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A Note on Agricultural Research Priorities in the Third World with Special Reference to Nepal

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This is, if you wish, a report on "research about research". Although we are all aware of the potential power of research-especially biological research of the "Green Revolution" type-in the less developed parts of the world, academics and policy makers have almost universally felt uncomfortable in making strong statements about just where to put new research investments, and just what form the distribution of benefits is likely to take. We can, of course, make broad historical and cross-cultural comparisons which allow us to see the effects of different patterns of investments in research and allow us to draw broad conclusions about both the total benefits of research in increasing agricultural production, and about the distribution of the benefits. The policy makers, however, are quick to observe that conclusions drawn from broad historical and cross-cultural date are frequently inadequate for the decisions that they must make today in order to meet the needs of tomorrow and of future generations.

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Technical Change in Agriculture-a Broad View

In the post-war years, economists and agricultural economists have been successful in quantifying the relations between inputs and outputs with production functions and input-output models. In the case of agriculture, production functions relate quantities of inputs, such as land, labour, capital, fertilizers, irrigation, etc., to outputs. The outputs may be specific commodities such as poultry, cotton, and wheat or an aggregate of all agricultural commodities. Production functions may be used to estimate the percentage change in output resulting from a one percent change in an output or in a group of inputs. They may also be used to estimate changes in the final value of output resulting from reasonable incremental changes in any given input. Traditionally, little has been done in the way of integrating explicit variables for technical change into the production function.

Technical changes, to a great extent in the more developed countries, and, to an even greater extent In the less developed countries, is the consequence of public investment in research. Because of this, it is desirable to discover decision rules governing the allocation of public resources between research and other public sector expenditure sectors, and among the various competing disciplines within the research sector itself. Studies which have estimated rates of return on research are an important step in this direction. Studies which try to account for the sources of economic growth provide other insightful examples.

Table 1 provides an accounting of the differences in labour productivity between eleven less developed countries and four recently developed countries. The categories of "resource endowments", "technical inputs", and "human capital" account for 96 percent of the differences in labour productivity. The importance of human capital relative to resource endowments and technical inputs is stunning. Table 2 presents a summary of findings about the productivity of agricultural research resulting from the sources-of-growth-type literature. Again, the magnitude of the internal rates of reture reported by these researchers suggests that both the developed and the less developed countries have long overlooked-and may still be overlooking-a very important source of growth in their agricultural sectors. Table 3 summarizes cost-benefit-type research on various crops in various countries. Here we observe very high internal rates of return across a wide spectrum of crops and geographic areas, suggesting that high rates of return on agricultural research may be generally attainable throughout the world.

Despite this evidence of high productivity in agricultural research, the policy-maker, research director and untversity administrator may feel seme uncertainty in research funds. And well they might. beacause the functional relationships between research expenditures and increases in productivity are still obscure. Monies are expended on research, and agricultural productivity increases.

Somewhere in the process there are scientists, laboratories, experiment stations etc.; somewhere decisions are made about the allocation of research monies between basic or science-oriented research on one hand and applied or technology-oriented research on the other. One way to unveil the mysterious linkages lying behind the expenditures of monies and the increase in production is to include scientific research somehow in the aggregate production function for agriculture. A first and very significant step in this direction has been taken by Robert E. Evenson.

Research on Research

Evenson postulates a relationship between research and increases in productivity which incorporates a set of time lags and a relationship between basic and science oriented research and applied or technology-oriented research.[1] Discriminating between applied and basic research is no easy task; indeed, even deciding what is research and what is not, is very difficult when making cross-country and inter-temporal comparisons. At the conceptual level, however, it is possible to discriminate between applied and basic research on the grounds that basic research is research which extends the frontiers of knowledge in a particular field. Applied research is that research which translates, modifies, and adapts basic research and other applied research in such a way as to give it an economic application. Thus, for instance, research on gene linkages which determine the amino acid composition in a particular millet or family of millets would be basic research. Work by plant breeders to in-corporate those desirable characteristics into a new variety of millet would be classed as applied research. Within these terms of reference it should be quite clear that the productivity of applied research is ultimately dependent on the stock of knowledge which has been and continues to be generated by basic research.

Lest the differentiation of research into the categories "basic" and "applied" be misunderstood, let me state very clearly that both types of research require very high levels of skill and training. When I refer to scientists doing basic and applied research in agricultural I am, in general, referring to the men and women with Ph. D.'s from the better universities of the world. Often they will have formal and in-service training beyond the Ph. D. level. These two classes of scientists have different skills,

1. Evhnson, Robert E "Comparative Evidence on Returns to Investment in National and International Research Institutions". Paper delivered at the conferenc on Research Allocation and Productivity in International Agricultural Research, Arlie House, Virginia, January 26-29, 1975.

but in no way is it reasonable to assume that the applied scientist is less trained well than the basic scientist. In fact, if applied agricultural sciences depend on the basic sciences to provide them with new information on the frontiers of knowledge of the various disciplines, it is imperatave that the applied scientist be able to read and understand the full extent and meaning of the research of the basic scientist.

What Evenson has tried to do is to estimate a production function for knowledge in the agricultural sciences. The measures of both inputs and outputs presented him with considerable difficulties. The definition of who is a scientist is by no means constant across countries and time. The conceptual and operational difficulties in defining and measuring scientific knowledge are even more mind-boggling. Evenson's solution was ingenious: for a measure of research inputs, he used the number of publications abstracted in two international abstracts of scientific articles; for a measure of the output of (relevant) knowledge, he used changes in agricultural productivity.

What Evenson has done is to fit a production function using an index of output as the dependent variable and indices of land, fertilizer, and scientific publications as independent variables. By using abstracted scientific publications as a measure of scientific input in efficiency terms, Evenson avoided the difficulties related to the definition of a scientist which arise in international and time series data. What he substituted was a measure of scientific input in efficiency terms. In this sense his use of scientific articles as as an input to the regression equation is akin to the use of "capital services" instead of a complex vector of physical capital stocks in a planning model. Evenson's use of abstracted scientific articles as an input to the production function is, in itself, a highly relevant measure of scientific output. It has enabled him to divide research projects according to his typology of basic (science-oriented) and applied (technology-oriented) research. It has also allowed research to be conveniently identified with particular crops (where crop-specific) and with specific micro-climatic and geographic zones As a source of information about basic os science oriented publications, he used journal Biological Abstracts; for a source of applied or technology-oriented publications he has used Plant Breeding Abstracts. Biological Abstracts routinely screens the international literature for articles of merit in the areas of plant physiology, plant genetics, experimental design, microbiology, phytopathology, soil science, and related agricultural scientific subjects. Plant Breeding Abstracts routinely screens the international literature for articles of merit relating to specific crops.

Evenson's regressions are appealing on two counts: first, the functional form which has been chosen addresses the question of how basic research relates to applied research, how research in one agro-climatic zone or region relates to research in another and how both basic and applied research relate to agricultural productivity;

second, the estimates of the parameters are good enough to be used to estimate the economic value of research expenditures once a linkage is made between research expenditures and the production of publishable journal articles of merit.

Prior to dealing in detail with Evenson's findings and their implications for a country like Nepal, I will present some background information on the conceptual and practical linkages between basic and applied research.

The Nature of Biological Constraints

The rapid adoption of high-yielding varietis of rice and wheat by large numbers of so-called "backward" peasants-as well as by the better educated-across Asia, North Africa and Latin America rather strongly suggests that the constraints on increased production lie more substantially in the lack of appropriate genetic material than in any fundamental economic, social, political or intellectual deficiency on the parts of governments, societies, farmers, or modes of economic production.*

I do not mean to imply that socio-economic and political constraints were not binding in some cases or that they will not become binding in the future.

The first and most basic biological constraint to be broken was that of plant architecture. Native varieties of paddy and wheat tend to lodge under even sub-optimal environmental conditions. Experiments in the Philippines have shown that some of the high-yielding varieties of paddy give a higher yield per hectare than native varieties, even without the application of chemical fertilizers. Along with the improved architecture of the paddy plant came erect leaves which are photosynthetically more efficient than those of the traditional varieties. Most of all, the high-yielding varieties were able to utilize large quantities of chemical fertilizers, and to do so more efficiently than the native varieties.

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* By no means do I wish to suggest that the adoption of high-yielding varieties and the accompaning inputs of pesticides and fertilizers represents the only true path to agricultural self-sufficiency and the generation of marketable surplus on which to base a programme of industrialization. In particular, I would point to the People's Republic of China as an example of the productive power of radical re-organizations in social, political, and economic structure. Although I have not visited China and have not read extensively on the organization of agricultural production there, it appears to me that the ability of the Chinese people to feed themselves in the post-Revolution period has intimately associated with the re-organization of rural, social, and ecomic institutions and the use of more manpower at the farm and community level. This, I presume, was possible because of the Chinese leadership's intimate knowledge of agrarian conditions, stemming from the long march and the necessity of the revolutionaries to establish and hold a rural power base. The Russian Revolution stands in glaring contrast.

The new varieties also had serious drawbacks These were eloquently enumerated as early as 1969 by Clifton Wharton;[2] others have joined the chorus [3] From the technical standpoint the most penetrating criticisms focused on presumed disease susceptibility; the fact that the high-yielding varieties had been bred for and were edapted only to a narrow range of soil, water, and temperature conditions which were not typical of the vast majority of the paddy and wheat lands in Asia; and that they did not conveniently fit into the myriad cropping patterns which had been developed over many centuries Although we are now well into the second generation of high-yielding varities, I think it is fair to say that these early criticisms still hold. Where lies the possibility of breaking these newly binding constraints ?

Before addressing this question, however, it should be pointed out that the basic plant material which produced the dwarfing characteristics of the high yielding varieties of wheat and paddy were not the products of fundamental research in biology or plant genetics. The dwarf which provides part of the genetic heritage of the "miracle" wheats was first reported in Japan in 1872. The dwarfing gene in paddy came from Taiwanese varieties. The scientists at the International Rice Research Institute began with Taichung Native I, a semi-dwarf variety developed in Taiwan, a variety called Dee-geo-woo-gen" which had given Taichung Native I its short stature and with "I-geo-tze", a close relative of "Dee-geo-woo-gen". Using this genetic material, the plant breeders at IRRI "did their thing" in 1962, producing 38 crosses with other varieties from the tropics.[4] After three years, selections from one of the crosses with an Indonesian variety produced the variety IR-8. The variety IR-8 was non-photo-period sensitive, it matured in 120 days (as opposed to 140 and 160 days for traditional varieties) and it exhibited some desirable characteristics with respect to disease resistance: it had upright leaves; a stiff straw; and a high tillering propensity. By 1966/67, 2.7 percent of the paddy area in the Philippines was planted to the high-yielding varieties. By 1971/72, 56.7 percent of the area had come under the high-yielding varieties. By 1970/71, 50 percent of the area had come under the high-yielding varieties. After that the rate of increase diminished considerably; and in 1972/73, the proportion of the area planted to the high-yielding varieties fell below the portion achieved in the previous year. Table 4 gives the rates of adoption of several Asian countries in terms of the proportion of their respective paddy acreages which were planted to the high-yielding varieties.

2. Wharton, Clifton R. Jr. "The Green Revolution: Cornucopia or Pandora's Box." Foreign Affairs, April 1969, pp. 464-76.
3. For a recent work dealing with these and other issues, see: Castillo, Gellia T. All in a Grain of Rice. Southeast Asian Regional Center for Graduate Study in Research and Agriculture, 1975.
4. Ibid, Chapter 2

Although a great deal of attention has been focused on plants as converters of nitrates into vegetable proteins, the fact is often overlooked that plants are first and foremost organisms which fix carbon di-oxide through the mechanism of photosynthesis. There are perhaps a hundred or more chemical steps involved in this fixation among man's economic plants.[5] At any one time and place perhaps only one or a few of the chemical steps in the complex processes of photosynthesis are limiting or binding constraints. That is, in any particular environment, the rate of fixation of carbon di-oxide by a given plant may be limited by only one or a few of the many chemical reactions involved. The same plant, when moved to another environment, may become a more, or less, efficient organism for the fiixation of corbon di-oxide depending on the particular configuration of chemical processes which the plant in question uses and the new constellation of environmental characteristics in which it is growing.

Paddy, kodo and maize provide examples in parts of Nepal. In the kharif season they all grow well up to about 6000 feet of elevation That is the elevation approximately at which heavy clouds cling to many of the hillsides. Paddy appears to stop quite abruptly at this point; kodo and maize continue upward. Perhaps a thousand feet higher, maize becomes less common, until only kodo is seen. Somewhat higher, the kodo is replaced by summer barley. On the basis of casual observation, I would say that there are three principal environment a factors which confine paddy to elevations of less than 6000 feet: air temperature, water temperature and photosynthetic exposure. Of the three, I suspect that photosynthetic exposure is the most constraining environmental variable. Maize and kodo would appear to be relatively photosynthetically more efficient, given the other environmental conditions which exist. Below the limiting elevation for paddy, I suspect that distinctly different varieties are found growing on slopes with different exposures to the sun and different altitudes. Over many centuries it has been possible for farmers to select for successful paddy varieties which are relatively well suited to local environmental conditions. Even in the case of crops like maize and potato which are not likely to have been in use in Nepal for more than 200 on 300 years, the selection process has resulted in widespread adoption under a variety of environmental conditions.

An even more impressive example is to be found in the natural flora of the hills and mountains. Even minor differences in exposure, soil type, rainfall, and altitude may result in significant changes in plant species and plant communities. But here. the time for adjustment and "fine tuning" of the biological species to environmental coditions is to be measured in tens of thousands of years.

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5. Berry, Joseph A. "Adaptation of Photosynthetic Processes to Stress". Science, v. 188, no. 4188 (May 9, 1975) pp. 644-50.

Given the high vsriability in environmental conditions which are to be encountered in Nepal it seems highly likely that the high-yielding varieties developed by IRRI or by Indian research facilities will spead far beyond parts of the tarai and some of the environmentally similar inner valleys. The biological constraints which the rice breeders broke in producing the first generation high-yielding varieties are simply not likelp to be the constraints which are binding in much of Nepal. As in the case with many development issues, the problems in Nepal are unlikely to yield to solutions which have been worked out elsewhere. The IRRI varieties were developed in the Philippines and were developed in recognition of the kinds of constraints which are likely to be encountered in Central Luzon. Similarly, the Indian high-yielding varieties were developed to break the constraints encountered in India. It is tempting to suggest that if IRRI had been located somewhere in the Tropical Highlands there might by now be a second generation of high-yielding varieties suited to the major environmental niches of the Nepal hills and valleys. In fact, I think that such hopes would have been misplaced, although I would welcome a plant breeder's view on the question. The reason that I think it would be wrong to suggest that an IRRI in the Tropical Highlands would have met Nepal's needs for high-yielding varieties is that the basic biological constraints in the Tropical Highlands are not yet nearly as well understood as they are in the Gangetic Plain or in Central Luzon. After all, in great parts, the initial successes at IRRI and in the research stations in India were the result of plant breeders simply applying the tools of their craft within the context of a few large micro-climatic zones. In the monson-swept mountainous regions of Asia, micro-climatic zones are small and varied, unlike those of the lowlands

There and other serious non-biological constraints, too. In mountainous areas transportation costs make fertilizers very expensive and effectively preclude the development of any sizeable marketable surplus with which to buy exotic inputs ot any price. If the plant breeders are to make a sizeable contributions to the cereals economy in Nepal's rugged and inaccessible regions, I suspect that their contributions will be based on the results of basic biological research which has not yet been done; further, the identification of these biological constraints and the steps which will be necessary to break them are likely to be accomplished only within Nepal, by Nepalese scientists. No one else is likely to care that much.

In sum, the breeding of the "miracle" rice varieties should not be mistakenly compared with such feats of science as the placing of a man on the moon. Development of the high-yielding varieties was far more like designing and building next year's new car model. The component parts were assembled in a new way which met many of the requirements of the situation Indeed, it may well be the judgement of history that approximately the same new genetic combinations would have been achieved–

though perhaps they would have required several years longer–through the national experiment stations and plant breeding programs in several Asian nations. The same statement applies to the develpoment of wheat varieties. In fact, it may well be that the international plant breeding centers–principally CYMMIT and IRRI–actually diverted energy and monies from the national centers.

With the early history of IRRI and CYMMIT as a background it is tempting to suggest that the most significant opportunities in plant breeding lie in applied reasearch. To draw this conclusion, however, would be to misunderstand the tools of the plant breeder and to ignore the fact that a great deal of the basic research on the biological constraints which existed in the environments for which the high yielding varieties were developed were, so to speak, "on the shelf."

The Relationship between Basic and Applied Research in Agriculture

When maize breeders in the American corn belt combine different varieties of maize to produce new hybrids, they do so with the distinct intention of producing new plants which possess new characteristics desired relate to a host of environmental and economic conditions which must be satisfied if the new variety is to gain consumer acceptance. The plant breeder's knowledge of what characteristics are desirable and how they may be achieved is to a high degree the result of research in such fields as plant physiology, biochemistry, soil chemistry, and biophysics. Without a continuously expanding frontier of knowledge in these and other basic fields, the plant breeder's talents are less productive than they might be. Knowledge in these fields is as important to him as the equipment in his laboratories. The reverse relationship is also true. If the basic scientists are to provide the plant breeders with the information they need, then there must be a dialogue between the two. If that dialogue is to be productive, then it must relate to the opportunities and constraints which the plant breeder faces. Given the complexities of the basic processes of plant growth–of the fixation of carbon di–oxide, water minerals and sunlight into stable and valuable organic compounds–then both the applied and basic agricultural scientist must live and work in an intimate association with one another <u>and</u> with the agro-climatic environment they are intended to serve.

If this scenario concerning the relationships between basic research, applied research and the constraints of particular agro–climatic 'zones is valid, we would expect that research on the relations between basic research, applied research and agro-climatic zones would have the following characteristics: 1) the relationship between agricultural productivity and applied research should be positive; 2) the greater the stock of basic research available to the applied scientists, the greater would be the contribution of applied research. In addition we would expect that there would be some fuctional relationship between productivity in one ecological zone and the level of both applied and basic research in ecologically similar zones.

Evenson has examined these propositions in a complex regression model involving 87 crop-country combinations over the period 1948-71 for the Developed Countries and 78 crop-country combinations for the same years in the Less Developed Countries. The results are summarized below:

1. The interaction between basic and applied research in the less developed countries is of a form consistent with the proposition that applied research is more productive the greater the stock of relevant basic research also present. This relation is not statistically significant in the case of the developed country-crop combinations; however, this does not mean that basic research does not play a statistically significant role in the regression equation for developed countries, since it appears elsewhere as a positive interaction term with basic research in similar agro-climatic zones.

2. The direct relationship between applied research by agro-climatic or ecological neighbours and indigenous productivity is statistically significant in the case of the developed countries, but not in the case of the less developed countries. However, in both the developed and the less developed countries, indigenous research interacts strongly with research from the ecological neighbour in a way which indicates that indigenous research complements borrowable research at low levels (of indigenous research) and substitutes for it at high levels.

3. Increases in agricultural productivity by one's ecological neighbours have a positive and statistically significant impact on indigenous agricultural productivity. That is, productivity increases are transmitted across ecological and political boundaries, even in the absence of indigenous agricultural research. Further, the impact of indigenous applied research on indigenous productivity is reduced by fact that productivity gains do spread across political boundaries from similar ecological areas.

4. The "fit" of Evenson's regressions is excellent, with R^2 statistics exceeding. 98.

Evenson's discoveries about the relationships between agricultural research and agricultural productivity and the insights he has provided concerning the interaction effects between applied and basic research and between indigenous research and research in similar ecological zones is very impressive. As additional data about agricultural productivity and research investments in both the more developed and less developed parts of the world become available, new insights will undoubtedly be forthcoming. For the purposes of this paper, however, it is appropriate to enquire into the economic benefits and costs of agricultural research.

Economic Implications

In tables 2 and 3 (in the back) we summarized some earlier research on the economics of research programs. The results of those investigations, however, did not speak to the question of how research might best be allocated between basic and applied research. Evenson's research, however, with its discrimination between basic and applied research, does allow the policy maker, educator, and research administrator to make a reasonably well-educated guess about research priorities and strategies. Further, Evenson's research addresses a question which is quite critical for a small country like Nepal: to what extent can research be borrowed from ecological neighbours ? Table 5 presents estimates of the economic value of applied and basic research in developed and developing countries, based on his regression analysis In these calculations, cereal grains have been valued at $ 80 per ton, approximately 1973 prices. The income stream and present value estimates may be inflated or deflated proportionately for higher or lower grain price assumptions.

The fact that research dollars spent in the developing countries are more productive than those spent in developed countries is not especially surprising; although I find the ratio of the two to be larger than I might have expected. The relative magnitude of the returns to basic as opposed to applied research can proceed effectively only if there is an adequate stock of information in the form of basic research with which to work. The internal rates of return in both the developed and developing countries on both basic and applied research rather strongly suggest that under-investment in research-especially basic research-is a worldwide phenomenon.

A final important conclusion to be drawn from the information in Table 5 is that an indigenous research capability is necessary if a country is to benefit from the research done by ecological neighbors. Given the fact that Nepal shares a large common ecological zone with India, and given the fact that India is a relatively advanced scientific Nation, it would seem a prudential plan for Nepal to concentrate substantial resources on the transfer of Indian agricultural technology to the tarai and inner tarai. Whether or not Nepal has the indigenous scientific capacity to effect such a transfer at the high benefit levels suggested as possible in Table 5, I cannot judge. Certainly the indigenous scientific capacity of Nepal is not on a par with that of India, Israel or the Philippines. On the other hand, Nepal's scientific abilities are probably orders of magnitude greater than countries such as Laos, Bhutan, and the Spanish Sahara.

A Suggested Strategy for Capturing the Productivity Potential of Agricultural Research in Nepal

If research in the basic and applied agricultural sciences is as productive as the figures in Table 5 suggest, it would seem a simple matter of boosting the level of living in Nepal by dumping monies into agricultural research at a rate equal to the maximum absorptive capacity of the scientific community here. The problem, of course, is that there is no substantial number of idle agricultural scientists standing around waiting to be given research funds and a key to the laboratory. And, if one takes into consideration the time and expense involved in training men and women to become first-rate agricultural scientists, the high internal rates of return and high present values of research expenditures will fall considerably.*

In recognition of this fact, I have sketched out in Table 6 a simple time and resources budget for the training of agricultural scientists. Table 6 is constructed on the assumption that a group of ten young men and women would be carefully selected and given an M. Sc. intensively in one or more of the biological sciences in Nepal (or possibly in India) Of these ten, it is assumed that only eight or ten would be sent to Europe or North America for a Ph. D. course. Six years is budgeted for the Ph. D. course in recognition of the educational disadvantage that Nepalese students may encounter relative to students from Europe and North America. Of the eight who are sent abroad, it is assumed that one drops out after two years and that two more either fail to complete their dissertations or fail to return to Nepal. A four-year post-doctoral is allowed for further training or the acquisition of on-the-job experience in research institutions abroad.

The present discounted cost (at a ten percent discount rate) of such a programme per completed-and-returned scientist is just under $ 50,000. Using data from India concerning the absorptive capacity of agricultural scientists, I have calculated the present costs and benefits of the probable productive lifetime of a hypothetical scientist.[6] Discounting those costs and benefits back to year zero in the time budget of Table 6 and adding the discounted costs of the programme to train agricultural scientists, it is possible to calculate benefit-cost ratios for several different types of

* Of course, Nepal might hire foreign scientists to do the job in Nepal; indeed, a certain amount of research is done now by foreign scientists provided by bilateral and multilateral development assistance agencies. Research done by foreign scientists, however, has different economic and social costs than research done by Nepalese.

6. Boyce, James K. and Robert E. Evenson. Agricultural Researeh and Extension Systems. (forthcoming) Tables 2 and 5. In these data, Indian agricultural scientists are shown to produce about one scientific publication per scientist per biennium and to spend about $ 22,000 per publication.

agricultural research. Applied research yields a benefit-to-cost ratio of 14-to-1. Basic research yields a benefit-to-cost ratio of 83-to-1. Research directed toward adapting Indian agricultural research to the particular environmental characteristics of the tarai yields a benefit-to-cost ratio of 72-to-1.

It is hard to conceive of any other potential development activity available to Nepal which is likely to have benefit-cost ratios in this range.

I am not aware of any other development activity in Nepal which is characterized by benefit-cost ratios in this range. And, these benefit-cost ratios were calculated as if the entire costs of the education required were paid by Nepal. If foreign assistance were to pay for half of the educational costs, the benefit costs ratios would increase to 20-to-1, 117-to-1, and 102-to-1 for the research categories mentioned above.

It would appear, then, that investments in education in the agricultural sciences should be recognized as a potentially high priority item in the planning and budgeting process. At least one more question needs to be asked however: how many agricultural scientists would Nepal require if it is wished to achieve some specified target rate of growth of agricultural production ? Using some fairly careful calculations, I estimate that if 15 scientists were to begin applied research and another 15 were to begin basic research in 1988, following a training programme which might begin in 1976, the country might expect an increase of 1.5 percent per annum in the rate of growth of rice, wheat, and maize; in addition to growth arising from other causes. Given that the present rate of growth of agricultural output is between 2.0 and 2.5 per cent per annum, the addition of 30 new agricultural scientists and the research budgets and equipment they will require could put Nepal in a very comfortable position with respect to food exports and total domestic availability.

A Note of Caution

It is a truism which bears repeating that "Individuals, institutions and societies continue doing what they know how to do -- or think they know how to do -- long after their acts may have become irrelevant or even counter-productive". This observation may as fairly be applied to our educational and scienctific institutions as to international political institutions and human relations.

In the "bad old days" when most of the Third World nations were still securely under the oppressing thumb of colonial powers and their own indigenous feedal institutions, there was little agricultural reaserch of worth except that which was oriented to exportable cash crops such as cotton, sugar, and jute; or that directed toward increasing the revenue paying capicity of the land. The reasons are not hard to find. First, there was no effective rural constituency capable of bringing pressures upon government to apply resources to the problems of peasant production. Second, there was no indigenous scientific establishment capable of addressing the basic problems of agricultural science. Such was not the case in North America and in some of the European states where farmers organized to bring pressures on their governments for the allocation of resources to the agricultural sciences. There were, of course, tropical agricultural reseerch stations, but they did their best work in export-oriented crops. In the area of cereal crops, researchers tended to concentrate on making selections of what they supposed to be better genetic material. These researchers did little more than what the average peasant had always done: to select for drought resistance, disease resistance, and grain quality. It was not until the 1950's and 1960's when governments in Asia and Africa began to reflect on the concerns of their peasants, and when a significant group of elite agricultural scientists emerged, that truly productive agricultural researeh began to appear.

In my judgement, the agricultural future of the tarai region, the inner tarai region, the Kathmandu valley, and a few other selected regions of Nepal are well suited to receive the continued blessings of basic and applied agricultural scientific research. These areas have readily available markets for the disposal of marketable surpluses; they are also favorably situated with respect to the supply of inputs of chemical fertilizers and pesticides. Unfortunately, I think the prospects of increasing agricultural p oductivity in the hill regions are dim. Transportation cost will simply be too high, in the foreseeable future, to allow either the import of sizable quantities of either chemical fertilizers of food grains.

The danger, I fear, is that scientific resources will be focused on those areas where the fundamental virtues of the high-yielding varieties can best be utilized. In the remote areas of Nepal, a cereal variety's capacity to use heavy doses of chemical fertilizers is largely irrelevant. If the agricultural sciences are to provide new technology to many of the hill regions of Nepal -- and much of the world's Tropical Highlands in general -- then they must orient their research toward the very fundamental goal of increasing the photosynthetic efficiency of the cereal grains.[7] Photosynthetically more efficient plants could presumably be used as the hosts for nitrogen fixing bacteria, thus reducing the need for some chemical fertilizers.[8] The technology for breeding such new plant types may become available in the relatively near future.[9]

7. Zelitch, Israel. "Improving the efficiency of Photosynthesis." Science, V. 188, N. 4188 (May 9, 1975) pp. 626-33.
8. Hardy, R. W. F. and U. D. Havelka. "Nitrogen Fixation Research: A Key to World Food ?" Science, V. 188, No 4188 (May 9, 1975) pp. 623-43.
9. Carlson, Peter S. and Joseph C. Polacco. "Plant Cell Cultures: Aspects of Crop Improvement." Science, V. 188, No. 4188 (May 9, 1975) pp. 622-25.

My concern is that agricultural scientists, educational administrators, and planners may become so content with the successes in the application of scientific research within the context of the basic high-yielding technology that they may not move aggressively enough in breaking the constraints on agricultural productivity in the hills and mountains. In short, I am concerned that the agricultural scientists will continue doing in the future what they have done quite well in the past. The result will be missed opportunities and the creation of scientifically advanced backward sectors of the rural economy.

A second area of concern reletes to the needs for social science research on rural problems. New income streams create new social and political problems for which new social institutions are required. The current population explosion is based largely on modern medicines and improved public health. Although no one will dispute the value of these medical advances, we all might be better off if the advances in medical science had been accompanied by research which would have allowed individuals and societies to enjoy better health and lower rates of population growth.

The major aim of social science research -- as I see it -- is to provide the policy maker and legislater with information which he may use to improve the quality of life of those he serves As the need of new social, economic, and political institutions becomes apparent with the creation of new income streams arising from agricultural research, the demand for relevant social science research will increase.

Institutions like Center for Eeonomic Development and Administration, the Agricultural Projects Services Centre, are others; have begun to provide research findings which speak to the problems which may be encountered in the future. Unfortunately, the social science research institutions are not endowed with a large complement of Ph. D level researchers. Hopefully, these intellectual resources will increase in the future. If they do not, I am concerned that substantial and sustained economic growth in rural Nepal may be frustrated in the future.

Table 1

An Accounting of the ifferences in Labour Productivity between Eleven Less-Developed Countries (LDC's) and Four Recently Developed Countries (RDC's).

Source of differences			Index
Difference in output per male worker (93.6%)			100
Difference explained:			
Total			96
Resource endowments		35	
Land	10		
Livestock	25		
Technical inputs		26	
Fertilizer	16		
Machinery	10		
Human capital		35	
General education	21		
Technical education	14		

LDC's Brazil, Sri Lanka, Columbia, India, Mexico, Peru, Philippines, Syria, Taiwan, Turkey, United Arab Republic.

RDC's Australia, Canada, New Zealand, United States.

Source: Ruttan, Vernon W. "Induced Technical and Institutional Change and the Future of Agriculture," Agricultural Development Council reprint, December 1973.

Table 2

Summary of Selected Sources-of-Growth-Type Studies of Agricultural Research Productivity.

Study		Country	Commodity (time period)	Estimated output per research dollar	Marginal internal rate of return
Griliches	(1964)	U. S. A.	aggregate	7	35-40
Evenson	(1968)	U. S. A.	aggregate (1949-59)	10-12	47
Khaldi	(1972)	U. S. A.	aggregate (1949-64)	not calculated, but high returns implied	
Tang	(1963)	Japan	aggregate (1880-1938)	–	35
Ardito-Barletta	(1970)	Mexico	crops (1943-63)	2.9	45-93
Peterson	(1966)	U. S. A.	poultry	1.4	21
Evenson	(1969)	S. Africa	sugarcane (1945-58	15	40
Evenson	(1969)	Australia	sugarcane (1945-58)	35	50
Evenson	(1969)	India	sugarcane (1945-58)	40	60
Jha and Evenson	(1973)	India	aggregate	7.6	40

Source: Boyce, James K. and Robert E. Evenson. Agricultural Research and Extension Systems (in press) Table 6.2.

Table 3

Summary of Direct Cost-Benefit Type Studies of Agricultural research Productivity.

Study		Country	Commodity	Time period	Internal rate of return
Griliches	(1958)	U. S. A.	hybrid maize	1940–55	35–40
Griliches	(1958)	U. S. A.	hybrid sorghum	1940-55	20
Peterson	(1966)	U. S. A.	poultry	1915-60	21-25
Ardito-Barletta	(1970)	Mexico	wheat	1943–63	90
Ardito-Barletta	(1970)	Mexico	maize	1943–63	35
Evenson	(1969)	S. Africa	sugarcane	1945–62	40
Ayen	(1970)	Brazil	cotton	1924–67	77+
Hines	(1972)	Peru	maize	1954–67	35–40
Hayami-Akino	(1975)	Japan	rice	1915–50	25–27
Hayami-Akino	(1975)	Japan	rice	1930–61	73–75

Source: Boyce, James K. and Robert Evenson. Agricultural Research and Extension Systems (in press) table 6.1.

Table 4

Proportion of Paddy Area under High-yielding Varieties in Selected Asian Countries.

Country	Year							
	65/66	66/67	67/68	68/69	69/70	70/71	71/72	72/73
Burma	–	–	trace	3.6	3.0	3.8	3.7	4.0
India	trace	2.5	4.9	7.3	14.2	14.9	19.8	23.0
Indonesia	–	–	–	1.3	4.7	4.9	7.0	8.0
Laos	–	trace	0.2	0.3	0.5	8.1	7.0	7.5
Malaysia	9.8	14.3	18 9	19.1	24.8	30.9	36.9	40.7
Nepal	–	–	–	3.7	4.2	5.7	6.8	14.8
Philippines	–	2.7	19.8	30.4	43.5	50.3	56.3	54.3
Sri Lanka	–	–	–	1.3	4.3	5.3	5.3	3.1
Thailand	–	–	–	–	0.1	1.5	4.2	4.9

Source: Area under high-yielding varieties from Dana G. Dalrymple, "Development and Spread of High-Yielding Varieties of Wheat and Rice in the Less Developed Nations", Foreign Agricultural Economic Report No. 95 (Economic Research Service, U. S. Department of agriculture Washington D. C., 1974) Paddy, area figures from U. N. Statistical Yearbook, and other sources.

Table 5

Estimated Marginal Benefit Streams, Present Values, and Internal Rates of Return Associated with Indigenous Research Investments.

Source of Benefit	Developed Countries		Developing Countries	
	Applied	Basic	Applied	Basic
Direct contribution -- stream	630	12,300	3,710	35,600
Through complementarity with research in other countries -- stream	1,620	1,620	7,200	7,200
Total -- benefit stream	2,250	13,920	10,910	42,800
-- present value (at 10% discount rate)	7,095	64,920	34,400	199,670
-- internal rate of return	.30	.51	.52	.68
Benefits realized by a typical country from research investment by other countries in similar ecological zones.				
(a) with average indigenous research capacity				
-- benefit stream	8,580	520	55,000	1,700
-- present value (at 10% discount rate)	27,050	2,430	173,430	7,930
-- internal rate of return	.50	.16	.82	.26
(b) with no indigenous research capacity				
-- benefit stream	4,560	520	1,700	1,700
-- present value (at 10% discount rate)	14,380	2,430	5,360	7,930
-- internal rate of return	.42	.16	.27	.26

Notes: The benefit streams are the estimated levels (in 1973 U. S. dollars) to which benefits associated with a $ 1,000 research investment will rise in eight to ten years after initial investment, Experiênce suggests that benefits may be seen in as few as three years after initial investment. Present value calculations assume no partial benefits prior to ninth year at which time the full benefits are obtained. Discount rate is ten percent. Applied research benefit streams are assumed to continue for ten years after which they drop to zero for any single investment. Benefit streams for basic research are assumed to continue without time-limit. The choice of a time stream for calculating present value and the internal rate of return can influence the rates considerably, especially the assumption of when benefits begin to be realized and how fast they rise to their full estimated level. By assuming no benefits prior to the ninth year, we have been conservative. when present value and internal rate of return calculations were made under an assumption that benefits increased from zero in the third year after the initial investment was made and achieved the full benefit stream level in the eighth year, estimates of the present value of $ 1,000 worth of investment increased considerably; in some cases the internal rate of return exceeded 100 percent.

Source: Evenson, Robert E. "Comparative Evidence on Returns to Investment in National and International Research Institutions", paper presented to the conference on Resource Allocation and Productivity in International Agricultural Research, Airlie House, Virginia; January 26–29, 1975. (This and other papers presented at the conference are to be published by the University of Minnesota Press in 1976).

Table 6

Feasible Time and Cost Budget for Training of Agricultural Scientists

Year	Cost per students per year	Number of students remaining in programme	Total cost per year	Cost per repatriated scientist	Educational programme
0	1,500	10	15,000	3,000	Two year intensive M. Sc.
1	1,500	10	15,000	3,000	in biology in Nepal
2	7,500	8	60,000	12,000	
3	7,500	8	60,000	12,000	Six year Ph.D. Programme
4	7,500	7	52,500	10,500	in an European or North
5	7,500	7	52,500	10,500	American university
6	7,500	7	52,500	10,500	
7	7,500	7	52,500	10,500	
8	0	5	0	0	Four year post-doctoral
9	0	5	0	0	and in-service training
10	0	5	0	0	abroad
11	0	5	0	0	
12	....	....	....	....	Repatriation to Nepal and
13					Integration into a research
..					institution for 25 years of
..					work in basic or applied
36	....	....	....	....	research

Note: This budget is calculated on the basis of ten students, some of whom drop out of the academic training programme or fail to return to Nepal.