ELSEVIER

Agricultural Economics 19 (1998) 327–340

AGRICULTURAL ECONOMICS

National agricultural commodity research priorities for Pakistan

Joseph G. Nagy[a,*], M.A. Quddus[b]

[a] 407 Forsyth Way, Saskatoon, Canada S7N 4H7

[b] Planning Division, Pakistan Agricultural Research Council, P.O. Box 1031, Islamabad, Pakistan

Received 21 January 1997; received in revised form 15 November 1997; accepted 15 February 1998

Abstract

A future agricultural research agenda for Pakistan and its provinces was developed as part of the national master agricultural research plan (NMARP) under the *Government of Pakistan*, World Bank agricultural research project II (ARP-II). The current research agenda mainly keeps pace with maintenance research and little contribution is being made to increase the productivity above maintenance levels for most crop and livestock commodities. Thus, the present Pakistan agricultural research system cannot contribute in any substantial or efficient way to the narrowing of Pakistan's projected food deficit anticipated in the next 15 years. A major thrust of the ARP-II project was identifying a new research agenda with agricultural research priority setting as the basis. An ex ante economic surplus priority setting analysis at the national level was undertaken for selected agricultural commodities as part of the priority setting process. Three separate research funding scenarios were analyzed: (1) Scenario I: an ex ante analysis using the present research commodity funding levels and present research management level for each year over the next five years, (2) Scenario II: an ex ante analysis using double the present funding level for each year over the next 5 years with a higher research management level than at present, and (3) Scenario III: an ex ante analysis at an 'optimally' funded level with a higher research management level. An efficiency index (NPV divided by the present value of research expenditure) was used for the priority ranking of commodities. A framework for using the information generated by the ex ante economic surplus method is presented. The results of the analysis proved to be useful as baseline information for researchers and research managers to assess the overall budget commitment required for agricultural research in Pakistan and for identifying an overall research strategy at the national level.

1. Introduction

Three main sources of demand exist for Pakistan's future agricultural output. The first source is for food and fiber for Pakistan's 128 million population which is growing at a rate of 3% per annum. At this rate, the doubling and tripling times for population growth are 25 and 35 years respectively. Pakistan's population could reach 250 million by the year 2020 and 375 million by 2030. The second source is the moderately rising disposable income which is currently increasing at a real rate of 5% per annum. Tastes and preferences change with rising incomes often leading to a greater demand for edible oils and livestock products, in particular, milk and poultry meat. A third source of demand is for exports and the resulting foreign exchange earnings. These future sources of demand will define future production and trade patterns of agricultural commodities.

*Corresponding author. Tel.: +1 3062494196; fax: +1 3062495768; e-mail: jgnagy@sk.sympatico.ca

PII S0169-5150(98)00053-X

There are, however, concerns that future output from Pakistan's agricultural sector will not keep pace with the demand. International food policy research institute (IFPRI) supply and demand projections to the year 2020 indicate that under the existing low-investment/slow growth in the agricultural sector, substantial quantities of meat, edible oil, roots and tubers and cereal crops, with the exception of rice, will have to be imported (Rosegrant et al., 1995). Wheat imports, for example, would be 8 times higher than in 1993–94 and would cost US$ 5 billion per year at current prices.

Given Pakistan's abundant natural agricultural and human resources, the country could, if it chooses, efficiently increase agricultural production and productivity. A more efficient and productive agricultural sector could, through increased agricultural production and trade of both agricultural and non-agricultural products, keep pace with future food and fiber demand. To accomplish this, Pakistan requires a high-investment/high growth rate in the agricultural sector. Investments need to be made in agricultural research, extension, education, infrastructure and irrigation with appropriate price and trade policies that will give rise to a substantial increase in productivity growth and production. The Pakistan agricultural research system is a key component of a high-investment/high growth strategy. Pakistan's adaptive agricultural research, as it has demonstrated in the past, is the major driving force for increasing agricultural productivity and production on a sustained basis. At present, however, Pakistan's public agricultural research system is funded, organized, and managed at a level where, in most instances, only maintenance research is being achieved with little prospect for meaningful future increases in productivity from research. Although private sector research has considerable potential, it is in its infancy and for the foreseeable future, faces high risk and unresolved intellectual property rights issues (Mellor Associates Inc., 1994, p. 204). Thus, the present agricultural research agenda, both public and private, cannot be expected to make the substantial contribution it could to increase production and productivity growth.

A future research agenda for Pakistan has been spelt out in the national master agricultural research plan (NMARP) (PARC, 1997). A major thrust of the ARP-II and NMARP was agriculture research priority setting at the national, provincial and research institution level by commodity and research discipline and area. Priorities were set at the national and provincial levels on a commodity basis and at the research discipline and program area level within research institutions. The commodity research priorities were then used to identify long-term national and provincial research program thrusts upon which to base adaptive research projects and re-organize research efforts at both the component and farming systems research levels. Research could then be organized in such a way that only the top priority research would be undertaken first and lessor priority research undertaken only if funding became available. A second major thrust was institutional strengthening to increase the level of management and organization of research through monitoring and evaluation (ME), planning and program budgeting (PPB), investment in human capital, and changes in the civil service rules to allow advancement on merit. These two thrusts would enable the Pakistan agricultural research system to conduct research that would best attain the required productivity and production goals of the agriculture sector in an efficient and highly managed manner.

This paper presents and discusses the agricultural research priority setting method and strategy used at the national level in the NMARP. An ex ante economic surplus priority setting analysis, as outlined by Alston et al., 1995 was undertaken for selected commodities. A more comprehensive report of the analysis is given in Nagy and Quddus (1996). A step by step procedure for conducting the ex ante economic surplus analysis for Pakistan is presented in Nagy (1996). Examples of ex ante studies of this type can be found in Davis et al. (1987); Cessay et al. (1989); Dey and Norton (1993); Mills (1997). For a thorough review of the economic surplus methods and other ex ante priority setting methods, see Alston et al. (1995).

2. Model and data

2.1. The empirical model

The small open-economy economic surplus model (Alston et al., 1995, p. 380) was used ex ante to calculate the change in economic surplus from a shift downward in the supply curve due to the adoption of an intervention attributed to agricultural research as follows:[1]

$$\Delta TS_t = K_t P'_t Q'_t \cdot (1 + 0.5 K_t \epsilon) \qquad (1)$$

where ΔTS_t is the change in total economic surplus attributed to research investment, P'_t is the pre-research commodity price, Q'_t is the pre-research quantity produced in year t, ϵ is the elasticity of supply, and K_t is the proportionate shift downward in the supply curve in period t attributable to research investment. Quantity Q'_t can be adjusted for exogenous increases from non-research sources by a linear appreciation factor. Exogenous factors such as increased inputs, increased land utilization, or research spill-in effects from other countries can increase production apart from the production increases brought about through indigenous research and extension efforts. Also included under exogenous factors is the change in production that may occur from changes in cropping patterns from the adoption of indigenous research. The exogenous increase is calculated as $Q'_t = Q_0(1+s)^t$ where Q_0 is the initial base production quantity and s is the growth rate trend expressed as an annual percentage change. The proportionate shift K_t is further adjusted as follows:

$$K_t = (E(Y)/\epsilon - (E(C)/(1 + E(Y)))) \times (\rho A_t(1 - \delta_t)) \qquad (2)$$

where $E(Y)$ is the expected proportional yield change per hectare given that research is successful and the resulting interventions fully adopted, $E(C)$ is the proportionate change in the variable costs required to achieve the expected yield, ρ is the probability of research success, δ_t is the linear research depreciation factor, and A_t is the rate of intervention adoption.

The analysis is ex ante. The change in total economic surplus as calculated in Eq. (1) is calculated for a 15 year future time horizon for research that is undertaken in the first 5 of the 15 years. A net present value (NPV) and an internal rate of return (IRR) are calculated relating the benefits (ΔTS_t) to the 5 years of research expenditure.

An efficiency index is then used for the priority ranking of commodities. The efficiency index used in this analysis is the NPV divided by the present value of research expenditures as suggested by Alston et al. (1995). The efficiency index approximates a marginal rate of return which is more appropriate for the priority ranking of commodities for research investment as opposed to both the NPV and the IRR which are average measures of return. Eqs. (1) and (2) and the required data can be easily accommodated in a computer spreadsheet for analysis using the resident NPV and IRR formulas of the spreadsheet.[2]

2.2. Market related data and information

Table 1 presents the required market related data which includes the supply elasticities (ϵ) and the commodity prices (P'_t) and production quantities (Q'_t). Farm level prices and production are used in

[1]This analysis makes use of the small open-economy model with no allowance for market distortions. Assumptions include: (1) the 'small country' assumption meaning that the imports or exports of the commodity have no effect on the world price, (2) the 'open economy' assumption indicating unrestricted trade, and (3) the assumption that there are no market distortions. The extent to which the above assumptions are violated will in turn bias the magnitude of the change in economic surplus attributed to agricultural research. It is argued that the 'small' country assumption is appropriate for most Pakistani commodities; cotton and rice exports and wheat and edible oil imports may influence world prices, but marginally and only in specific years. Pakistan's agricultural economy can be classified as open for many of the minor crops although there exists both formal and informal barriers to trade for some of the major crops (import and export duties). The government support price system works somewhat, but not satisfactorily, for wheat, rice and cotton but has little effect on the prices of the other support price system commodities (Government of Pakistan, 1993, p. 12). A comparison of the results between the open-economy and the closed-economy model for gram and maize has been undertaken indicating little difference between the estimated NPV's (Nagy and Quddus, 1996). As this analysis is ex ante, the above distortions to the small open-economy model may prove not to be so significant for future years as both Pakistan and the rest of the World move toward freer trade and less market distorting policies.

[2]Future analysis could make use of the 'Dream' program as described by Alston et al. (1995), p. 386 which can more effectively take into consideration some of the more prominent market distortions and trade related issues, changes in cropping patterns, and changes in exogenous factors such increased input usage. Unfortunately, the 'Dream' program was not available in time to be used for this analysis. However, the data and information requirements and the time required to undertake the more sophisticated analysis appreciably increases.

Table 1
Market related data

Commodity	Elasticities[a]		Production[b] (000 tonnes)	Price[c] (Rs./tonne)	Production growth rate[d]	
	Supply	Demand			Actual (%)	Exogenous (%)
Food crops						
Wheat	0.43	0.25	15 500	4 500	1.2	2.0
Barley	0.43	0.25	145	4 000	−0.5	2.0
Rice-basmati	0.95	0.70	1 200	6 500	0.8	1.5
Rice-IRRI	0.60	0.40	2 100	3 375	0.1	1.5
Maize	0.60	0.35	1 300	4 500	0.9	1.5
Sorghum	0.55	0.38	230	8 000	0.1	1.0
Millet	0.55	0.38	200	10 000	−0.2	1.0
Cash crops						
Cotton	0.70	0.59	1 650	45 000	3.4	3.0
Sugarcane	0.80	0.45	39 000	550	0.7	1.0
Pulses						
Gram	0.60	0.30	575	16 000	0.4	1.0
Lentil	0.60	0.30	30	18 000	0.1	1.0
Mash	0.60	0.30	30	20 000	−0.5	1.0
Mung	0.60	0.30	90	12 000	2.2	2.0
Oilseeds						
Rapeseed	0.75	0.57	220	12 500	−0.5	2.0
Sunflower	0.75	0.57	70	8 750	5.9	6.0
Soybean	0.75	0.57	6	9 375	0.0	6.0
Groundnut	0.75	0.57	100	20 000	1.2	2.0
Vegetable crops						
Onions	1.00	0.50	850	3 700	5.7	7.0
Chilies	1.00	0.50	120	22 000	0.1	2.0
Tomatoes	1.00	0.50	230	4 500	7.8	10.0
Cole Crops	1.00	0.50	200	5 000	4.4	6.0
Peas	1.00	0.50	75	12 700	0.0	2.0
Cucurbits	1.00	0.50	900	5 000	4.6	5.0
Potato	0.50	0.40	1 100	3 500	2.8	5.0
Orchard crops						
Citrus	0.20	0.76	1 665	8 000	3.9	4.0
Mango	0.20	0.76	790	8 000	2.3	2.5
Banana	0.20	0.76	200	9 000	−5.7[e]	5.0
Apple	0.20	0.76	310	10 000	10.0	5.0
Guava	0.20	0.76	380	7 500	6.4	6.0
Stone fruits	0.20	0.76	255	18 000	7.5	6.0
Livestock (meat)						
Buffalo	0.20	0.80	550	40 000	3.1	3.0
Cattle	0.20	0.80	380	40 000	1.8	2.0
Sheep and goats	0.20	0.80	875	80 000	2.9	3.0
Livestock (milk)						
Buffalo	0.20	0.58	14 000	10 000	2.5	2.5
Cattle	0.20	0.58	4 000	10 000	2.1	2.0
Sheep and goats	0.20	0.58	900	6 000	1.9	2.0

[a] Supply and demand elasticities for food, cash crops, pulses, oilseeds, orchard crops and livestock and livestock products are intermediate elasticities (Pinckney, 1993). Vegetable supply elasticities based on Alston et al. (1995), (p. 322) suggestion of an elasticity of 1.0 if published data is non-existent. Vegetable demand elasticity (Ahmad and Ludlow, 1987). Potato elasticities (Davis et al., 1987).

the analysis. The interest rate used for discounting the benefits and research expenditures to the net present value is 8%. Alston et al. (1995) discusses discount rates and indicate that the World Bank uses a rate between 8% and 10% to reflect the opportunity cost of capital in developing countries.

2.3. Research related data and information

Research related data and information was solicited primarily from research managers and scientists and key extension personnel. A detailed set of questionnaires were developed for both crops and livestock commodities (see Nagy, 1996). Several meetings were held with commodity groups organized through a designated coordinator. While some groups did fill out the questionnaires on their own, it was necessary to work in direct contact with most of the groups using a scaled down set of questions.

Three separate research funding scenarios were analyzed: (1) Scenario I: an ex ante analysis using the present research commodity funding levels and present research management level for each year over the next 5 years, (2) Scenario II: an ex ante analysis using double the present funding level for each year over the next 5 years with a higher research management level than at present, and (3) Scenario III: an ex ante analysis at an 'optimally' funded level with a higher research management level.

In scenarios II and III, a higher level of management implies that the Pakistani agricultural research system would adopt a system of research priority setting and undertake a re-organization of its research program, implement research monitoring and evaluation, improve both national and international cooperation and coordination, and carry out human resource development in accordance with the proposed NMARP. In Scenario III, optimally funded research identifies a level of research funds for a commodity that, in the perception of the researchers, would be adequate to fund sufficient research and support staff and operating and capital costs to conduct high quality research on-station and on-farm within a multi-disciplinary farming systems perspective on the high and medium productivity constraints particular to their commodity. Each commodity group was asked for their perceptions on the required research related data (i.e., that required to calculate K_t in Eq. (2)) for the analysis in relation to the above three stated funding scenarios.

Table 2 presents an estimate of the current (reported) annual research expenditure by commodity along with the expenditure levels used in the analysis for each of the three scenarios. Table 2 also presents the perceptions that each commodity group had with respect to the contribution that research makes to maintenance research (maintaining productivity at its present level). For example, the wheat commodity group indicated that wheat would decline by 20% per hectare in the next 10–15 years if research was terminated as of today. The commodity groups were then asked to relate the three funding and management level scenarios with expected yield changes ($E(Y)$).[3] Again, taking wheat as the example, under Scenario I, the perception is that yield could only be increased by

[3]The commodity groups were given background information and asked a series of questions to elicit the information presented in Table 2. To ascertain the yield percentage that could be attributed to maintenance research, they were asked what the maximum percentage decrease in farm level yields/ha might be in 10–15 years time if all present research programs in Pakistan were entirely discontinued as of today. For each of the three scenarios, they were asked to indicate what the expected percentage yield/ha increase above maintenance levels might be (given that research was successful and the interventions derived from the research fully adopted) in 10–15 years time from a research program funded today at each of the three scenario funding levels. Similar questions were asked of the livestock commodity groups but in terms of livestock efficiency rates.

Footnotes to table 1

[b] 1990–1995 5 year average crop production figures (rounded) and 1994–95 estimated livestock product production figures (rounded) from Agricultural Statistics of Pakistan, (1993–94). Fruit, vegetables and condiment production from Government of Pakistan (1994).

[c] Current (1995–1996) crop farm gate prices from research scientists and extension personnel. Where applicable, grain prices include value of residue (straw). Livestock product prices are from the local rural markets.

[d] Compound growth rates of production figures for the years 1980–81 to 1993–94 based on data from Agricultural Statistics of Pakistan, (1993–94). Exogenous future production growth rates based on past growth rates and perceptions of scientists and extension specialists.

[e] Disease severely depressed banana production in the past several years. The growth rate before the disease problem was 6.0% per annum.

Table 2
Research expenditures and expected yield increases from research

Commodity	Research expenditures (millions of rupees)[a]				Percent yield attributed to research[b]			
	Reported	Scenario I	Scenario II	Scenario III	Maintenance	Scenario I	Scenario II	Scenario III
Food crops								
Wheat	27.5	34.0	68.0	200.0	−20	2	15	35
Barley	0.1	0.1	6.0	60.0	0	1	15	100
Rice-basmati	12.5	16.0	32.0	65.0	−25	1	75	100
Rice-IRRI	12.5	16.0	32.0	65.0	−20	2	75	125
Maize	22.0	28.0	56.0	85.0	−40	3	20	40
Sorghum	2.0	2.5	5.0	15.0	0	2	20	80
Millet	1.5	1.9	4.0	11.0	−1	2	20	80
Cash crops								
Cotton	88.0	110.0	220.0	550.0	−35	0	20	85
Sugarcane	21.0	26.0	52.0	155.0	−35	1	20	40
Pulses								
Gram	4.0	5.0	10.0	30.0	−40	1	20	70
Lentil	0.9	1.5	3.0	9.0	−40	1	20	70
Mash	0.5	1.0	2.0	6.0	−40	1	20	70
Mung	0.5	1.0	2.0	6.0	−40	1	20	70
Oilseeds								
Rapeseed	10.0	14.5	25.0	50.0	−30	20	30	100
Sunflower	12.0	15.0	30.0	60.0	−30	25	30	100
Soybean	5.5	7.0	14.0	28.0	−50	3	30	100
Groundnut	2.4	3.0	6.0	12.0	−15	2	20	75
Vegetable crops								
Onions	5.5	7.0	14.0	28.0	−35	1	15	35
Chilies	2.7	3.5	7.0	14.0	−50	1	20	40
Tomatoes	5.1	6.5	13.0	26.0	−40	1	60	125
Cole crops	2.4	3.0	6.0	12.0	−35	1	15	35
Peas	1.9	2.5	5.0	10.0	−50	1	40	60
Cucurbits	2.4	3.0	6.0	12.0	−30	1	15	30
Potato	12.5	16.0	32.0	65.0	−30	2	5	20
Orchard crops								
Citrus	19.4	24.0	48.0	120.0	−30	5	25	80
Mango	5.4	7.0	14.0	70.0	−30	0	5	40
Banana	1.6	2.0	4.0	10.0	−30	0	10	20
Apple	12.6	16.0	32.0	65.0	−25	10	30	50
Guava	4.5	5.5	11.0	28.0	0	5	50	70
Stone fruits	8.5	10.5	21.0	53.0	−30	10	20	50
Livestock (meat)								
Buffalo	61.6	75.0	150.0	300.0	−2	0	5	20
Cattle	50.0	60.0	120.0	240.0	−2	0	5	20
Sheep/goats	10.0	12.5	120.0	200.0	−2	0	5	20
Livestock (milk)								
Buffalo	—	—	—	—	−2	0	5	20
Cattle	—		—	—	−2	0	5	20
Sheep/goats	—	—	—	—	−5	0	5	20

an absolute 2% whereas under increased management and funding levels, the increase to yields from research in Scenario II and III are 15% and 35%, respectively.

As not all research is successful, the proportionate shift down the supply curve due to research is adjusted by the probability of research success (ρ). Coming to a conclusion about the probability of research success proved to be difficult. (Alston et al. (1995), p. 438) offer an estimation method but it proved to be difficult to use. However, a consensus emerged from the commodity groups that: (1) the larger and more varied the commodity research program, the more the overall research success rate would drop, and (2) crop commodity research programs, at this time, have a higher probability of success than livestock commodity research programs with the possible exception of orchard fruit crops. On this basis, the probability of research success used for field crops was set at 0.8, 0.7 and 0.6 for Scenarios I, II, and III respectively. The probability for orchard crops, livestock, and livestock products research was set at 0.7, 0.6 and 0.5 for Scenarios I, II, and III, respectively.

The commodity groups decided to use what they determined as a standard research lag and expected farmer adoption rate (A_t) across all commodities and funding scenarios with the exception of orchard fruit crops. The average research lag for all commodities was set at 5 years with the exception of fruit crops which was set at 7 years. The farmer adoption rate was set at 5% starting in year 6 to allow for the research lag (year 8 for orchard crops) and increased to 10% in the next year increasing by an absolute 5% a year thereafter.

Production increases occur from sources other than agricultural research or can occur from research spill-in by directly using interventions researched and totally funded by other than Pakistani sources. Discussions were held and the commodity groups were asked for their perception of the average yearly percentage increase in production (s) that may occur over the next 15 years from non-research sources, research spill-in and from possible changes in the cropping pattern. Table 1 presents past production growth rates and the exogenous growth rates (s) that were used in the analysis for each commodity.

Assessing expected research depreciation rates (δ_t) proved to be difficult. The same research depreciation rates as given in the original economic surplus model specified by (Alston et al. (1995), p. 382) were used. Depreciation sets in the 9th year and increases yearly by an absolute 5%.

The adoption of an intervention may involve a change in the amount of purchased inputs required to make use of the new intervention. The costs from intervention adoption may increase or decrease the production costs/ha or may have no effect on the cost structure. These cost changes ($E(C)$) must be accounted for by either subtracting or adding them to the overall change in economic surplus. There was a consensus that for Scenarios I and II research programs, there would be little or no change in these costs as most interventions from the two research agendas would likely be improved seed and better agronomic management practices. However, the expanded research agenda of Scenario III would likely mean some changes in farming system practices and methods resulting in an increase in such costs. A 10% increase in the proportionate change in the cost/tonne

Footnotes to table 2

[a] Reported research expenditures obtained from senior Pakistani research scientists, provincial research master plans (PRMP's), and personal communication with PARC and Provincial researchers and research managers. Scenario I is the reported research expenditures plus 25% added for management and cross-commodity discipline costs. The Scenario II expenditure is twice than that of Scenario I funding and Scenario III expenditures are the optimal funding levels as given by the research scientists (except for barley expenditure in Scenario II which researchers estimated so as to be on par with other commodities).

[b] Estimates of maintenance research and percentage yield changes under the three scenarios from personal communication with Pakistani senior research scientists and their colleagues. Maintenance research is the maximum percentage decrease in farm level yield/ha or productivity/animal that may occur in 10–15 years time if the present research programs were entirely discontinued today. Scenario I: the percentage increase in farm level yield/ha or productivity/animal above maintenance (if research is successful and fully adopted) in 5–15 years time if future research programs are funded at present expenditure levels with existing management and organization of the research system. Scenario II and Scenario III: the percentage increase in farm level yield/ha or productivity/animal above maintenance (if research is successful and fully adopted) in 5–15 years time if the research programs were funded at double present and at optimum funding levels respectively.

of output is used in the Scenario III analysis to account for the anticipated cost increase.

3. Results and discussion

3.1. Scenario I results

Table 3 presents the NPV and IRR resulting from the economic surplus analysis for each commodity under Scenario I data and assumptions. The commodities are arranged in descending order of magnitude of their NPV. The NPV are the projected benefits from undertaking research in the future at present yearly funding amounts (as given in Table 2 Column 3) and present management levels. The NPV reflect both the benefits from doing maintenance research and any benefits from research above the maintenance levels. For example, Scientists indicated that maintenance research on wheat is responsible for 20% of current wheat yield/ha and it was their perception that under current funding levels, they could only increase wheat yield/ha through research by an absolute increase of 2% (Table 2).

Table 3
Scenario I net present value and internal rate of return

Commodity	NPV (Rs. million)	IRR (%)
Field and orchard crops		
Cotton	37 000	101
Wheat	32 200	141
Citrus	13 650	91
Sugarcane	7 800	100
Apple	6 950	69
Stone fruits	6 600	92
Gram	5 200	146
Mango	4 800	97
Rapeseed	3 600	75
Maize	3 450	74
Rice-IRRI	2 350	79
Potato	2 075	76
Rice-basmati	1 775	71
Onions	1 700	87
Cucurbits	1 700	116
Chilies	1 230	91
Banana	1 200	91
Tomatoes	830	69
Mung	667	127
Sunflower	550	47
Guava	495	53
Cole crops	471	77
Peas	436	82
Groundnut	385	82
Mash	334	103
Lentil	303	93
Soybean	280	17
Millet	75	49
Sorghum	45	34
Barley	0	0.0
Livestock and livestock products		
Buffalo	10 800	78
Sheep and goats	6 400	116
Cattle	4 000	58

Under Scenario I, the monetary return to research (NPV) is largest for cotton, wheat and citrus with a number crops experiencing little or no effect from research programs. The IRR from most commodity research programs are high. However, the information from Table 2 and the ex ante economic surplus analysis results presented in Table 3 identify three important points. First, much of the research undertaken by the Pakistan agricultural research system is maintenance research and little contribution is being made by Pakistan's present research system to increase crop yields and livestock productivity. Second, the results underscore the importance of maintenance research and the effort that is required from the Pakistan agricultural research system to just keep crop yields and livestock productivity at their present levels. Third, the Pakistan agricultural research system can not hope to contribute much to the narrowing of any food and fiber deficit over the coming years (as projected by IFPRI) under an agricultural research system with Scenario I funding and research management levels. Most crop scientists believe that any further erosion of funding and research management levels will lead to a decrease in the ability of the Pakistan agricultural research system to even keep pace with maintenance research and ultimately, crop yields will begin to decrease.

The Scenario I results give the current situation, and the likely future situation, if the Pakistan agricultural research system does not invest more funds in research and increase the management level of the research system in accordance with the proposed NMARP. Ordinarily, for a fully funded research system, an efficiency index would be calculated for each of the commodities in Table 3 and they would be ranked. However, it was decided

Table 4
Scenario I and Scenario II commodity ranking by efficiency index

Scenario II				Scenario III			
Efficiency				Efficiency			
Rank	Commodity	Index	IRR (%)	Rank	Commodity	Index	IRR (%)
1	Gram	183	128	1	Wheat	80	97
2	Wheat	180	108	2	Citrus	71	74
3	Mung	118	111	3	Gram	71	104
4	Citrus	104	82	4	Mung	62	89
5	Mango	100	80	5	Cucurbits	53	81
6	Cucurbits	98	101	6	Rice-IRRI	50	85
7	Stone fruit	93	79	7	Stone fruit	50	104
8	Banana	90	77	8	Banana	48	68
9	Rice-IRRI	77	99	9	Cotton	46	81
10	Cotton	62	90	10	Guava	46	66
11	Chilies	60	89	11	Millet	39	84
12	Guava	60	71	12	Chilies	33	70
13	Mash	58	89	13	Mango	33	58
14	Rice-basmati	50	86	14	Mash	30	70
15	Sugarcane	40	78	15	Tomato	27	100
16	Onions	39	73	16	Sorghum	27	70
17	Tomato	37	71	17	Rice-basmati	26	68
18	Peas	36	75	18	Rapeseed	23	57
19	Apples	35	62	19	Onions	22	59
20	Lentil	35	90	20	Apples	22	52
21	Millet	33	75	21	Sugarcane	20	61
22	Groundnut	31	76	22	Peas	19	58
23	Rapeseed	30	58	23	Lentil	18	58
24	Cole Crops	26	64	24	Cole crops	15	51
25	Sorghum	23	66	25	Maize	15	34
26	Maize	20	63	26	Potato	11	49
27	Potato	17	55	27	Groundnut	7	71
28	Barley	6	37	28	Sunflower	4	32
29	Soybean	6	16	29	Barley	3	20
30	Sunflower	4	30	30	Soybean	0	0
Livestock and livestock products							
1.	Buffalo	56	86	1.	Buffalo	69	96
2.	Sheep/goat	36	74	2.	Sheep/goat	60	92
3.	Cattle	27	65	3.	Cattle	33	74

to expand the analysis to Scenario II and Scenario III data and assumptions to identify a research strategy based on a more robust funded research system.

3.2. Scenario II and Scenario III results

Table 4 presents the commodity rankings by their efficiency indexes (NPV's/present value of research expenditures) from future agricultural research given the data and assumptions for Scenario II (double present funding) and Scenario III (optimal funding).[4] The IRR are also presented for both scenarios and are substantial with the exception of the new

[4]The difference between prioritizing research on a commodity basis using the efficiency index criteria versus a prioritization by the NPV criteria was compared using Scenario III (for details, see Nagy and Quddus, 1996). To exhaust a total research budget of Rs. 5 billion, prioritizing crops by the efficiency index allowed for a larger number of commodities to be researched (15 vs. 8) and returned a NPV of Rs. 3.53 billion (US$ 100 million) more than a research strategy based on a criteria of highest NPV.

Table 5
Summary by commodity group

Commodity group	Scenario II			Scenario III		
	NPV (Rs. million)	Present value of research expenditures (Rs. million)	Efficiency index	NPV (Rs. million)	Present value of research expenditures (Rs. million)	Efficiency index
I. *Crops*						
Pulses	9 130	68	134	14 255	244	58
Fruits	41 855	464	90	64 250	1 371	47
Cereal crops	70 225	811	87	92 835	2 004	46
Cotton	54 700	880	62	102 000	2 200	46
Vegetables	9 436	182	52	11 011	404	27
Sugarcane	8 450	210	40	12 700	620	20
Potato	2 150	130	17	2 855	260	11
Oilseeds	4 425	287	15	5 725	525	11
Total	200 371	3 032	66	305 631	7 628	40
II. *Livestock and livestock products*						
Buffalo	34 000	600	56	82 800	1 200	69
Sheep/goat	17 500	480	36	48 300	800	60
Cattle	12 800	480	27	31 600	960	33
Total	64 300	1 560	41	162 700	2 960	55

development crop of soybeans. All Scenario III crop and livestock commodity NPV's (not shown) attributed to the research investment are larger than those for Scenario II and both have substantially higher commodity NPV's than Scenario I. In general, Scenario III crop efficiency indexes are lower than those of Scenario II (with the exception of millet and sorghum) as are Scenario III IRR relative to Scenario II IRR (with the exception of millet, sorghum, stonefruits, tomato, and sunflower). It would be expected that, as each commodity research budget increases, a point would be reached (diminishing returns) where the IRR would begin to decrease. For livestock and livestock products, Scenario III efficiency indexes and IRR are lower than those of Scenario II indicating, that based on the information provided by the commodity groups, the point of diminishing returns has not been reached.

Table 5 presents a summary by commodity groupings. As a group, pulses have the highest efficiency index followed by fruits, cereal crops and cotton. Oilseeds, as a group, have the lowest efficiency index indicating that all other crop groupings would be likely to give a higher return on investment from research. Rapeseed is the only oilseed with a significantly high efficiency index in both Scenarios II and III (Table 4). Groundnut, sunflower and soybeans have very low relative efficiency indexes especially in Scenario III. Although scientists indicated that oilseed yields could be substantially increased under Scenario II and III, the major reason for the low efficiency index is that their present levels of cropped area and production are very low. This is same for potatoes and barley. These crops could be classified as new development crops although both barley and rapeseed are not new crops. The funding effort for these crops should rest on what researchers and extension specialists think will happen to the future increase in the planted area and production of each crop. If the increase in cropped area over the next 10–15 years is estimated to be low, then the efficiency index will not improve relative to the other crops and the research funds should go elsewhere. But if plans are put into place to accelerate the planted area of a commodity, then the efficiency index will increase and may be on par with other commodities. For example, a reworking of the economic surplus analysis for Scenario III indicates that production would have to be five times current production for potatoes, ten times that of current sunflower, barley and groundnut production, and 1000 times that of soybean production before the NPV's and resulting efficiency indexes for each commodity would approach 50. If these magnitudes of planted area and resulting production increases can be achieved within 5–10 years, then these crops deserve to be elevated to a higher priority ranking than presently indicated in Table 4.[5]

3.3. Sensitivity analysis

The commodity rankings presented in Table 3 through 5 are subject to the assumptions made for each commodity and commodity group and the ranking could well change with a change in these assumptions. In particular, the research related data and information elicited from scientists on the subjective yield increases will always be a matter of debate. A sensitivity analysis of the economic surplus model parameters for wheat was conducted (Nagy and Quddus, 1996). IRR were not sensitive to parameter changes but the NPV does appreciably change with large parameter changes. In the case of wheat, a 11% decrease in the subjective wheat yield in Scenario III (from Table 2) would be required before wheat would be dislodged from its number one ranking with an Efficiency Index of 70. A 25% decrease in the subjective wheat yield in Scenario III would decrease the NPV so that the resulting efficiency index was equal to 56 which would then rank wheat as number four in Table 4. An increase in the supply elasticity parameter by 0.1, the changing of the probability of research success parameter by 0.1 from 0.6 to 0.5, and the increase in annual research expenditures by 20% for wheat in Scenario III would result in an Efficiency Index of 63, 68, and 79 respectively. Thus the ranking of a particular commodity could change by one or more rankings given different assumptions but it would take unrealistic changes in the assumptions before a commodities ranking would substantially change.

[5]The economic surplus method is, as are most other priority setting methodologies, best at working with established commodities that have a history from which data and information for the ex ante analysis can be projected into the future. The economic surplus method can be used to include new development commodities into the priority setting process, however, scientists, research managers and extension specialists will be called upon to make projections for the required information based on little historical evidence.

4. Discussion

4.1. A strategy for research organization

The commodity research priority rankings presented in Tables 4 and 5 are to be used as information by research managers and funding agencies (GOP and Donors) to help identify appropriate overall funding levels and focus the research agenda of the overall Pakistan agricultural research system. In Table 4, the commodities and commodity groups are prioritized on an efficiency criteria basis – the commodities that give the best returns for the research investment are given priority. A strategy would be to identify the size of the overall research budget and which Scenario to follow for the next 5 years and invest in the commodities in order of research priority until the research budget is exhausted. Those commodities that exhibit a negative IRR and those commodities that have lower IRR than alternative uses for the funding should not be funded. If the total budget is exhausted before the end of the list is reached, then those commodities and commodity groups remaining would not be funded. Research prioritized on this basis would translate into a research agenda that is best at increasing productivity from an efficiency standpoint.

The above strategy may be unpalatable to both politicians and research managers. Both equity and security criteria have not been brought into the analysis.[6] A country may not wish to implement a

[6]There will be those who will also want to include the non-efficiency objectives of equity (increasing the well-being of various deprived groups in society) and security (reducing the variability of well-being over time) as research objectives along with the efficiency objective. However, it has to be pointed out that an agricultural research system is best at helping a country achieve its efficiency objectives through increasing productivity (Alston et al., 1995, pp. 14–16). (Ruttan, 1982, p. 346) indicates that "a nation's agricultural research budget can be a powerful instrument for expanding its capacity to produce food and fiber, but it is a relatively week instrument for changing income distribution in rural areas". There is a cost to society in biasing the research portfolio by pursuing non-efficiency goals. The returns to agricultural research investment are higher from an efficiency driven research portfolio than from a research system that includes non-efficiency goals and objectives. Before committing scarce agricultural research resources to non-efficiency goals and objectives, other policy instruments should be considered first.

research strategy that does not fund most commodities to at least the maintenance level. In the first instance, the commodity research priorities at the national level should be used as baseline information for dialogue for setting an agricultural research agenda and the level of investment. The information from Table 4, which is based on the efficiency criteria, should be adhered to as close as possible with equity and security considerations only catered to when shown to be practical and when other policy instruments are not available. Other issues may be brought into the discussion such as sustainability, soil degradation and environmental issues. The discussions on equity and security and these other issues may change the ranking of some of the commodity and commodity groups in Table 4. With this in mind, a proposed strategy is to identify three categories of research intensity as follows (adapted from Dey and Norton, 1993):

- Category I. High priority: The commodities in this priority group would receive full funding and would be the core of the research conducted within the research system. Research programs would cover a broad spectrum of research on the high and medium priority constraints to increased productivity through research conducted within the appropriate disciplines on-station and through farming-systems on-farm research and have extensive linkages to extension and other regional and international programs. These commodities should be those that exhibit high efficiency indexes.
- Category II. Medium priority: This second group of commodities would receive research funding for partial programs that would concentrate on researching the most critical constraints to increased productivity where there is a likelihood of there being a good return to the research investment. Extension and regional and international linkages would be focused on these critical constraints.
- Category III. Low priority: This third group would include commodities that might not maintain research programs or at most, be maintenance research programs. However, funds would be used to keep abreast of regional and international research so that any opportunity for appropriate technology transfer from other regions or countries can be fully taken advantage of.[7]

The above strategy has been proposed to the PARC and is part of the overall NMARP strategy. Once the level of overall financial commitment is made and the commodities and commodity groups organized on a national basis within each of the three research intensity categories, research managers can then identify and reorganize research programs at the institution and program levels of the Pakistan agricultural research system that reflect the national commitment. Included in the strategy is the need to identify which research should be left to the private sector, which research should remain within the public sector domain and what proportion of research should be funded through traditional block grants or through competitive research grants to which both public and private researchers are eligible.

4.2. Concluding comments

The methodology and analysis has limitations. The economic surplus model used for the analysis is a partial equilibrium model. A general equilibrium model could, if modeled correctly, deal with cross-commodity effects on prices and technology spillovers and better deal with such issues as cropping pattern changes and other variables that were treated as exogenous in the present model. Such a model could also deal with the market distortions and trade related issues which the open economy model assumed away. The elicitation of judgment parameters such as the probability of research success, expected yield increase from research, and research depreciation

[7] Organizing a national research agenda within the three Category framework emulates what the results of a mathematical programming priority setting analysis might produce (see Alston et al., Chapter 6 for a review of the mathematical programming methodology). Each commodity has a number of research program alternatives that focus on various constraints or sets of constraints that hinder productivity increases. Associated with each program alternative is the benefit (increase in productivity) and the cost of doing the research. Category I commodities would include those commodities that have had all or most of their research programs come into solution. Category II commodities are those that have only one or two program alternatives come into solution, and Category III commodities are those that may not have any research programs come into solution, or at best one.

factors could be made more robust. While a worthwhile pursuit, such detailed modeling may be beyond the scope of the most priority setting exercises and unmanageable from the standpoint of the time required, available information, and existing resources and expertise. When using the model and approach used in this paper, the researcher must decide whether the results are sufficiently robust through sensitivity analysis, discussions with peers, and from an intimate knowledge of the agriculture sector and the agricultural research system. Using a general equilibrium model as described above and better methods to obtain more robust judgment parameters will undoubtedly change some of the commodity rankings relative to the rankings from the method used in this paper. However, based on the sensitivity analysis and a priori knowledge, it is anticipated that in most cases, the change in ranking would likely be a change in one, two or three positions. This is unlikely to substantially change the placing of commodities in one of the three categories of research intensity identified and discussed above.

This is a first major attempt at priority setting by commodity at the national level for Pakistan using an ex ante economic surplus analysis. Priority setting on a national basis need only be undertaken every 5 years and should be made to coincide with, and be part of, Pakistan's Five Year Plans. Subsequent work needs to be carried out over the next few years to streamline the process and make the results more robust. It may take several more attempts at priority setting before this process becomes institutionalized and policy makers and research managers become comfortable with using the results. The use of formal priority setting methodologies such as the ex ante economic surplus method should be used to add to the information used by policy makers and research managers but should not be used as a substitute for logic and good judgment. Obtaining a list of commodity priorities is only part of the work: the remaining part is organizing and using the information to formulate a long-term research strategy and communicating the results to research managers and policy makers.

A future research agenda awaits the Pakistan agricultural research system. The NMARP has mapped out a long-term strategy that would culminate in organizing the research system in accordance with Scenario III priorities and funding levels. Scientists and research managers indicated that an optimally funded research system would require funding at five–six times current funding levels which would bring it close to 1.5% of agriculture gross domestic product. However, the present national and international climate for funding agricultural research will not entertain an immediate five or six fold increase in funding, nor is the Pakistan research system, at this point in time, in a position to accept these higher levels of funding without further institutional strengthening so that research resources are used effectively and efficiently. Achieving the goals of an optimally funded agricultural research system can only be done in stages and may take 10 to 15 years to accomplish.

Acknowledgements

The authors would like to acknowledge the contributions made by the Chairman, PARC, the coordinators of the priority setting commodity groups, and the contributing PARC and Provincial research scientists. Our gratitude is also extended to Drs. Rashed-ul-Qayyum and Ivar Serejski, The World Bank, and to Stan Western, Hunting Technical Services Ltd. However, comments and conclusions drawn from the analysis are to be associated with the authors and may not entirely reflect PARC, GOP, or World Bank views.

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