priorities in terms of regions (states in India) and individual commodities/ commodity groups (Jha *et al*., 1995; Mruthyunjaya *et al*., 2003; Jha and Kumar, 2006). The efforts of APAARI (Asia Pacific Association of Agricultural Research Institutions) for countries in Asia Pacific are also significant in identifying research priorities using quantitative and consultative approaches initially and quantitative approach lately (APAARI, 1996; 2002; 2005). In the case of India, Jha and Kumar (2006) apart from identifying commodity and regional priorities, have identified recent resource-orientation priorities also.

Numerous studies have shown that investments in agricultural research along with investments in infrastructure and education help in increasing food supply and meeting the objectives of food and nutritional security and poverty reduction. The obvious issues in this context are identification of (a) research priorities in agriculture, (b) level of research investment, and (c) focus of investments to attain specific goals. These issues have been examined in this paper by identifying research priorities with a focus on food security for each country in South Asia by using the quantitative approach.

Methodology

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. The present study followed the modified congruence model because of the ease of its application, time and data constraints. The con-gruence 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 sound starting point in rationalizing research resource allocation. The Indian agricultural research system (Jha *et al.*, 1995; APAARI, 2002; Mruthyunjaya *et al.*, 2003) also followed this approach because of its simplicity, transparency and flexibility.

Identification of Goals, Research Objectives and Extensity Parameters

For prioritization analysis, the goals normally emphasized in the national documents of the governments, namely growth, equity, sustainability (of the resources) and export are taken. They help in the identification of research objectives. The identification of research objectives and their extensity parameters (indicators) and weights for the construction of initial baseline (IBL) is the most crucial step in the priority setting exercise. In the construction of IBL, only extensity parameters are taken as these reflect that the size of problem to be addressed by the research system is large. The selected research objectives and their extensity parameters along with weights are given in Table 1. Prioritization of commodities and regions (countries) involved calculation of an initial baseline matrix consisting of the value of output from different commodities in different countries. A composite baseline was then developed using the value of output (efficiency), number of poor people (equity), and arable land (sustainability) indicators, and export (agricultural export earning) using equal weights for these four parameters. A comprehensive data set was compiled for each country, covering a large number of variables. The data are centred on the year 2005. These were obtained from various published sources.

Extensity Parameters

1. **Value of output (VOP)** (current value of 17 commodities/commodity groups, projected for the years 2010, 2015 and 2025): The priorities were defined to meet the future demands of commodities with 3.5 per cent per capita GDP growth rate and the accompanying dietary changes.
2. **Poverty:** Number of people below the national poverty line in each country.
3. **Sustainability:** Land area (arable land and forests) in each country.

Table 1. IBL - based goals, objectives and extensity parameters of agricultural research system in South Asia

Sl No.	Goal	Research objective	Extensity parameter	Weight (%)
1.	Growth acceleration	Increase in productivity	Value of production	25
2.	Equity	Increase in income of people below poverty line	Number of people below poverty line	25
3.	Sustainability of production	Sustainable use of natural resources	Arable land	25
4.	Improvement in balance of payment	Proportion of export	Agricultural export earning	25

4. **Export:** Agricultural export earning of each country.

Construction of Initial Baseline (IBL)

The initial baseline is the weighted sum of extensity parameters and is constructed by country. The construction of initial baseline can be illustrated by the following steps:

(i) Compute percentage distribution of each extensity parameter (P_{ij}):

$$P_{ij} = \left(A_{ij} / \sum_{i=1}^{n} A_{ij} \right) \times 100; i = 1, ..., n; j = 1, ..., k$$

where, A_{ij} is value of jth extensity parameter in the ith country, n is the number of countries and k is the number of extensity parameters.

(ii) Assign weight (Wj) to each extensity parameter.

(iii) Compute initial baseline for individual country (B_i):

$$B_i = \sum_{j=1}^{k} W_j P_{ij} \quad i = 1, ..., n; \quad j = 1, ..., k$$

where, B_i is the baseline for the ith state, W_j is the weight for the j^{th} extensity parameter.

The sum of initial baseline over the country is 100 and therefore, initial baseline shows the initial relative priorities by country. This means that available research resources may be allocated among the states according to their relative priorities.

Value of production (VOP) reflects the research objective of increase in productivity. The VOP can be adjusted by supply side factors like probability of research success, expected level of adoption of research, research spill over, etc. But, these were not considered owing to lack of availability of prior information. The VOP unadjusted to supply side factors means assuming equal probability of research success and equal or no spill over effects across countries and commodities.

The extensity parameter and number of people below poverty line were selected to further strengthen research activities in the area where the number of poor people was comparatively high. This helped in reducing interpersonal and interregional disparities in the country. Agricultural production can be sustained through conservation of natural resources, particularly land and water. Land area was selected as one of the extensity parameters and land area comprised arable lands. Agricultural exports improve balance of payments situation and hence all governments intend to enhance exports and was thus included as a research objective and agricultural export earnings as an extensity parameter. Table 2 presents the per cent distribution of VOP, poverty (poor), sustainability (land) and exports by country in South Asia.

The constructed IBL with different objectives for South Asian countries is given in Table 3. It can be seen from the objective of VOP, poor, land, export enhancement and their sum that the top 3 priority countries are India, Pakistan and Bangaldesh.

Modification of Initial Base Line: Selection of Modifiers

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 country where intensity of the problem is severe. For example, the country with high groundwater exploitation should

Table 2. Per cent distribution of value of output (VOP), poverty (poor), sustainability (land) and exports (EXPO) by country in South Asia

Goal	Bangladesh	Bhutan	India	Nepal	Pakistan	Sri Lanka	South Asia
VOP	7.23	0.06	75.50	1.71	14.45	1.06	100
Poor	14.55	0.05	71.96	0.09	12.01	1.35	100
Land	4.16	0.07	82.94	1.23	11.09	0.51	100
EXPO	6.47	0.21	76.43	0.67	11.51	4.71	100

Table 3. Initial baseline (IBL) with different objectives

Objectives	Bangladesh	Bhutan	India	Nepal	Pakistan	Sri Lanka
VOP	7.23	0.06	75.50	1.71	14.45	1.06
VOP and Poverty	10.89	0.05	73.73	0.90	13.23	1.20
VOP, Poverty & Sustainability	8.64	0.06	76.80	1.01	12.52	0.97
All objectives (FVOP)	8.10	0.10	76.71	0.92	12.26	1.91
Ratio of FVOP/VOP	1.12	1.54	1.02	0.54	0.85	1.80

be accorded a high priority. Here, the direction of impact of modifier is positive. On the contrary, the country 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 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:

Impact of modifiers (C_{ij}) = $[1+\{M_{ij} /\text{Max} (M_{ij})\} \times W_j] B_i$

where, M_{ij} denotes data for the jth modifier for the i^{th} country, Max (M_{ij}) denotes the maximum value of the j^{th} modifier, and W_j is the weight for the j^{th} modifier.

Modifiers may have positive as well as negative impact on initial baseline. The above formula holds true for the modifiers having positive impact. In the case of modifiers carrying a 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:

$$\text{Adjusted baseline}\,(D_i) = B_i + \sum_{i=1}^{k} C_{ij}$$

New priority distribution or final baseline (E_i) =

$$\left(D_i / \sum_{i=1}^{n} D_i \right) \times 100$$

Several modifiers were initially considered. Finally, based on the appropriateness arrived through review of literature and collective judgment, 6 modifiers were chosen for the study. Correlation studies among these modifiers indicated no duplication. The intensity parameters selected as modifiers were:

1. Growth potential: Irrigation (%) in each country
2. Water withdrawal per capita (m^3/inhab/year)
3. Population density (population per sq km)
4. Forest land (% of total land)
5. Average size of holding (ha)
6. Scientists (per million population) in each country

To take these into account, the composite initial baseline was modified by using intensity parameters or modifiers. After careful screening of the modifiers, impact as well as multi-collinearity, modifiers, representing growth potential (irrigation), equity (size of holding), sustainability (water withdrawal, population density, forest land), research and extension system capacity (number of scientists per million population) were used.

Irrigation is one of the major inputs for enhancing agricultural productivity and hence was used as a modifier to enhance productivity. Water withdrawal per capita is increasing for different uses and contributes to unsustainable use and hence was used as a modifier. Increasing population density again contributes towards unsustainable natural resource use and was retained as a modifier. One more modifier used to reflect sustainable use of resources was area under forest. To reflect equity, farm size was used as a modifier as it determines the income earning potential of a farmer. One of the modifiers used to achieve the objective of adequate man-power to attain the goal of research system capacity was the number of qualified agricultural scientists per million population. Equal weights (25%) were assigned to for each of these modifiers [equal weight (8.33%) to sub-modifiers under sustainability goal]. The parameters for prioritization and weighting schemes were decided on the basis of information provided by the NARS. Details regarding these variables, their direction and weights are provided in Table 4.

Personal judgement was used to identify and specify the objectives, extensity and intensity (modifier) parameters and weighting schemes and to arrive at modified base line (MBL) which incorporated multiple objectives (Table 5). The modifier effect was positive and high for Bangladesh (1.40) and India (1.48). This effect was negligible for small economies, viz. Bhutan, Nepal and Sri Lanka. However, the effect was negative for Pakistan (-3.07). The Priority Index (ratio of MBL and VOP) suggests that Bhutan, Sri Lanka and Bangladesh need higher resource allocations to meet the objectives of their development.

Growth in Research Investment

It was calculated as follows:

$$TFP = f(R)$$

$$\dot{TFP} = E_R^{TFP}\,\dot{R}$$

$$S = g(TFP)$$

$$\dot{S} = E_{TFP}^{S} \cdot \dot{TFP}$$

or

$$\dot{S} = E_{TFP}^{S} \cdot E_R^{TFP}\,\dot{R}$$

or

$$E_S^R = \frac{1}{\left(E_{TFP}^{S} \times E_R^{TFP}\right)}$$

$$\dot{R} = E_S^R / \dot{S}$$

$$R_t = (1+\dot{R})^t \cdot \dot{S}$$

where,

R = Research investment
S = Supply of commodity
$\dot{S}$ = Growth in supply of commodity
TFP = Total factor productivity
$\dot{TFP}$ = Growth in TFP

Table 4. FBL-based goals, objectives and modifiers for agricultural research system in South Asia

Goals	Research objectives	Country modifiers	Direction	Weight (%)
1. Growth acceleration	Increase in productivity	Irrigated area (% of total crop area)	Negative	25
2. Sustainability of production	Sustainable use of natural resource base	Water withdrawal per capita (m^3/inhab/yr)	Positive	8.33
		Population density (population per sq km)	Positive	8.33
		Forest land (% of total land)	Negative	8.33
3. Equity	Increase in income of small farmers	Average farm size (ha)	Negative	25
4. Research system capacity	Balanced development of research system infrastructure	Number of agricultural scientists per million population	Negative	25

Table 5. Final baseline and impact of extensity and modifiers on South Asian countries

Base line	Bangladesh	Bhutan	India	Nepal	Pakistan	Sri Lanka
VOP	7.23	0.06	75.50	1.71	14.45	1.06
Final VOP (FVOP)	8.10	0.10	76.71	0.92	12.26	1.91
Modified base line (MBL)	9.50	0.13	78.19	1.03	9.19	1.96
Priority Index (MBL/VOP)	1.314	2.071	1.036	0.606	0.636	1.850
Modifier effect	1.40	0.03	1.48	0.11	-3.07	0.05

VOP: Per cent share of gross output in South Asia at 1999-2001 measured in US$

E^{S}_{TFP} = Elasticity of commodity supply with respect to TFP

E^{TFP}_{R} = Elasticity of TFP with respect to research

E^{R}_{S} = Elasticity of research investment with respect to commodity supply at average food demand growth

$\dot{R}$ = Required growth in research investment to attain one per cent growth in food supply

R_t = Research investment in the year 't' corresponding to required supply to meet demand.

Trends in Food Demand

In order to capture the effects of changes in the demand on commodity priorities, VOP of a commodity has to be adjusted with the expected growth in its demand in the country. Since research and extension lag is about 8-11 years, the growth had to be extrapolated to 2015 and 2025. This adjustment in VOP implies that commodities with higher expected growth in the demand should get high priority. The food demand was estimated based on food characteristics demand system (FCDS) following Bouis and Haddad (1992) and using consumption data from FAO.

In South Asia, while cereals remain important constituents of food basket, high-value foods such as fruits, vegetables, milk, meat, eggs and fish are rising in importance. Trends in food consumption pattern over the past two decades suggest changes in the composition of the food basket from coarse grains to superior grains (rice and wheat), and from grains to livestock and horticultural products. This has significant implications for future food demand, research priority setting, and resource allocation to achieve food and nutritional security.

Tables 6 and 7 present the projected food demand and annual growth in South Asian countries for the years 2015 and 2025. It is evident that by 2025, foodgrain demand will be of 339 million tonnes, comprising 147 million tonnes rice, 122 million tonnes wheat, 46 million tonnes coarse grains and 24 million tonnes pulses. By the year 2025, South Asia will need 13 million tonnes roots and tubers (in dry equivalent), 17 million tonnes edible oils, 144 million tonnes vegetables, 103 million tonnes fruits, 47 million tonnes sweeteners, 205 million tonnes milk, 15 million tonnes meat, 4.8 million tonnes eggs, and 16 million tonnes fish to meet its domestic demand. High growth in livestock products' demand will put a pressure on foodgrains and oilcakes to meet the feed demand for livestock. Fast growth of income will diversify the dietary pattern in favour of non-foodgrain crops, livestock and fisheries products.

The per capita availability of arable land in South Asia is quite low and is declining over time. Diversification towards these high-value commodities, which are labour-intensive, can also provide adequate income and employment to the agricultural labourers and small farmers who dominate the agriculture in these countries. It is important to make significant efforts to increase yield per unit of inputs using science, by accelerating TFP, as the required yield targets would be quite challenging to attain national food and household nutritional security in South Asia. The growth in food demand suggests that (i) these countries will have to produce not only additional food but also diversify food production towards products of higher nutritional value, (ii) the targets to be achieved are quite challenging, and (iii) the research system has to proactively respond through structural and functional changes. Research priorities have to be worked out keeping in view these trends in demand. To address such a challenge, the goals and objectives of the research system should be changed and the priorities so identified should contribute to achieve those goals.

Table 6. Projected demand for food in South Asia

(Thousand tonnes)

Commodity	Year	Bangladesh	India	Nepal	Pakistan	Sri Lanka	South Asia
Rice	2005	22651	87460	3059	2981	2001	118151
	2015	25808	98107	3793	3751	2172	133631
	2025	28958	106575	4552	4552	2354	146991
Wheat	2005	2846	68044	1209	24433	910	97441
	2015	3278	74753	1471	30125	996	110623
	2025	3710	79863	1738	35968	1087	122367
Coarse cereals	2005	215	34271	1742	2304	87	38619
	2015	243	37331	2106	2821	92	42594
	2025	271	39612	2477	3349	99	45809
Pulses	2005	606	15129	224	1472	161	17592
	2015	719	17864	288	1896	185	20952
	2025	833	20221	356	2343	210	23963
Edible oils	2005	672	9558	140	1911	68	12349
	2015	794	11191	178	2459	77	14699
	2025	916	12582	218	3039	86	16840
Sweeteners	2005	1257	28334	155	5022	592	35359
	2015	1469	32727	195	6381	664	41436
	2025	1683	36395	236	7803	740	46857
Roots & tubers	2005	579	7350	274	555	129	8888
	2015	689	8918	354	724	154	10839
	2025	801	10316	439	904	179	12639
Vegetables	2005	1817	78166	1814	6567	815	89180
	2015	2235	102182	2454	8907	1043	116821
	2025	2666	125482	3156	11478	1289	144071
Fruits	2005	1503	52188	557	7432	946	62627
	2015	1889	68660	765	10283	1165	82763
	2025	2293	84750	995	13466	1397	102901
Milk	2005	2395	88922	1423	34160	885	127784
	2015	2977	114108	1934	46395	1118	166532
	2025	3581	138059	2498	59851	1369	205359
Meat	2005	459	5494	302	2248	112	8615
	2015	589	7536	424	3094	147	11790
	2025	727	9619	562	4033	185	15127
Eggs	2005	195	2068	31	410	54	2758
	2015	250	2837	43	565	71	3766
	2025	309	3622	57	736	89	4812
Fish	2005	1555	7234	33	514	496	9831
	2015	1995	9923	46	707	649	13320
	2025	2462	12666	61	922	817	16928

Source: Kumar *et al.* (2007)

Table 7. Projected growth in demand for food in South Asia

(in per cent)

Commodity	Year	Bangladesh	India	Nepal	Pakistan	Sri Lanka	South Asia
Rice	2005-15	1.31	1.16	2.17	2.32	0.82	1.24
	2015-25	1.16	0.83	1.84	1.95	0.81	0.96
Wheat	2005-15	1.42	0.94	1.98	2.12	0.91	1.28
	2015-25	1.25	0.66	1.68	1.79	0.88	1.01
Coarse cereals	2005-15	1.23	0.86	1.92	2.05	0.56	0.98
	2015-25	1.10	0.59	1.64	1.73	0.74	0.73
Pulses	2005-15	1.72	1.68	2.54	2.56	1.40	1.76
	2015-25	1.48	1.25	2.14	2.14	1.28	1.35
Edible oils	2005-15	1.68	1.59	2.43	2.55	1.25	1.76
	2015-25	1.44	1.18	2.05	2.14	1.11	1.37
Sweeteners	2005-15	1.57	1.45	2.32	2.42	1.15	1.60
	2015-25	1.37	1.07	1.93	2.03	1.09	1.24
Roots & tubers	2005-15	1.75	1.95	2.59	2.69	1.79	2.00
	2015-25	1.52	1.47	2.18	2.25	1.52	1.55
Vegetables	2005-15	2.09	2.72	3.07	3.09	2.50	2.74
	2015-25	1.78	2.08	2.55	2.57	2.14	2.12
Fruits	2005-15	2.31	2.78	3.22	3.30	2.10	2.83
	2015-25	1.96	2.13	2.66	2.73	1.83	2.20
Plantation &	2005-15	1.75	1.95	2.59	2.69	1.79	2.00
other crops	2015-25	1.52	1.47	2.18	2.25	1.52	1.55
Milk	2005-15	2.20	2.53	3.12	3.11	2.36	2.68
	2015-25	1.86	1.92	2.59	2.58	2.05	2.12
Meat	2005-15	2.53	3.21	3.45	3.25	2.76	3.19
	2015-25	2.13	2.47	2.86	2.69	2.33	2.52
Eggs	2005-15	2.52	3.21	3.33	3.26	2.77	3.16
	2015-25	2.14	2.47	2.86	2.68	2.29	2.48
Fish	2005-15	2.52	3.21	3.38	3.24	2.73	3.08
	2015-25	2.13	2.47	2.86	2.69	2.33	2.43

Source: Computed from Table 6

Country and Commodity Priorities

The modified congruence model gives priorities by commodities and countries (Table 8 and Table 9). This priority matrix can be used to arrive at different priority dimensions, such as country priorities (sum over commodities by countries), commodity priorities (sum over countries by commodity) or commodity group priorities for the region (sum over commodities and countries). In this exercise, country priorities, and commodity priorities within and across countries have been discussed. For the benefit of national programs, commodity priorities by countries will be helpful. The 'priority score' is the share of a commodity/group or country (in per cent), and, higher the priority score, higher is the priority. The national systems can use the priority matrix for allocation of resources across commodities. Fund facilitators can also use the priority matrix to track priority country and commodity or vice versa. Since identification of research priorities was the major objective of this exercise, we have focused on country and commodity priorities.

Table 8. Priority score of commodity groups by country in South Asian countries

Commodity	Year	Bangladesh	India	Nepal	Pakistan	Sri Lanka	South Asia
Rice	2005	45.9	14.1	19.4	4.8	22.1	17.6
	2015	43.7	12.9	18.4	4.6	20.2	16.2
	2025	41.8	11.9	17.7	4.4	18.8	15.1
Wheat	2005	2.1	8.6	7.2	12.5	0.0	7.5
	2015	2.0	7.7	6.7	11.6	0.0	6.8
	2025	1.9	7.0	6.3	11.0	0.0	6.2
Coarse cereals	2005	0.7	3.3	10.0	2.5	0.4	2.8
	2015	0.7	2.9	9.2	2.3	0.3	2.5
	2025	0.6	2.6	8.7	2.2	0.3	2.3
Cereals	2005	48.7	25.9	36.6	19.8	22.5	27.8
	2015	46.3	23.4	34.4	18.5	20.5	25.4
	2025	44.4	21.5	32.7	17.5	19.1	23.6
Pulses	2005	1.2	4.0	2.3	1.3	0.3	3.2
	2015	1.2	3.8	2.3	1.2	0.3	3.1
	2025	1.2	3.7	2.3	1.2	0.3	3.0
Edible oils	2005	1.4	9.7	2.0	6.8	11.9	8.7
	2015	1.4	9.2	2.0	6.6	11.3	8.3
	2025	1.4	8.9	1.9	6.4	10.9	7.9
Sweeteners	2005	1.3	3.7	1.5	4.0	0.7	3.2
	2015	1.2	3.4	1.5	3.8	0.6	3.0
	2025	1.2	3.3	1.4	3.7	0.6	2.9
Roots & tubers	2005	4.5	2.5	9.3	1.0	3.4	2.8
	2015	4.4	2.5	9.2	1.0	3.4	2.7
	2025	4.4	2.5	9.1	1.0	3.4	2.7
Vegetables	2005	3.8	8.6	12.6	1.5	6.9	7.5
	2015	3.9	9.1	13.1	1.5	7.4	7.9
	2025	4.0	9.6	13.5	1.6	7.9	8.2
Fruits	2005	2.5	8.9	4.3	5.2	1.8	7.3
	2015	2.6	9.5	4.5	5.4	1.8	7.8
	2025	2.7	10.0	4.7	5.6	1.9	8.2
Plantation	2005	2.3	6.8	1.3	5.6	34.1	8.3
crops	2015	2.3	6.7	1.2	5.5	34.2	8.1
	2025	2.3	6.6	1.2	5.5	34.2	8.0
Horticulture	2005	13.1	26.8	27.5	13.3	46.2	25.8
	2015	13.3	27.9	28.1	13.5	46.9	26.6
	2025	13.4	28.7	28.5	13.6	47.3	27.2
Milk	2005	5.3	18.3	14.9	35.7	1.9	16.8
	2015	5.5	19.2	15.6	36.6	2.0	17.7
	2025	5.6	19.8	16.0	37.2	2.1	18.4
Meat	2005	5.7	4.0	12.9	15.5	6.6	5.3
	2015	6.1	4.5	13.8	16.1	7.3	5.8
	2025	6.4	4.9	14.6	16.5	7.9	6.3
Eggs	2005	1.3	1.2	1.0	1.3	1.5	1.2
	2015	1.4	1.4	1.0	1.3	1.7	1.4
	2025	1.5	1.5	1.1	1.4	1.8	1.5
Livestock	2005	12.26	23.60	28.79	52.48	10.04	23.44
	2015	12.96	25.05	30.45	53.97	11.01	25.01
	2025	13.52	26.19	31.80	55.12	11.82	26.29
Fish	2005	22.05	6.38	1.26	2.37	8.41	7.89
	2015	23.62	7.13	1.35	2.46	9.26	8.63
	2025	24.90	7.76	1.43	2.53	10.00	9.25

Note: Adjusted value of output product was obtained for the year 2005 after taking into account extensity and intensity parameters, as explained in methodology. The adjusted VOP has been projected for the years 2015 and 2025

Table 9. Priority score of commodity groups across South Asian countries

(in per cent)

Commodity	Year	Bangladesh	India	Nepal	Pakistan	Sri Lanka
Rice	2005	29.1	58.8	0.8	1.9	9.5
	2015	29.4	58.5	0.8	2.1	9.1
	2025	30.0	57.8	0.9	2.3	9.0
Wheat	2005	3.1	84.7	0.7	11.6	0.0
	2015	3.2	83.3	0.7	12.8	0.0
	2025	3.3	81.8	0.8	14.0	0.0
Coarse cereals	2005	2.8	87.5	2.5	6.3	1.0
	2015	2.9	86.5	2.7	7.0	0.9
	2025	3.0	85.4	3.0	7.7	0.9
Cereals	2005	19.5	68.6	0.9	4.9	6.1
	2015	19.8	67.9	1.0	5.4	5.9
	2025	20.3	66.8	1.1	5.9	5.9
Pulses	2005	4.3	91.6	0.5	2.7	0.8
	2015	4.3	91.4	0.5	3.0	0.8
	2025	4.4	91.0	0.6	3.2	0.8
Edible oils	2005	1.8	82.2	0.2	5.4	10.4
	2015	1.8	82.1	0.2	5.9	10.0
	2025	1.9	81.6	0.2	6.5	9.9
Sweeteners	2005	4.4	85.0	0.3	8.6	1.6
	2015	4.4	84.3	0.4	9.4	1.5
	2025	4.5	83.4	0.4	10.2	1.5
Roots & tubers	2005	18.0	67.7	2.3	2.5	9.4
	2015	17.7	67.8	2.5	2.7	9.2
	2025	17.7	67.5	2.6	2.9	9.2
Vegetables	2005	5.7	84.7	1.2	1.4	7.0
	2015	5.4	85.0	1.2	1.5	6.9
	2025	5.2	85.0	1.3	1.5	6.9
Fruits	2005	3.8	89.1	0.4	4.9	1.8
	2015	3.6	89.1	0.4	5.2	1.7
	2025	3.5	88.9	0.4	5.5	1.7
Plantation	2005	3.2	60.8	0.1	4.7	31.3
crops	2015	3.1	60.9	0.1	5.1	30.8
	2025	3.1	60.5	0.1	5.4	30.8
Horticulture	2005	5.7	76.5	0.7	3.6	13.6
	2015	5.4	77.1	0.8	3.8	12.9
	2025	5.3	77.2	0.8	4.0	12.6
Milk	2005	3.5	80.4	0.6	14.7	0.9
	2015	3.4	79.7	0.6	15.4	0.8
	2025	3.3	78.9	0.7	16.3	0.8
Meat	2005	12.0	56.5	1.7	20.3	9.5
	2015	11.4	57.1	1.7	20.6	9.2
	2025	11.0	57.1	1.8	21.0	9.1
Eggs	2005	11.5	71.7	0.5	7.0	9.2
	2015	10.9	72.5	0.6	7.1	8.9
	2025	10.6	72.7	0.6	7.3	8.8
Livestock	2005	5.6	73.9	0.7	16.3	3.4
	2015	5.4	72.8	0.7	16.8	3.4
	2025	5.3	71.6	0.8	17.4	3.4
Fisheries	2005	30.0	59.3	0.1	2.2	8.5
	2015	28.4	60.0	0.1	2.2	8.2
	2025	27.6	60.3	0.1	2.3	8.1
All commodities	2005	10.7	73.3	0.6	7.3	8.0
	2015	10.4	72.7	0.6	7.8	7.6
	2025	10.2	71.8	0.6	8.3	7.5
Priority ratio (FBL/VOP)	2005	1.3	1.0	0.6	0.6	1.9
R&D allocation	2002	6.4	79.2	1.5	10.0	3.0

Table 10. Shift in priority ratio among commodity groups in South Asia

Commodity	Year	Bangladesh	India	Nepal	Pakistan	Sri Lanka	South Asia
Rice	2005	1.00	1.00	1.00	1.00	1.00	1.00
	2015	0.95	0.91	0.95	0.95	0.91	0.92
	2025	0.91	0.85	0.91	0.91	0.85	0.86
Wheat	2005	1.00	1.00	1.00	1.00	1.00	1.00
	2015	0.96	0.90	0.93	0.93	0.91	0.91
	2025	0.93	0.82	0.88	0.88	0.84	0.82
Coarse cereals	2005	1.00	1.00	1.00	1.00	1.00	1.00
	2015	0.94	0.89	0.93	0.92	0.89	0.90
	2025	0.90	0.80	0.87	0.86	0.82	0.82
Cereals	2005	1.00	1.00	1.00	1.00	1.00	1.00
	2015	0.95	0.90	0.94	0.93	0.91	0.91
	2025	0.91	0.83	0.89	0.88	0.85	0.85
Pulses	2005	1.00	1.00	1.00	1.00	1.00	1.00
	2015	0.99	0.96	0.99	0.97	0.97	0.96
	2025	0.98	0.93	0.97	0.95	0.94	0.93
Edible oils	2005	1.00	1.00	1.00	1.00	1.00	1.00
	2015	0.99	0.95	0.97	0.97	0.95	0.96
	2025	0.97	0.91	0.95	0.95	0.91	0.92
Sweeteners	2005	1.00	1.00	1.00	1.00	1.00	1.00
	2015	0.98	0.94	0.96	0.96	0.94	0.95
	2025	0.95	0.89	0.93	0.92	0.90	0.90
Roots & tubers	2005	1.00	1.00	1.00	1.00	1.00	1.00
	2015	0.99	0.99	0.99	0.98	1.00	0.99
	2025	0.99	0.98	0.98	0.97	1.00	0.97
Vegetables	2005	1.00	1.00	1.00	1.00	1.00	1.00
	2015	1.03	1.07	1.04	1.02	1.08	1.06
	2025	1.05	1.12	1.06	1.04	1.14	1.10
Fruits	2005	1.00	1.00	1.00	1.00	1.00	1.00
	2015	1.05	1.07	1.05	1.04	1.04	1.07
	2025	1.09	1.13	1.09	1.08	1.07	1.12
Plantation	2005	1.00	1.00	1.00	1.00	1.00	1.00
crops	2015	0.99	0.99	0.99	0.98	1.00	0.99
	2025	0.99	0.98	0.98	0.97	1.00	0.97
Horticulture	2005	1.00	1.00	1.00	1.00	1.00	1.00
	2015	1.01	1.04	1.02	1.01	1.02	1.03
	2025	1.02	1.07	1.04	1.02	1.02	1.05
Milk	2005	1.00	1.00	1.00	1.00	1.00	1.00
	2015	1.04	1.05	1.04	1.02	1.06	1.05
	2025	1.07	1.08	1.07	1.04	1.12	1.09
Meat	2005	1.00	1.00	1.00	1.00	1.00	1.00
	2015	1.07	1.12	1.08	1.04	1.10	1.10
	2025	1.13	1.22	1.14	1.07	1.19	1.20
Eggs	2005	1.00	1.00	1.00	1.00	1.00	1.00
	2015	1.07	1.12	1.06	1.04	1.11	1.10
	2025	1.13	1.22	1.12	1.07	1.19	1.19
Livestock	2005	1.00	1.00	1.00	1.00	1.00	1.00
	2015	1.06	1.06	1.06	1.03	1.10	1.07
	2025	1.10	1.11	1.10	1.05	1.18	1.12
Fishries	2005	1.00	1.00	1.00	1.00	1.00	1.00
	2015	1.07	1.12	1.07	1.04	1.10	1.09
	2025	1.13	1.22	1.13	1.07	1.19	1.17

With the objectives of increasing productivity (VOP), increase in income of small farmers (poor), sustainable use of natural resources (land) and contribution to more exports (exports), independently and together, the top 3 priority countries are India, Pakisthan and Bangladesh. The commodity priority scores (by country) and commodity groups are given in Tables 8, 9 and 10. It can be seen from these Tables that the priority commodity groups in South Asia were: cereals, horticulture, livestock and fishery and the priority commodities were: rice and milk.

In the case of countries in the region, cereals topped the priority list in Bangaldesh and Nepal, horticulture topped the priority list in India and Sri Lanka, and livestock in Pakistan. In case of individual commodities, rice topped the list in Bangladesh, and Nepal, milk in India and Pakistan and plantation crops in Sri Lanka. The other important commodity/ies in different countries included rice in India, milk, meat and vegetables, in Nepal, rice and edible oils in Sri Lanka and meat and wheat in Pakistan. By and large, these priorities will continue up to 2025, with noticeable increase in priority for horticulture, livestock and fishery in both South Asia as well as countries in the region with the passage of time, 2015 and 2025. Shift in priority ratios by adjustment of VOP on the basis of growth in demand as stated earlier during 2015 and 2025 by commodities in different countries and South Asia as a whole suggested augmentation of research resources towards vegetables, fruits, milk, meat, eggs, and fish (Table 11). These priorities need to be kept in view while deciding the research agenda and research resource allocation and other needed development support. It is important to mention here that these results on commodity priorities are only indicative in nature and more degree of scientific judgement needs to be applied to capture other relevant external factors and opportunities (including chances of research success) in setting research priorities at the micro level (research programs and projects).

Shift in Research Resources

An exercise was done to compare the existing resource allocation among commodity groups with the optimum level as per the identified priority score using the methodology described to find out the mismatch and needed changes. The existing level of resource allocation for South Asian countries was taken from ASTI datasets at www.asti.cgiar.org. The current research allocation information was not available for cereals and horticulture in Sri Lanka. The optimal and existing research allocations, presented in Tables 12 and 13, revealed that in case of cereals, the existing research allocations were less than optimal in Bangladesh and more than optimal in India, Nepal and Pakistan. In case of horticulture, it was more than optimal in Bangladesh, India, and Pakistan, whereas it was less than optimal in Nepal. In case of livestock, it was less than optimal in all countries, except Sri Lanka. In case of fishery, it was less than optimal in case of Bangladesh, India, and Sri Lanka, whereas in case of Nepal and Pakistan, it was more than optimal. How resources are to be shifted keeping in view the optimal allocation has been shown in Table 13. There is a need to shift additional resources to Bangladesh for cereals. Nepal needs more resources for horticulture. Bangladesh, India and Sri Lanka require additional resource allocations for fisheries. Livestock will be priority for all the South Asian countries and they require substantial additional resource support.

Box 1

Commodity Priorities in South Asia

	Bangaldesh	India	Nepal	Pakistan	Sri Lanka	South Asia
Commodity priority	Rice	Milk Rice	Rice Milk Meat Vegetables	Milk Meat Wheat	Plantation Rice Vegetable oil	Rice Milk
Commodity group priority	Cereals Fishery Livestock Horticulture	Horticulture Cereals Livestock Fishery	Cereals Livestock Horticulture Fishery	Livestock Cereals Horticulture Fishery	Horticulture Cereals Livestock Fishery	Cereals Horticulture Livestock Fishery

Table 11. Optimal allocation profile and adjustment coefficients, South Asia

Commodity	Year	Optimum shares (FBL)*	Priority ratio over 2005	Shift in existing resources
Rice	2015	16.2	0.92	-8.3
	2025	15.1	0.86	-14.4
Wheat	2015	6.8	0.91	-9.1
	2025	6.2	0.84	-16.2
Coarse cereals	2015	2.5	0.90	-10.3
	2025	2.3	0.82	-18.3
Cereals	2015	25.4	0.91	-8.7
	2025	23.6	0.85	-15.3
Pulses	2015	3.1	0.96	-3.6
	2025	3.0	0.93	-7.1
Edible oils	2015	8.3	0.96	-4.5
	2025	7.9	0.92	-8.4
Sweeteners	2015	3.0	0.95	-5.1
	2025	2.9	0.90	-9.6
Roots & tubers	2015	2.7	0.99	-1.4
	2025	2.7	0.97	-2.8
Vegetables	2015	7.9	1.06	6.0
	2025	8.2	1.10	10.4
Fruits	2015	7.8	1.07	7.1
	2025	8.2	1.12	12.3
Plantation	2015	8.1	0.99	-1.4
crops	2025	8.0	0.97	-2.8
Horticulture	2015	26.6	1.03	3.1
	2025	27.2	1.05	5.3
Milk	2015	17.7	1.05	5.3
	2025	18.4	1.09	9.1
Meat	2015	5.8	1.10	10.4
	2025	6.3	1.20	19.5
Eggs	2015	1.4	1.10	10.4
	2025	1.5	1.19	19.2
Livestock	2015	24.9	1.07	6.7
	2025	26.1	1.12	12.0
Fishries	2015	8.7	1.09	9.0
	2025	9.3	1.17	16.8

(FBL)* stands for final base-line

Table 12. Allocation of research resources in South Asia

(in per cent)

Commodity	Bangladesh	India	Nepal	Pakistan	Sri Lanka
Rice	20.6	14.7	25.2	6.8	-*
Wheat	6.8	6.3	19.1	16.1	-
OCER	7.7	5.4	0	3.7	-
Cereals	35.1	26.4	44.3	26.6	-
Pulses	4.7	7.7	5.5	8.7	-
Edible oils	7	10.6	7.2	10.1	-
Sweeteners	5.7	5.5	2.4	8.1	-
Roots & tubers	7.2	3.2	3.5	3.2	-
Vegetables	8.9	6.8	7.5	6.9	-
Fruits	13.2	9.2	4.5	12.5	-
Plantation crops	-	7.4	-	-	-
Horticulture	29.3	32.1	15.5	22.6	-
Crop	81.8	76.8	74.9	76.1	81.5
Livestock	8.1	17.6	19.1	19.6	10.6
Fish	10.1	5.2	5.9	4.3	7.9
Total	100.0	100.0	100.0	100.0	100.0

Source: Computed by using Agricultural S&T Indicators (ASTI) datasets at www.asti.cgiar.org
*Data not available

Table 13. Reallocation of research resources by commodity group in South Asia: 2005

Commodity	Bangladesh	India	Nepal	Pakistan	Sri Lanka
Cereals					
Optimal	48.7	25.9	36.6	19.8	22.5
Existing	35.1	26.4	44.3	26.6	NA
Shift in existing resources (%)	38.6	-1.8	-17.4	-25.5	-
Horticulture					
Optimal	13.1	26.8	27.5	13.3	46.2
Existing	29.3	32.1	15.5	22.6	NA
Shift in existing resources (%)	-55.3	-16.7	77.2	-41.0	-
Livestock					
Optimal	12.3	23.6	28.8	52.5	10.0
Existing	8.1	17.6	19.1	19.6	10.6
Shift in existing resources (%)	50.9	33.9	50.4	167.4	-5.2
Fishries					
Optimal	22.1	6.4	1.3	2.4	8.4
Existing	10.1	5.2	5.9	4.3	7.9
Shift in existing resources (%)	118.0	22.6	-78.8	-44.2	6.4

NA: Not available

Table 14. Required investment in research to attain food security in South Asia

Commodity	Share of TFP in total production (%)	Elasticity of TFP with respect to research investment (%)	Average food demand growth	Elasticity of research investment with respect to supply	Required growth in research investment to attain one % growth in supply
Rice	10 to 20	0.05-0.10	1.24	1.24-1.60	1.00-1.29
Wheat	10 to 20	0.05-0.10	1.28	1.28-1.40	1.00-1.10
Coarse cereals	05 to 10	0.05-0.10	0.98	0.98-1.96	1.00-1.99
Pulses	05 to 10	0.05-0.10	1.76	0.98-1.97	0.56-1.12
Edible oils	20 to 30	0.05-0.07	1.76	1.76-3.53	1.00-2.01
Sweeteners	20 to 30	0.05-0.07	1.60	1.07-1.60	0.67-1.00
Roots & tubers	10 to 20	0.05-0.15	2.00	1.34-2.00	0.67-1.00
Vegetables	20 to 30	0.05-0.10	2.74	1.37-1.82	0.50-0.67
Fruits	20 to 30	0.05-0.15	2.83	0.94-1.41	0.33-0.50
Plantation &	20 to 30	0.05-0.10	2.00	1.00-1.34	0.50-0.67
Other crops					
Milk	20 to 30	0.05-0.10	2.68	1.34-1.79	0.50-0.67
Meat	20 to 30	0.05-0.10	3.19	1.59-2.12	0.50-0.67
Eggs	20 to 30	0.05-0.10	3.16	1.58-2.11	0.50-0.67
Fish	20 to 30	0.05-0.10	3.08	1.54-2.06	0.50-0.67
All commodities	05 to 30	0.05-0.15	2.14	1.30-1.87	0.61-0.87

Box 2

Allocation of Additional Resources

Country	Commodity
Bangladesh	Cereals
Nepal	Horticulture
Bangladesh, India and Sri Lanka	Fisheries
All South Asian Countries	Livestock

Augmentation of Research Resources to Make South Asia Food Secured

To attain food security by meeting the projected demand during different years in future up to 2025, it is important to estimate the required investment in research in South Asian countries. The current (2002) level of research investment (at 2005 US $) is provided in the publication by Beintema and Stads (2008). Based on review of TFP studies pertaining to South Asian countries (Birthal *et al*., 1999; Joshi *et al*., 2003; Kumar *et al*., 2004; 2008; Pasha *et al*., 2002), the share of TFP in total production varies across commodities and ranges from 5 to 30 per cent. It was low for cereals and high for horticulture, livestock and fisheries. The elasticity of TFP with respect to research investment ranges from 0.05 to 0.15, as reported in various studies. Using these parameters, elasticity of re-search investment with respect to food supply (production) was estimated for all the commodities and used to suggest the required growth in research investment needed to maintain one per cent growth in food supply in future (Table 14).

The research investment has been projected under two scenarios: (i) existing growth in food supply (2.14%) to meet the national food security, and (ii) target growth of 4 per cent to meet the challenge of hunger and poverty in South Asia. The results revealed that at the current annual growth rate of food supply (2.14%), the resource funding has to be increased to 2390 million

Table 15. Required investment in R&D to attain food security in South Asia

(million US dollar at 2005 price)

Country	Recent investment (2002)*	2010	2015	2020	2025
Scenario 1: 2.14% agricultural growth (to attain national food security)					
Bangladesh	109	126.4	138.7	152.1	166.9
India	1355	1571.5	1724.0	1891.4	2074.9
Nepal	26	30.2	33.1	36.3	39.8
Pakistan	171	198.3	217.6	238.7	261.9
Sri Lanka	51	59.1	64.9	71.2	78.1
South Asia	1712	1985.5	2178.2	2389.7	2621.6
Scenario 2: 4% agricultural growth (to attain household food security and alleviation of hunger)					
Bangladesh	109	143.3	170.0	201.8	239.4
India	1355	1781.5	2113.8	2508.2	2976.0
Nepal	26	34.2	40.6	48.1	57.1
Pakistan	171	224.8	266.8	316.5	375.6
Sri Lanka	51	67.1	79.6	94.4	112.0
South Asia	1712	2250.9	2670.8	3169.0	3760.1

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

(at current price in million US dollar)

Country	2002	2010	2015	2020	2025
Scenario 1: 2.14% agricultural growth (to attain national food security)					
Bangladesh	101.2	143.0	177.5	220.3	273.5
India	1258.3	1778.0	2206.9	2739.3	3400.0
Nepal	24.1	34.2	42.4	52.6	65.2
Pakistan	158.8	224.4	278.5	345.7	429.2
Sri Lanka	47.4	66.9	83.1	103.1	128.0
South Asia	1589.8	2246.4	2788.3	3461.0	4295.8
Scenario2: 4% agricultural growth (to attain household food security and alleviation of poverty and hunger)					
Bangladesh	101.2	162.1	217.6	292.3	392.3
India	1258.3	2015.6	2705.8	3632.6	4876.5
Nepal	24.1	38.7	52.0	69.7	93.6
Pakistan	158.8	254.3	341.5	458.4	615.5
Sri Lanka	47.4	75.9	101.9	136.7	183.5
South Asia	1589.8	2546.7	3418.8	4589.7	6161.4

US dollars from the current 1712 million USD by 2020 in South Asia. If we target 4 per cent growth rate, then it has to be raised to 3169 million USD (Table 15) by the year 2020. Four per cent growth in agricultural GDP can only be attained with greater emphasis on the development of livestock, horticulture and fishery sectors. This will generate additional income to the small and marginal farmers and reduce poverty and

under-nourishment and will contribute to social empowerment. The results relating to required investment at current price are indicated in Table 16. It can be seen that investment has to be nearly doubled at constant prices and tripled at current prices.

Concluding Remarks

The food demand projections in South Asia suggest that these countries will have to produce not only additional food but also diversify food production towards products of higher nutritional value. The targets to be achieved are quite challenging, and the research system has to proactively respond to them through structural and functional changes.

There is lot of similarity in agricultural development situations and issues in South Asian countries, though their nature and extent vary. South Asia as a whole needs augmentation of research resources towards vegetables, fruits, milk, meat, eggs, and fish. These priorities need to be kept in view while deciding the research agenda and research resource allocation and other needed development support. The priorities for resource allocation across the countries generally include cereals, horticulture, livestock, fishery and forestry and the commodities which require greater resources include rice and milk (livestock). There is a need to shift additional resources to Bangladesh for cereals. Nepal needs more resources for horticulture. Bangladesh, India and Sri Lanka require additional resource allocations for fisheries. Live-stock will be priority for all the South Asian countries. It is important to mention here that these results on commodity priorities are only indicative in nature and more degree of scientific judgment needs to be applied to capture other relevant external factors and opportunities (including chances of research success) in setting research priorities at the micro level (research programs and projects). To address priority areas with additional resources, research resources have to be tripled by 2025 in relation to the resource level of 2002 and they need to be doubled in relation to the allocation around 2010 in these countries.

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