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THE GREEN REVOLUTION: SEVEN GENERALIZATIONS

Vernon W. Ruttan

AGRICULTURAL DEVELOPMENT COUNCIL
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Historical Perspective

☐ The "green revolution" in grain production in the developing countries of Asia has now been in progress for just slightly longer than a decade. The potential and the performance of the new grain varieties have been the subject of intense controversy from the initial transfer of the first wheat varieties from Mexico to Pakistan and the first rice varieties from Taiwan to India in the mid 1960's.

Some of the early critical evaluation appeared to reflect little more than an interdisciplinary pique or aggression. The green revolution shifted attention from the earlier architects of development—planners, economists and other social scientists—to geneticists, plant breeders and agronomists. Social scientists and publicists rushed in to explore the second and third generation problems before establishing whether the initial impact on production had been adequate to meet the problem of lagging food supplies.[1]

A second set of criticisms has clearly been more ideologically motivated. Hope for the radicalization of the lower peasantry and landless laborers has been viewed as dependent on the continuation of the process of "immiserizing" growth.[2] The scale neutral green revolution technology, which was equally effective on small and large farms, has been viewed as increasing the political cost of revolutionary change. By offering a prospect for improvements in the welfare of rural people, without revolution, the seed-fertilizer technology has become the target of substantial radical rhetoric.

Discussion of the impact of the new grain varieties on production, employment and income distribution has also been burdened by extreme looseness in the use of the "green revolution" terminology. The term is most appropriately used to refer to the rapid development and diffusion of new early maturing fertilizer responsive varieties of wheat, rice, and other cereal grains in the developing countries of the tropics and semi-tropics since the mid-1960's.[3]

It is consistent with the available evidence to view the mechanization of land preparation and harvesting operations that have sometimes been identified with the green revolution as primarily a response to changes in the relative prices of mechanical power, relative to animal power and labor, rather than as a technical complement to the new seed-fertilizer technology (8, 26).

Generalizations from specific investigations

By the mid-1970's, a substantial body of empirical evidence had emerged that permits some clarification of the initial impact of the adoption of the new varieties on production and on the functional and personal distribution of income.[4] The conclusions that emerge from these studies can be summarized in a series of seven generalizations. Broad generalizations of the type presented below are never able to capture the rich detail of the particular location specific investigations on which they are based. The net effect of this review of the literature does, however, add up to a quite different perspective of the impact of the green revolution than the views that dominate much of the earlier social sciences literature.

The new wheat and rice varieties were adopted at exceptionally rapid rates in those areas where they were technically and economically superior to local varieties. In the Indian Punjab, the proportion of total wheat area planted to the new high yielding varieties of wheat rose from 3.6 per cent in the 1966/67 the year of initial introduction, to 65.6 per cent in 1969/70 (51, p. 221).[5] In three important wheat producing districts in the Pakistan Punjab, 73 per cent of wheat acreage was sown with Mexican wheats during the 1969/70 rabi (winter) season (2, p.408).

In the Philippines, 95 per cent of the farmers in the barrios and almost 60 per cent of the farmers in the en-

[1]For a review of a number of the early evaluations see Byres (10) and Castillo (11). Among the early evaluations that were most thoroughly grounded on personal experience or empirical evidence were those by Falcon (17), Johnston and Cownie (30), Ladejinsky (34, 35), Lockwood, Mukerjee and Shand (37), and Wharton (63).

[2]The radical critics have welcomed the "green revolution" in socialist economies such as Cuba and China. In non-socialist economies the introduction of the high yielding varieties is viewed as raising the "cost" of radical change by channelling new income to the middle and upper peasantry.

It is assumed that continued stagnation would lower the cost of radical change by identifying the interests of the middle peasants with the landless workers. See for example, Cleaver (13), Fatemi (18) and Griffin (25).

VERNON W. RUTTAN is the President of the Agricultural Development Council, Inc., Singapore and New York. After January, 1978, he becomes Professor, Department of Agricultural and Applied Economics, and Department of Economics, University of Minnesota.

tire municipality where the new rice varieties were initially introduced (Gapan, Nueva Ecija) had adopted the new varieties in 1969, four years after initial introduction (11, p. 32–96; 28). These rates compare favorably to the diffusion rates of new crop varieties in developed countries (47).

The rate of adoption of the new wheat and rice varieties has declined since the early 1970's (Figure 1.0). In the case of the new wheat varieties the largest yield increments have been achieved in relatively arid areas where farmers have had access to effective tubewell or gravity irrigation systems. In the case of rice, the largest yield increments have been achieved on irrigated rice during the dry season in areas such as Central Luzon (Philippines) or Western Uttar Pradesh (India).

The agro-climatic regions where the wheat varieties developed at CYMMIT and the rice varieties developed at IRRI were best adapted have achieved relatively rapid and high level of adoption. Where diffusion of the CYMMIT and IRRI based varieties has depended on the adaptation or development of varieties suited to other environmental conditions, or on the modifications of environmental conditions, the rate of diffusion has been slower and the yield impact has been lower.[6] Diffusion to other areas will depend, to a very substantial degree, on the development of varieties of wheat and rice suited to other ecological niches and on investment in irrigation and drainage in those areas where well adapted varieties are available. It will also depend on the successful development of high yielding varieties of other food grains, coarse grains and grain legumes.

Neither farm size or tenure has been a serious constraint to the adoption of new high-yielding grain varieties. This is not to say that differential rates of adoption by farm size and tenure have not been observed. What the available data do seem to imply is that within a relatively few years after introduction, lags in adoption rates due to size or tenure have typically disappeared.

The data on adoption of new wheat varieties from the Pakistan Punjab, presented in Table 1.0, are fairly typical of the data available from other areas where the high yielding varieties are technically well adapted. Essentially similar results have been reported for wheat in India, rice in the Philippines (39, 40), India (50), Indonesia (55, 56), and for maize in Kenya (21). A stylized model of the difussion process similar to that in Figure 2.0 would describe the results of a very large number of the diffusion studies that have attempted to measure the association between farm size and the level of adoption from the time the HYV's are introduced.

Neither farm size nor tenure has been an important source of differential growth in productivity. Sidhu's evidence from the Indian Punjab indicates that the new wheat technology has been approximately neutral with respect to scale—it has not been strongly biased in either a labor-saving or a capital-saving direction, and small and large farmers have achieved approximately equal gains in efficiency.[7]

Azam interprets the data that are available from a number of studies in the Pakistan Punjab to indicate "that while the smaller farmers do face relatively more severe constraints of irrigation water and credit, the differences in the severity of these constraints is not serious enough to have caused any significant differences in the yields obtained by the small farmers as compared with the large farmers." (2, p.418). Similar results have been reported from the Philippines by Mangahas (39, pp.23–43) and from Indonesia by Soejono (55, 56).

The introduction of the new high yielding wheat and rice technology has resulted in an increase in the demand for labor. Sidhu's results indicated a very substantial shift to the right in the labor demand function on wheat producing farms, as a result of the introduction of the new wheat varieties in the Indian Punjab (51). Similar results were obtained by Staub (57). In an analysis of the sources of growth in the demand for labor in the Punjab Bisaliah found, using the Sidhu data, that the direct output effect of the new technology on the demand for labor was partially offset by substitution effects (9). The net effect of the increase in demand for labor has been a significant rise in real wages in the Punjab at a time

[3]Early maturing rice varieties were known in China as early as 1,000 A.D. The new varieties that were developed at the International Rice Research Institute (IRRI), the University of the Philippines and in several other national programs in the mid-1960's were based on genetic materials drawn from China, Taiwan, and Indonesia.
The model of the biologically efficient rice plant was, however, based very heavily in Japanese experience in the development of Norin rice varieties in Japan and the Ponlai varieties in Taiwan. The new wheat varieties developed in Mexico also draw on the Norin varieties for genetic materials (13a).
The "green revolution" technology that has become available to farmers in South and Southeast Asia since the mid-1960's is essentially the same technology that has contributed to the growth of productivity in Japan and Taiwan during the interwar period.
There continue to be references to the "green revolution" technology which identify it as a "Western" technology even by authors who ought to know better. See, for example Wade (62) and Griffin (25).

[4]For a comparison of the factors affecting adoption of the new technology among villages throughout the rice growing regions of Asia, see Randolph Barker (4). Among the particularly useful studies literature see: Azam (2), Bell (7), Castillo (11), Gotsch *et al.* (23), Rao (45), and Sen (50). Castillo is particularly critical of what she regards as superficial comments on the Philippine experience by Griffin.
One limitation of the "green revolution" literature is its overwhelming "South Asian" bias.

[5]For a more complete account see Sidhu (51). The Sidhu study utilized farm level survey data for the four years 1967/68, 1968/69, 1969/70, 1970/71. For a very interesting extension of the Sidhu study see Bisaliah (9). For a review of the empirical evidence on the diffusion of the high yielding wheat varieties in India, see Vyas (61).

[6]See Barker and Mangahas (5) and Frankel (20). In the case of rice the environmental constraints that limit the yields of the new high yielding varieties are the same as those that limited yields in the pre-green revolution period. See Hsieh and Ruttan (27)

when real wages were constant or declining in most states in India (3, 36, 42).

An extensive review of the literature by Bartsch (6) indicates that the introduction of high yielding varieties into traditional wheat and rice production systems has typically resulted in substantial increases in annual labor use per hectare. The increase in labor use has been due to greater labor utilization per unit of cropped area, and in some cases, to higher cropping intensity.

Even mechanized farms typically were utilizing increased labor inputs per hectare although simulation results conducted by Bartsch (6) and by Singh and Day (53) indicate that labor input per hectare might be expected to decline substantially under fully mechanized techniques combined with adoption of the high yielding variety technology.[8]

At this stage it seems more accurate to view the growth of tractor mechanization, in areas such as the Punjab, as an economic response to the rising demand for labor associated with the intensification of crop production rather than as an autonomous source of technological change leading to labor displacement. This process was underway prior to the introduction of the new wheat varieties and has been reinforced by the more rapid growth in demand for labor since their introduction.

Landowners have gained relative to tenants and laborers from the adoption of the higher yielding grain varieties. Data assembled by Mellor indicate that although the percentage increase in labor earnings from increased employment and wages is often fairly large, the percentage of the increased output allocated to labor is relatively small (41, p. 81). Data reported by Dayanatha Jha (29, p. 211) indicate that the factor share to land rose in every state in India between 1960/61 and 1970/71.

For example, in Aligarh district, where 10 per cent of the increased output went to labor, 67 per cent went to land and capital and 23 per cent to other costs (including 8 per cent to fertilizer).[9] In the Philippines, Mangahas found that the effect of tenure on productivity was neutral. There were no significant differences among owner operators, leaseholders and share tenants on the adoption of the high yielding varieties or in efficiency in the use of inputs (40, pp. 75-87). However, differences in tenure remain, as before the introduction of the high yielding varieties, a major source of income disparity in rural areas.

Much of the discussion about the income distribution effects of the green revolution has failed to distinguish between its absolute and relative effects on income distribution. Many authors who refer to the worsening position of the smaller owners and tenants or landless laborers are apparently referring to the widening absolute gap in the income distribution rather than to an actual decline in the income of those who occupy the lower end of the income distribution in rural communities. This point is effectively illustrated with data from a study by C. Geoffrey Swenson in Thanjavur District in South India (58, 59).

Similar results have been reported by Soejono in Indonesia (55, 56). Swenson's results are of interest because of extreme inequality in the distribution of income in the villages he studied (Table 3.0). Between 1965/66 and 1970/71 paddy (rough rice) production increased by approximately 22 per cent. Median and mean household real income from all sources rose by 12 per cent. The distribution of income among income and tenure classes remained essentially unchanged. Real income of owner operators rose by 14 per cent, of tenants by 17 per cent, and of landless laborers by 14 per cent. In 1965/66 the Gini ratio for all households was 0.707 and in 1970/71 it was 0.700.[10]

This recitation of the essentially neutral effect of the initial impact of the new technology does tend to obscure perhaps the most important observation that might be drawn from Swenson's data – the extreme disparity of income among classes – both in 1965/66 and 1970/71. Almost 60 per cent of the increase in income, primarily from increases in rice production, went to the 5 per cent of households which had the highest income in 1965/66.

The effect of introduction of the new high yielding varieties has been to contribute to a widening of wage and income differentials among regions. As mentioned in the first generalization, the varieties have been developed to respond most favorably to those elements in the environment which are subject to man's control. They are more responsive than the varieties they replaced to higher levels of fertilization, to more effective irrigation and drainage; and more effective control of pathogens, insects, weeds. Reductions in sensitivity to certain natural variations such as day length and temperature make them more adaptable to intensive systems of crop production.

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[7]Sidhu concludes "(1) that small and large wheat producing farms have equal relative *economic efficiency* and equal relative *price efficiency*," and "(2) that tractor-operated and non-tractor operated wheat producing farms have equal economic efficiency and equal relative price efficiency . . . This implies that these farms also have equal technical efficiency." (52, p. 746).

[8]Dantwala cautions that "Studies based on field investigations of what had actually happened or was happening are less pessimistic about the labor absorption capacity of the new technology than the findings based on econometric models and attempted projections." (14, p. 189).

[9]Considerable caution should be exercised in interpreting these results. The data presented in the article by Jha cited above indicated that the factor share to land rose more rapidly in states with slow growth in output than in states with rapid growth in output. The implication is that in many areas in India the rise in the factor share to land must be explained along classical Ricardian lines – as a result of rising pressure of labor against land.

The contribution of the new varieties to productivity growth has, therefore, been greatest in those regions where there has been substantial investment in physical and institutional infrastructure development (46, 54). This pattern is reinforced by the location specific character of agricultural technology.

In India production increases have been concentrated in a relatively limited number of districts (43). The differential regional impact on productivity is seen quite clearly in state data from India (Table 4.0). The differential rates of productivity growth have been associated with the widening of wage rate differences among regions. Edward A. Baker (3) indicates that in India during 1954/55 and 1968/69 the supply curve for labor in the agricultural sector appeared to have been perfectly elastic in all areas except Punjab-Haryana and a few intensive wheat producing districts in other states. Since the mid-1950's average annual daily real wages have apparently decreased in all states except Punjab-Haryana, Uttar Pradesh, Kerala and possibly Tamil Nadu (3, 31, 36).

The contribution of the new seed-fertilizer technology to the widening of regional income disparities has apparently been greater than its impact on disparities in income within communities and regions. The associated changes in the regional distribution of political resources, can be expected to become a more important source of institutional stress and institutional change than the stress at the community level which has received so much attention in recent literature.

The effect of the introduction of the new high yielding varieties has been to dampen the rate of increase in food grain prices at the consumer level. During the 1974/75 crop year the new higher yielding or modern varieties of wheat were planted on over 20 million hectares and the new high yielding varieties of rice were planted on close to 25 million hectares in Asia and the Near East (Figure 1).

In Asia over 60 per cent of the wheat area and over one quarter of the rice area are planted to the modern varieties developed since the mid-1960's. Evenson has estimated that in crop year 1974-75, the supply of rice in all developing countries was approximately 12 per cent higher than it would have been if the same total resources had been devoted to production of rice using only the traditional rice varieties available prior to the mid-1960's (15, 16).

The impact of a shift to the right in the supply of food grain is particularly significant for both the urban and rural poor. The distribution of grains among consumers depends primarily on the relative amount of a particular commodity consumed by each income stratum/and on the price elasticity of demand in each stratum. The larger the quantity consumed and the higher the absolute value of the price elasticity of demand in the lower income strata, relative to the higher income strata, the more favorable will be the distributional benefits.

This is illustrated quite dramatically by the impact of the new rice technology on consumer welfare in Colombia since the mid-1960's. Between 1966 and 1974 the percentage of the area planted to modern varieties rose from 10 per cent to 99 per cent. Yields on irrigated land rose from 3.1 to 5.4 metric tons per hectare, and total rice production increased from 600 thousand to 1,570 thousand metric tons. Most of the increased production was absorbed in the local market. The benefits were transmitted to consumers through both lower prices and increased per capita consumption.

The benefits were strongly biased in favor of low income consumers. The lowest income quartile of Colombian households, which received only 4 per cent of household income, captured 28 per cent of the consumer benefits resulting from the shift to the right in the supply curve for rice.[11]

In most countries, increases in food grain production have generally not been adequate to prevent substantial increases in food grain prices, when measured in current dollars, in the face of the general inflationary pressures that have dominated world commodity markets between the late 1960's and the early 1970's. It is clear, however, that in the absence of the contribution of the new high yielding varieties, food grain prices would be even higher in many countries of Asia, Africa and Latin America. Part of the new income streams generated by the new varieties have been transferred from producers to consumers either through the market or through administered distribution schemes.

Thus while there may be some ambiguity regarding the distribution of the gains by size of farm or by economic or social class within the agricultural sector, there can be little question that the distributional effect on the consumption side has been positive. And among those who have gained on the consumption side have been the landless and near landless workers in rural areas.

Issues of the distribution of gains between producers and consumers in the developing countries which have benefited from the new high yielding varieties have been given less attention than in developed countries. This may be in part because the rapid growth of demand stemming primarily from population growth has tended to equal or exceed the rate of growth in supply even when the growth in supply has been augmented by rapid technical change.

Perhaps the more important factor is that with relatively few exceptions the peasant producers of food crops in Asia are not effectively organized to reflect their

[10]An indication of the extreme bias in income distribution in Thanjavur District studied by Swenson is that in India as a whole the Gini ratio for the distribution of rural and agricultural incomes are 0.41 and 0.49 respectively (50, p. 66). In the Aligarh District in Western Uttar Pradesh the Gini ratio for farm families declined from 0.514 in 1963/64 to 0.428 in 1968/69 (53, p. 5, 6). In the Phillippines scattered data from village studies suggests Gini ratios for farm families in the 0.35-0.40 range.

economic interests at the policy level. Resistance to low price levels tends to take the form of attempts to adjust the crop mix to relative price shifts rather than to directly influence price policy.[12]

Conclusion

The picture that emerges from this review of the evidence on the initial impact of the green revolution can be summarized as follows—a technology that is essentially neutral with respect to scale has been introduced into environments in which the economic, social and political institutions have varied widely with respect to their neutrality.[13] This view has been eloquently expressed by Wolf Ladejinsky, "When all is said and done, it is not the fault of the new technology that the credit service doesn't serve those for whom it was originally intended; that the extension service is not living up to expectations; that the panchayats are essentially political rather than development bodies; that security of tenure is a luxury of the few; that rentals are exorbitant; that ceilings on land are merely notional; that for the greater part tenurial legislation is deliberately miscarried, or wage scales are hardly sufficient to keep soul and body together." (35).

Where the technology has been introduced in areas characterized by a reasonable degree of equity in the distribution of resources, the effect has been favorable both in terms of productivity and equity. When the technology has been introduced in areas characterized by great inequality in the distribution of resources, the productivity impact has been weak and the pattern of inequity has been reinforced (22). The differential impact of the technology on income growth has apparently been greater among regions than among economic factors and social classes within regions.

It is still premature to attempt a definitive evaluation of the impact of the green revolution technology on institutional change. Few attempts have been made to separate the effects of technical change from the other dynamic changes that have also impinged on the rural areas which are experiencing rapid productivity gains.

It does seem clear, however, that the contribution of the new seed-fertilizer technology to food grain production has weakened the potential for revolutionary change in political and economic institutions in rural areas in many countries in Asia and in other parts of the developing world. The green revolution has not turned red. In spite of widening income differentials, the gains from productivity growth, in those areas where the new seed-fertilizer technology has been effective, have been sufficiently diffused to reinforce interests of most classes in an evolutionary, rather than a revolutionary, pattern of rural development (1, 12, 24, 38, 45, p.17).

The most serious criticism that can be levelled at the green revolution is that it has not yet become sufficiently pervasive. The most disturbing evidence of failure in agricultural development in Asia over the last decade is the evidence of declining real wages in many areas where the impact of the new seed fertilizer technology on productivity growth has been marginal (32, 33, 36).

Furthermore there is evidence that even in the more favored areas the productivity gains are coming more slowly and at greater cost than during the last decade. A combination of continued rapid growth in the rural labor force pressing against inadequate rate of growth in productivity is resulting in increasing immiserization of the landless and near landless in many areas in Asia. It is possible that this increasing immiserization may, in the next decade induce the revolutionary changes in rural institutions which were anticipated in the 1970's by the radical critics of the green revolution.

[11]See Scobie and Posada (48) and Scobie (49). Pinstrup-Anderson shows that in Colombia if commodity priorities for research were established in terms of a criterion of consumer benefits for the low income strata the priority ranking should be cassava, maize, plantain, rice, potatoes and beans (44).

[12]Timmer reports, for example, that in the early 1970's Indonesian policy makers had to again learn the lesson "that farmers do not like to repay debts with stalk paddy at below market prices." (60, p.216).

[13]By the mid-1970's the essential neutrality of scale of the new cereals technology had been conceded even by the more outspoken critics of the effects of the green revolution. ". . . The new technology for producing food is not characterized by important economies of scale, and the growth of inequality which has in practice accompanied technical change is not a necessary consequences of attempts to raise yields. The problem arises not from the nature of the most appropriate technology, but from the bias of government policy and the fact that public institutions clearly are not scale-neutral." (25, p.69).

Table 1.0
Mexican Type Wheat Acreage as Percentage of all Wheat Acreage During Rabi 1969–70 by Size and Tenure of Holdings; Lyallpur, Sahiwal, and Sheikhupura Districts, Pakistan

Size of holding (acres)	Owner holdings (percent)	Owner-cum-tenants (percent)	Tenant holdings (percent)	All holdings (percent)
Up to 12.5	71.0	80.4	66.7	72.5
12.5 to 25	63.3	71.7	69.2	68.0
25 to 50	71.9	92.7	81.9	82.0
50	73.2	87.3	57.3	78.6
All sizes	69.4	80.5	70.0	73.4

Source:
Government of the Punjab, Planning and Development Department, Statistical Survey Unit, Fertilizer and Mexican Wheat Survey Report, (Lahore 1970) p. 38. Reported in K. M. Azam, "The Future of the Green Revolution in West Pakistan: A Choice of Strategy," *International Journal of Agrarian Affairs*, Vol. V, No. 6 (March 1973): 408.

Table 2.0
Patterns of Distribution of Total Value Income Among all Agricultural Households in Survey Villages: Shares of Ordinal Groups of Households, 1965–66 and 1970–71

Households[a]	1965–66	1970–71
	Percent	
Top 5 percent	66.4	58.0
Top 10 percent	66.7	67.1
Top 20 percent	75.7	75.8
Second 20 percent	10.2	9.3
Third 20 percent	6.7	6.6
Fourth 20 percent	5.0	5.4
Bottom 20 percent	2.3	2.9
Gini Ratio	0.707	0.700

[a]The observations for landless labor households were adjusted by a factor of 3.43 to represent the proportion of landless labor households relative to farm operator households.

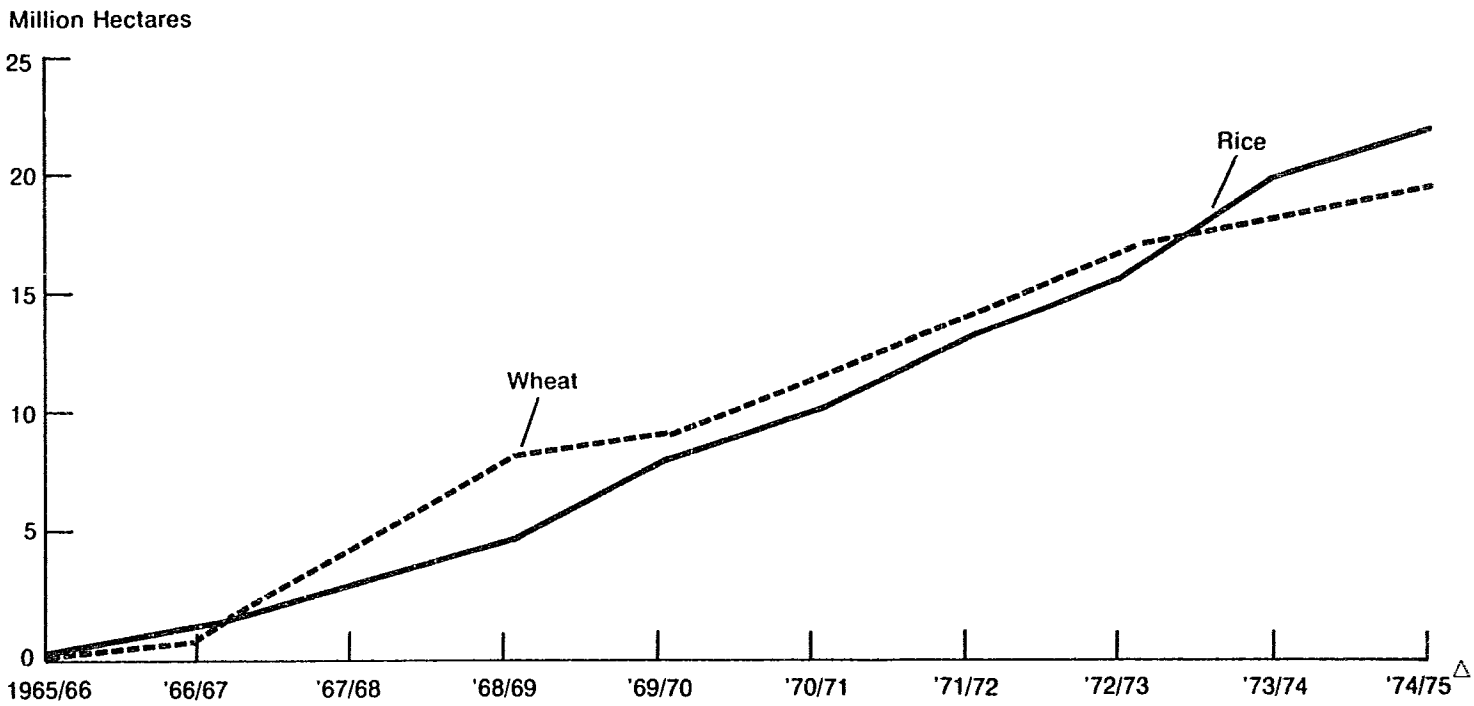
Source:
C. Geoffrey Swenson, "The Distribution of Benefits from Increased Rice Production in Thanjavur District, South India," *Indian Journal of Agricultural Economics*, 31 (January-March, 1976), pp. 1–12.

Table 3.0
Annual Linear Growth Rates of Agricultural Output and Residual Productivity: 1958–61 to 1963–63 to 1969–71

State	1958–51 to 1963–65		1963–65 to 1969–71	
	Output	Residual productivity	Output	Residual productivity
North West India				
Gujarat	4.71	2.81	7.13	4.78
Haryana	1.23	−0.70	20.40	16.10
Punjab	3.60	0.52	19.20	13.40
Rajasthan	0.06	−0.99	13.60	12.70
North Central & Eastern India				
Andhra Pradesh	2.63	0.11	−0.24	−1.05
Assam	1.48	−0.18	5.45	3.98
Bihar	2.36	0.32	1.57	−0.82
Madhya Pradesh	0.76	0.05	3.00	−1.52
Maharashta	0.85	−0.93	0.08	−2.13
Orissa	4.80	1.93	3.15	1.30
Uttar Pradesh*	2.47	0.66	4.87	1.43
West Bengal	4.66	2.67	2.18	−0.36
South India				
Kerala	1.30	−1.25	2.15	−0.67
Mysore	2.96	0.69	1.93	0.27
Tamil Nadu	1.77	−1.43	3.08	0.61

Figure 1.0

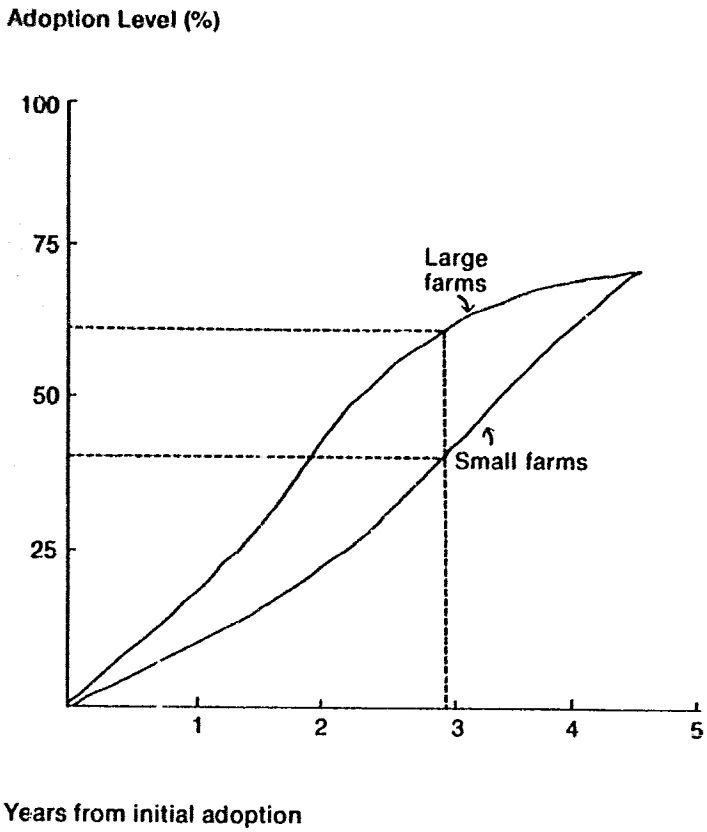
Estimated area of high-yielding varieties of wheat and rice, Asia and Near East



Excluding developed countries and Communist nations (except South Vietnam). Δ Preliminary.

Source: 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, Washington: US Department of Agriculture, August 1976, p. ix.

Fig. 2.0
Stylized Model of HYV Diffusion Process.



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