Increasing Agricultural Productivity

Proceedings of the Third Annual Agricultural Sector Symposium
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Third Annual Agricultural Sector Symposium

Ted J. Davis, editor

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SYMPOSIA ORGANIZATION
These proceedings are the third in a series of records of Agricultural Sector Symposia presented at the World Bank each January since 1980.

In planning this third program, the Symposium Working Group reviewed the evaluations by participants of the previous year's experience and sought to reflect the staff's wishes in the content and organization of the Symposium. An overriding concern was to select topics and speakers of broad interest and relevance to Bank work in the sector. Additionally, the Working Group recognized the need to sharpen the focus and to tailor the Symposium to maximize staff participation.

The Working Group chose the theme: "Approaches to Increasing Productivity in Agriculture," selected component topics, and suggested names of speakers. An important feature of the 1982 Symposium was the use of a number of Bank staff members as principal speakers. This was done to accommodate suggestions that Bank experience should be the basis for presentations on subjects in which the Bank had a comparative advantage in its knowledge of the subjects concerned.

Ten symposia topics were selected, and the program was arranged such that none ran simultaneously. Each consisted of a plenary session in the morning and more detailed follow-up discussions in the afternoon each day.

The year 1982 saw the introduction of a closing session featuring Mr. Clausen, the Bank's President and Mr. Yudelman, Director of the Agriculture and Rural Development Department, who presented his annual review on the state of global agriculture and rural development. Mr. Clausen used this forum to present his views on the Bank's work in agriculture and rural development to staff working in the sector.

This volume contains the papers presented by the speakers, chairpersons' statements, and summaries of the discussions prepared by the rapporteurs. The decision to publish formal proceedings is justified by the heavy demand, both inside and outside the Bank, for a permanent record of the papers presented and the interchange between speakers and participants in the Symposium. It is hoped that the material that follows will provide a means of enhancing the professional knowledge of all readers.
SESSION I

MACRO POLICY,
AGRICULTURE DEVELOPMENT and POLICY
AGRICULTURAL GROWTH, PRICE POLICY & EQUITY

by

Raj Krishna

1. Introduction

This paper discusses some aspects of (1) the relation between agricultural and nonagricultural growth and the allocation of investment between the agricultural and nonagricultural sectors in developing countries, (2) the relative role of price policy and technology policy in stimulating agricultural growth, (3) tax, trade and subsidy policies for agricultural growth, and (4) the possible reconciliation of agricultural growth and equity.

2. Agricultural Growth and Investment

Raising the level of investment and inducing its rational allocation is clearly recognised, even in the neoclassical tradition, as the most important task of macropolicy makers in developing countries because privately

*Thanks are due to P. Kumar for competent research assistance.
**Professor of Economics (India) Visiting Professor, Food Research Institute, Stanford University.
preferred investment is inadequate, and its allocation suboptimal; and/or capital markets are non-existent or fragmented; and/or there are large fields of divergence between private and social return. (Musgrave 1969, Ch. 8; McKinnon 1973, Ch. 2.) The share of direct State investment in the total may be high or low. But the broad allocation of the total must be "steered" by the State either directly or through an appropriate incentive system.

Farm specialists are of course deeply concerned about the adequacy of investment in agriculture. It is therefore necessary to develop some objective method of determining the required rate of agricultural growth and hence some standard of the minimum necessary share of agriculture in national investment. The actual share of investment in agriculture in any country can then be compared with the standard appropriate for it, and some judgment made about the "priority" given to agriculture, or its neglect. In some recent research the terms of trade of agriculture have been used as a criterion of priority. But it seems that the share of investment is a better criterion than terms of trade.

The use of the terms of trade rests on at least two assumptions: first, that the growth of aggregate farm output is related positively and strongly to the terms of trade; and, second, that governments can vary the terms of trade as they like. The first assumption may be true but its proof requires a large number of empirical aggregate farm supply functions (as distinguished from single-crop functions) with positive and significant terms of trade coefficients. But very few of these have been estimated so far. (See Section 3 below.)
The second assumption that governments control terms of trade can be true where the government confiscates, taxes or purchases a substantial part of farm output, and/or monopolizes, taxes or sells a substantial part of farmers' purchases. This is the case in some but not in all countries.

Therefore a judgment about priorities is better made on the basis of investment allocations rather than price movements.

The allocation of investment between farm and nonfarm sectors is necessarily related to their projected or targeted rates of growth. Given the projected rates of growth, and reasonable magnitudes of incremental capital-output ratios, the desirable share of agriculture in total investment can be approximated. The following argument on these lines will show that some developing countries have been investing enough in agriculture, but quite a few seem to be underinvesting in the sector. In this sense agriculture seems to be suffering neglect in many countries.

In projecting agricultural and industrial growth, the two are best regarded as complementary, rather than competitive, processes. Satisfactory growth in either sector depends on adequate deliveries of its input requirements from the other sector. Grain, raw materials and labour must flow from agriculture to industry in adequate measure. And consumption goods, modern farm inputs, and advanced technological skills must flow back from industry to agriculture.

The interdependence of the two sectors on the demand side is no less than on the input supply side. In relatively closed economies a succession

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1Industrial and nonagricultural growth are not distinguished in this discussion.
of bad harvests can generate an industrial demand recession, as in India in the mid-60s and mid-70s. And in agricultural export-dependent economies an industrial recession at home or abroad can severely depress farm incomes.

If the intimate supply-demand interdependence of agriculture and industry is recognised, the voluminous literary controversies between agricultural and industrial fundamentalists appear to be quite irrational and unnecessary. The estimation of "balanced growth" rates for the two sectors emerges as the only rational approach. Their growth has to be balanced in the important sense that the total output of each sector has to grow enough to meet the total (final plus intermediate) demand for it. Input-output modelling (of the consistency or optimizing variety, with exogenous or endogenous final demands) is the obvious technique for computing such balanced rates.

Numerous modelling exercises suggest that, at least in economies with relatively low trade/GNP ratios, such as India and Pakistan, farm growth rates of the order of 2 to 5 percent can be balanced only by fairly high industrial growth rates in the range of 6 to 10 percent. (Rudra 1972; PPD 1964; Eckaus and Parikh 1967; Lieftinck 1969). The industrial growth rate normally turns out to be two to three times the agricultural growth rate.

The actual record of the last two decades in the entire group of low-income and middle-income countries is consistent with an approximate average two-to-three ratio between the rates of growth in the two (aggregated) sectors, as well as the dominance of complementarity between them. Focusing on the 70s (for the experience of the 60s is similar) it is seen that agricultural growth
in the low-income and middle-income countries (combined) averaged 2.9 percent and industrial growth 6.4 percent. If we, therefore, choose 3 percent as the cut-off point to separate "low" and "high" agricultural growth, and 5 percent to separate "low" and "high" industrial growth, it turns out that 36 of the 58 countries for which both growth rates were available and positive in the 70s, a high agricultural growth rate was associated with a high industrial growth rate, and a low agricultural growth rate with a low industrial growth rate. In 23 countries both growth rates were "high;" in 13 both were "low." In a minority of 22 countries the relation between the two growth rates was not complementary: the agricultural growth rate was low and the industrial growth rate was high; or the agricultural growth rate was high and the industrial growth rate was low. But it is interesting that 15 of these 22 countries managed to have a high industrial growth rate with a low agricultural growth rate. And only a few (7) could have a high agricultural growth rate with a low industrial growth rate.

In generalised terms, this would mean that complementarity between agriculture and industry is dominant; but where it does not obtain, the probability of a high industrial growth without a high agricultural growth is higher than the probability of a high agricultural growth without a high industrial growth. The possibility of a high industrial growth without a high agricultural growth exists particularly in open economies where the input-dependence as well as the demand-dependence of industry on agriculture is weak. (In other words the input-output matrix and the matrix linking value added and final demand has block-angularities.)

1 The data are derived from WDR 1981. "Industry" includes mining, manufacturing, construction, gas, water and electricity.
This possibility reduces the importance of agricultural growth in some parts of the world; but in most parts planning can rightly proceed on the assumption of strong complementarity between agricultural and nonagricultural growth. Recalling the experience of the 70s the contrast between the low-growth complementarity of the two sectors in South Asia (India, Pakistan and Sri Lanka) and the high-growth complementarity in Eastern Asia (Indonesia, China, Thailand, Malaysia and the Philippines) is particularly striking. The latter countries successfully achieved industrial growth of the order of 8 to 11 percent along with agricultural growth in the range of 3 to 6 percent. Similar groups of countries are identifiable in Latin America, with Brazil, Colombia, Guatemala, El Salvador and the Dominican Republic in the high-growth complementarity group, and Argentina, Peru, Panama and Uruguay in the low-growth complementarity group.

In contemplating the relation between agricultural and industrial growth it is also useful to bear in mind the long-run historical perspective. As Prof. D.G. Johnson has noted, "agriculture is a declining industry when economic growth occurs. This is inevitable and desirable." (Johnson 1973, p. 33.) He does not mean, of course, that absolute agricultural output should decline; it must keep growing. But the share of agriculture in national output and employment must decline. There is "no theoretical basis for assuming that the decline of employment opportunities in agriculture will come to an end." (Johnson 1973, p. 98.) This monotonic reduction of the relative size of agriculture in the economy is confirmed by the Chenery-Syrquin stylization of long-term structural change. A rise in income per capita from 70 to 1500 dollars (in 1964 U.S. prices) reduces the share of food consumption
in GNP from 41 to 17 percent, the share of primary production in GNP from 52 to 13 percent, and the share of the primary sectors in the labour force from 71 to 16 percent. (Chenery and Syrquin 1975, p. 20.)

Two forces drive down the share of agriculture in demand (output) and employment: the Engel's law on the demand side, and absolute and differential (labour) productivity growth on the supply side.

The income elasticity of demand for food products keeps falling steadily from 0.9 at a per capita income of $165 to a mere 0.16 at a per capita income of $2190. The income elasticity of demand for textile fibres too declines from unity to nearly zero across the same income-range. (Johnson 1973, pp. 72-73.) On the other hand, productivity per worker in agriculture eventually grows very fast (4 to 7 percent per annum) but productivity in industry grows even faster, so that value added per capita in agriculture comes to be only around one-third of value added in nonagriculture. (Johnson 1973, pp. 68, 214, 215.)

Developing countries as well as developed countries cannot escape the working of these long-run laws. But the tendency more relevant to poor countries is that in the medium run the agricultural growth rate can, and normally should, accelerate, though later it may decelerate. This is evidenced by some well-documented case histories. In successive phases the Japanese agricultural growth rate accelerated from 1.6 to 3.1 percent; the Taiwanese from 2.8 to 4.2 percent; and the Korean from 0.5 to 4.5 percent. But over long periods the Japanese agricultural growth averaged only 1.7 percent (1876-1967); the Taiwanese only 3.0 percent (1913-1970); and the Korean only 1.94 percent (1920-69). (Hayami et al. 1979 pp. 17, 35, 61, 92.)

Cross-sectionally, too, we see that in the 70s the agricultural growth rate averaged 2 percent in the low-income countries, 3 percent in the middle income countries and about 1 percent in the high-income countries. (WDR 1981,
Thus the historic role of agriculture in the developmental transition seems to be to accelerate its own rate of growth, thereby to facilitate industrial growth at a rate which is at least twice its own rate of growth, and keep shrinking in relative size all the time. In the early stages of development, agricultural growth can and should accelerate to 3 to 5 percent; but over the long run it is normal for it to average 2 percent or less. On the other hand the industrial growth rate can and should be not less than 5 percent in the early stages and keep accelerating to 8 to 10 percent or even more.

Very little material is available on agricultural incremental capital-output ratios in developing countries. Practical planners as well as theoretical economists have generally tended to underestimate them and hence the investment requirements of agricultural growth in low-income countries. It has been customary in development theory to exclude capital altogether from the agricultural production function. (See, for example, Jorgenson 1969 and Taylor 1979.) Planners usually assume low capital-output ratios of the order of 1.0 to 1.5 for agriculture and therefore come up with relatively small investment allocations for its development. But there is some evidence to show that at least in some phases of development, the incremental capital-output ratio in agriculture can be as high as in manufacturing. In a U.N. study, for example, the ratio for the mid-sixties in a number of developing countries was reported to be 3.2 for agriculture, 2.8 for manufacture and 3.0 for the whole economy. (UN 1971, p. 1981.) For Pakistan a World Bank

\[ k \]

In the following discussion this ratio is denoted by \( k \).
study computed the agricultural $k$ as 3.5 in making projections for the period 1963-75. (Lieftinck et. al. 1969)

In India $k$ seems to have been relatively low; but it has risen from 1.9 in the early fifties to 2.7 in the early 70s. (Kelkar 1980.)

Taiwanese time series of fixed capital and gross value added for the long period 1911 to 1972 show that in the first 5 years of the period the incremental ratio between the two was as high as 6.4. In the last 5 years at the end of the period it was still 4.3. Including working capital, for which estimates are not available, the ratios would, of course, be higher.

The Japanese $k$ (fixed capital/gross value added) as computed from the long series appears to have risen from 1.7 in the late 70s of the last century to as high as 14.2 in the late 60s of this century. (Hayami et. al. 1979.)

Recent national accounts show the American $k$ to have increased to 2.7 in the early 70s and 3 in the late 70s. (UN 1980.)

These numbers are hardly comparable. They can be used only as broad indicators of the range of $k$. The measurement of $k$ involves numerous well-known problems of concept-choice, valuation and data collection. But the bits of available data, particularly the relatively reliable Japanese and Taiwanese data, do suggest that it would be an error to assume values of $k$ below 3 for planning investment in the early stages of development. Detailed studies of $k$ and its behavior over time are necessary. It evidently does vary a great deal over time. The long Japanese and Taiwanese series indicate that in Japan $k$ was high in the very early period, declined and stabilised in the middle period, and rose steeply in the 1960s. In Taiwan it rose in the early period, declined in the middle period, and remained stable.
thereafter.

This behavior is consistent with the surmise that in the Asian context, k rises (a) in early periods when basic investments in irrigation/drainage and/or land development are made, and (b) later when mechanization becomes necessary. And it declines when, in a middle period, given irrigation, productivity grows mainly due to bio-chemical input growth.

It is specially important that wherever there is a large irrigation slack, a high k be assumed. One reason why k could fall from a high level in Japan and Taiwan in the middle periods was that the paddy-irrigation ratio had been raised to 100 percent in Japan as early as 1880, and to 60 percent in Taiwan as early as 1910. (Hayami et. al 1979). Some Asian countries have raised their overall irrigation ratio to more than 50 percent in recent decades (Pakistan, Sri Lanka and Malaysia). In other countries it still remains less than half (India, Indonesia and the Philippines.) (ESCAP 1980, p. 105). India has raised its overall irrigation ratio from 17 to only 25 percent over 30 years at a very high and rising investment cost. The irrigation investment cost per hectare has risen 10 times over this period. (CMIE 1981, 3.2, 12.4.)

The high overall investment cost of agricultural development simply has to be accepted as a necessity, and provided for. Many estimates of the investment requirements of agriculture in the near future are available. All of them show the insufficiency of current investments. To cite an estimate for irrigation alone, the Trilateral Commission (1977) has estimated that "foodgrain production can be doubled at present levels of technology by 1990 (4.8% per annum) at an annual irrigation-investment cost of $4.5 billion (at 1975 prices)
or about six times the current investment rate of $700 million. This
implies an annual growth in irrigated command area of over 5% per annum
compared with the current rate of 2%. This rate of irrigation growth in
demand will be inadequate to meet a 3 to 4% growth in demand for food." (Barker
in Schultz 1978, pp. 156-57.) The Brandt Commission's estimate of investment
requirements for food self-sufficiency in all regions is $7 billion a year
over the next 20 years.

When one considers the rapidly rising cost of raising the NPK input
per hectare to levels already reached in the world's intensive agricultures;
or the cost of agricultural research and extension for quickly adapting and
extending basic research findings to tens of millions of farms over vast
territories; or the cost of producing and supplying hybrid seed, pesticides,
energy and equipment to them, it is safe to contemplate a steadily rising k
in the next few decades.

The tendency of the agricultural k to rise would be in tune with the
general tendency of the overall k to rise over time. In the U.S. for instance
it rose from 2.9 to 5 between 1900 and 1953. (Klein and Kosobud 1961.) But
the real cost per unit of output still declines because technology embodied
in new capital raises total productivity faster than it raises k.

The share of national investment that needs to be devoted to agricultural
development can be roughly computed if, in the light of the empirical tendencies
mentioned above, a realistic agricultural growth rate g and a realistic
agricultural k are selected. Two additional parameters are required: the
share of agriculture in national income r, and the national investment-income
ratio $s$. The required share of agricultural investment in total investment can then be calculated as $(gkr/s)$. Thus, if for a low-income country a 3 percent farm growth rate is desired, the incremental capital-output ratio is assumed to be 3, the share of agriculture in national income ($r$) is 0.5 and the investment rate 0.2, the country should be earmarking 22.5 percent of total investment for agriculture.

Over time $g$ should be expected to rise and then decline; $k$ to rise, decline and rise again; $r$ to fall; and $s$ to rise and then stabilise. The required share of agriculture in total investment therefore differs at various stages of development. For most low-income and middle-income developing countries the required share, computed with reasonable parameters, appears to be between 20 and 30 percent. But in the mid 60s (1966-68) data for 20 countries given in the UN study cited above show that not a single one of those countries allocated 20 percent of total investment to agriculture. Only 3 allocated more than 15 percent. And about half of them allocated less than 10 percent. More recent national accounts for the early 70s also reveal low shares of agriculture in investment: 8 to 9 percent in Korea, for example, 11 percent in Thailand, and 15 percent in Malaysia. The share was less than 10 percent in most of the African and Latin countries for which national accounts are reported; only in a few it was between 15 and 20 percent. (UN 1980.)

These numbers are subject to obvious pitfalls. National accounts are often defective. Criteria for categorising direct agricultural investments are arbitrary and differ across countries. The estimates of direct private capital formation by farmers, particularly with family inputs, are often unavailable or unreliable. There are also the usual problems of valuation. Direct agricultural investment in any case excludes much investment which is classified as nonagricultural but is critical for agricultural growth. For instance the investment in the industries producing farm inputs (seeds,
fertiliser, pesticides and equipment) is usually classified as "industrial," and the rural share of public investment in infrastructure and human capital is classified as utility or service investment. More research is needed to develop better estimates of actual and required investment shares.

Nevertheless, the available range of shares (which are almost all subject to similar errors and hence perhaps comparable!) constitute prima facie evidence of widespread underinvestment in agriculture in many parts of the developing world. Agriculture does not need, as some extremists seem to think, a major share of total national investment; a 20 to 30 percent share would suffice in most situations as direct investment. It seems that even this is not provided in many countries. In this sense agriculture is neglected. And opinion needs to be built up to rectify this situation.

For the allocation of total agricultural investment between different growth-promoting activities, programming has been attempted. (Good examples are available in Coreux and Manne 1973.) But at least 3 difficulties beset the practical use of agricultural investment modelling. First, private (farmers') investment decisions can be influenced only indirectly. Second, much interdependence (complementarity) characterises agricultural investments. This makes it difficult to separate and compare the productivity of different specific investments, or creates the need for substantial mixed packages. The same increases in income/output are attributed to different investment inputs, depending on which investment is currently being justified! The zone of interdependence extends beyond direct agricultural investments to "nonagricultural" infrastructural and human capital investments. And, third, the usual, successive processing of single projects can hardly produce an overall allocation which is rational in any sense. Thus an ambitious modelling of agricultural
investment allocation may not be feasible.

But there is one paradoxical feature of farm input relationships which allows considerable flexibility in the allocation of investment. Farm inputs are interdependent, and yet independent over a wide range. An \( x \) percent simultaneous increase in many inputs, say improved seed, irrigation and NPK, would produce a greater percentage increase in output than the sum of the percentage increases in output due to an \( x \) percent increase in each of the inputs separately. But at the same time an increase in either of them alone would yield a high enough return over a considerable interval.

Therefore agricultural investment can be in a state of dynamic Hirschmanian imbalance: some rough allocation can be initially made, covering clearly linked requirements; unforeseen constraints (or opportunities) are then encountered, and investments to relax (utilise) them follow.

But research on the decomposition/explanation of growth in success cases suggests that at every stage the farm investment package should include investments in technology as well as infrastructure and human capital. Except in very sparse regions, the growth of farm area per capita ceases to be a significant growth factor after a short initial period (as in almost all Asian countries.) After this period output growth depends almost entirely on yield growth. In the dynamic growth phase when output grows 3 to 4 percent a year about 50 to 75 percent of output growth is attributable to total factor productivity growth i.e., technological change, and only a minor part to conventional input growth. (Hayami et.al.1979). Hence the obvious need for investment in research and extension, and modern inputs. Recent World Bank documentation (World Bank, AR, 1981, p. 58) shows up the research slack. Poor countries have 16 scientists per million of agricultural population, the
rich have 62; poor countries spend 26 U.S. cents per head of agricultural population, the rich spend 157. Similar slacks exist in extension density. In respect of modern inputs (HY seed, irrigation and fertiliser) again there are large technological gaps to be bridged. After a decade of the introduction of HY seeds only about one-third of the wheat and rice area in the developing world is planted with them. (World Bank, AR, 1981, p. 21.) Unutilised irrigation potential around the world is estimated to be 1.1 billion hectares. The range of NPK use is as wide as 20 to 500 kg. per hec. And cereal yields, still stagnating at 1.5 tons per hec. or less in most of the developing world, can be doubled. (Scrimshaw and Taylor 1980.)

As for infrastructure and human capital development, their criticality for agricultural development has been documented in much recent work. (See WDR 1980; Welch 1978 for education; Hasan 1976 for Korea; and FRK 1979 for Taiwan.)

One may even say that there is no need now for more detailed benefit-cost studies to prove the productivity of research, extension, HY seed, irrigation water and fertiliser, energy and transport, health and schooling. Analyses are needed only to choose the most cost-effective forms and dosages of these inputs, adapted to different farming communities. But the access of every community to all these inputs can now be regarded as a right.

3. Price Policy

In the field of price policy, as in the field of growth policy, we have to reckon with the prevalence of fundamentalism. Like agricultural/industrial growth fundamentalism, there is price fundamentalism. The rational escape from the former is provided by the notion of balanced
sectoral growth; likewise, a rational answer to price fundamentalism would be a balanced view of the role of price policy and nonprice (technology) policy in promoting growth. The need for balance is clearly suggested by the present state of research on farm supply response.

Although supply response is a heavily researched area, there are surprisingly few studies of the response of aggregate farm output to lagged terms of trade *inter alia*. Such studies are obviously crucial for measuring the marginal leverage of terms of trade as a means of stimulating agricultural growth. In recent survey papers of the World Bank tabulating about one hundred single-crop price elasticities of acreage/supply for developing countries, only two aggregate supply elasticities are recorded: for Argentina, and Punjab (India). (Sobhan 1977, Table 1 and p. 13; Scandizzo and Bruce 1980, Appendix II, Table 1.) For Europe and the USA, however, as many as 9 of the 36 elasticities tabulated by Professor D.C. Johnson (1973, p. 113) are aggregative.

In the OECD region, of course, the (short-run) aggregative elasticities are in the same range (.25 to .45) as single major-crop elasticities. The Argentinian (short-run) elasticity came out to be .21 to .35 in different regressions. The Punjab study yielded a significant positive elasticity (0.22) for the prewar period (1907-46) but a negative elasticity (-0.06) for the postwar period. The author explicitly noted that in the postwar period output expanded while the terms of trade declined; and suggested that growth was primarily due to technological change. (Herdt 1970.)
In order to examine the effect of the terms of trade of agriculture on aggregate farm output two new equations have been estimated\(^1\) for Japan and India using the available terms of trade series. The most satisfactory of the alternative regressions tried are:

**Japan (1881-1919)**

(J.1) \[ Q_t = \text{constant} -132.80 \ P_{t-1} + 30.52 \ T + 0.17 \ Q_{t-1} \]

\[ (t) \ (-0.53) \ (4.77) \ (0.97) \]

\[ (e) \ [-0.05] \]

\[ R^2 = 0.90 \]

(J.2) \[ Q_t = \text{constant} -188.05 \ P_{t-1} + 36.40 \ T \]

\[ (t) \ (0.78) \ (17.78) \]

\[ (e) \ [-0.08] \]

\[ R^2 = 0.90 \]

**India (1952-53/1974-75)**

(I.1) \[ Q_t = \text{constant} + 0.14 \ P + 0.49 \ W_t + 3.08 \ Z_t + 0.45 \ Q_{t-1} \]

\[ (t) \ (1.49) \ (4.68) \ (2.11) \ (2.44) \]

\[ (e) \ [0.18] \ [0.54] \ [0.67] \]

\[ R^2 = 0.92 \]

(I.2) \[ Q_t = \text{constant} + 0.25 \ P_{t-1} + 0.53 \ W_t + 0.81 \ Q_{t-1} \]

\[ (t) \ (2.78) \ (4.71) \ (9.41) \]

\[ (e) \ [0.32] \ [0.58] \]

\[ R^2 = 0.91 \]

\(^1\)For this paper, using series from Hayami et. al. 1979, Kelley and Williamson 1974 and Thamarajakashi 1977. Of the three terms of trade series available for India, the foodgrains terms of trade yielded relatively more significant coefficients.
Here:

- \( Q \) = farm output,
- \( P \) = terms of trade,
- \( T \) = time-trend,
- \( W \) = weather index, and
- \( Z \) = irrigation ratio.

The price coefficient is marginally significant in the first Indian equation and clearly significant only in the second Indian equation; the price elasticity is about 0.2 in the first and 0.3 in the second. In the Japanese case the trend coefficient is very significant but the price coefficient is statistically zero in both equations; the implicit price elasticities are negative and extremely low (-0.05) and (-0.08). Thus the Japanese equations suggest a negligible price-response. And the Indian equations suggest a price elasticity of about 0.2 to 0.3.

The terms of trade plainly do have a positive output effect in Argentina and India and perhaps in most other currently developing countries; so a favorable price-environment is essential for agricultural growth.

But for a balanced view of the relative role of price and nonprice factors in promoting growth two implications of supply studies need to be noticed.

First, if we consider, for a moment, price policy as the sole instrument for fostering agricultural development, the order of annual terms of trade increases required is certainly more than a poor country can manage on macro grounds. Suppose for instance, that the price elasticity is 0.2 and a low-income country needs 3 percent annual growth in farm output. Then,
the "long run" implied by the usual lag coefficient (.05) being about 5 years, the long-run elasticity would be 0.4, and 16 percent growth over 5 years would require a 40 percent increase or about 7 percent annual increase in the real terms of trade of agriculture. This is hardly a practical proposition, assuming that a government can fix terms of trade.

The second important fact relevant here is that in most supply regressions the elasticities of supply with respect to shifter variables (proxies for technological change, such as the irrigation ratio) exceed the price elasticities. In the Indian function (I.1) above, the irrigation elasticity (0.67) is more than 3 times the price elasticity (0.18). In post-war Indian wheat functions the irrigation elasticity (0.75 to 0.80) has been found to be 1.5 times the price elasticity (about 0.5). (Krishna and Rai Chaudhuri 1979; Krishna and Chhibber 1980.) And in an early supply response study of 11 crops in the Punjab (India) (Krishna 1963 (Table 1b); Krishna 1967) it was observed that the irrigation elasticity exceeded the price elasticity in every equation where irrigation was included. The irrigation elasticity was in fact 1.5 to 5.5 times the price elasticity in the case of various crops (cotton, millets and wheat.)

Thus there can be little doubt that a unit percentage change in the important shifter (technology) variable will yield much greater growth than a unit percentage price-shift. Output growth is, after all, mainly the gift of resource-growth or productivity-raising technology which shifts the supply curve; price movements do move output, but much less, along the supply curve.
There are many episodes in the record of advanced countries in which the (lagged) terms of trade facing agriculture have stagnated; and yet farm productivity has grown 2 to 3 percent a year for considerable periods. (See Johnson 1973 pp. 68-122 for OECD countries and Kelley and Williamson 1974 and Hayami et. al. 1979 for Japan.) The explanation, again, lies in technological dynamism.

The price-fundamentalist would, of course, argue that technological change itself is induced by relative price movements. This proposition has a core of proven truth. (Hayami and Ruttan 1971.) But only some aspects of innovation, in the broadest sense, can be shown to be price-induced. The price milieu would determine the relative (private) profitability of different lines of completed applied research; or the rate of adoption (diffusion) of its results. But it cannot by itself explain the evolution of basic scientific knowledge and the level and growth of public investment in research, extension, infrastructure and human capital in different parts of the world. The growth of basic knowledge has some irreducible non-linearity, discontinuity and randomness. And governments have been far less rational than peasants in making investment decisions. If relative price movements were sufficient to generate high-yield technology, this technology should have emerged in the areas of recurrent drought-induced food-price inflations (in South Asia and African societies) in the 19th and early 20th centuries. But it did not develop there; it developed elsewhere, was transferred to the scarcity-ridden societies, and is still to be indigenised and widely adopted in these needy societies.
The upshot is that a congenial price regime is a necessary but not a sufficient condition for agricultural growth.

Technological change, by definition, increases the total factor productivity of the aggregate conventional input. Even at unchanged output and input prices, therefore, it must increase the return per unit of cost. To see this one has only to write the return/cost ratio \( r = \frac{PQ}{pF} \), where \( Q \) and \( F \) are total output and total input, and \( P \) and \( p \) are output and input prices, as the product of the terms of trade defined as \( p^* = \frac{P}{p} \) and total factor productivity defined as \( t^* = \frac{Q}{F} \). Then, if a hat (\(^\hat{\cdot}\)) denotes the growth rate, \( \hat{r} = \hat{p}^* + \hat{t}^* \). Thus profitability \( r \) can be raised either by improving the terms of trade \( (p^*) \) alone without innovation \( (\hat{t}^* = 0) \); or by improving productivity \( (t^*) \) at unchanged prices \( (\hat{p}^* = 0) \); or by improving both.

Successful innovation is thus an alternative, as well as a strong supplement, to an increase in the output-input price ratio, as a means of raising the return/cost ratio and thereby stimulating growth.

In this important sense a good technology policy is equivalent to a good price policy. A balanced policy should of course include both. But there is a case for giving primacy to a technology policy. For, as we have seen, the (partial) elasticity of output with respect to indices of technical change is known to be generally higher than with respect to relative price indices. The measured social return to agricultural research and extension is also known to be very high (48 to 53 percent) (Hayami and Ruttan 1971, p. 41). It is in all probability much higher than the return to price policy. National policymakers and international development bankers will therefore do well
to devote more attention and effort to the development of technology, infrastructure, and human capital than to the price environment.

Price policy should not, however, be negative. If possible, the output-input price ratio should not be allowed to fall; for otherwise the growth-inducing effect of innovation is reduced. The relevant price ratio is of course net of taxes and subsidies. Abstracting here from tax and subsidy policy two major issues arise with regard to direct product price policy: (1) the determination of the support price/purchase price level for any product, and (2) the maintenance of appropriate inter-product price relatives in the support/purchase prices.

Despite numerous studies showing the undesirable allocative and distributive effects of price support, it is a safe assumption that support policies will continue in the OECD and developing countries alike, though the mixture of motives for these policies differ as between these two sets of countries. In the OECD group, it includes income support, stabilization, risk reduction and/or the discouragement of excess production. In developing countries it covers stabilization, risk reduction, encouragement of production growth, food security and diversification. (All these concepts carry varying meanings across countries.)

Taking growth promotion to be the major aim in a poor country, there seems to be no alternative to the adoption of "full average cost" (including the imputed value of family resources at market prices) as the basic principle of support price fixation for any single crop. This principle is opposed on many theoretical grounds: the cost of specialised resources is demand-determined;
the relevant cost is subjective, opportunity cost in the presence of uncertainty; and the cross-sectional variance of cost is very high. (Pasour 1980.) But there are counter-arguments favoring the full cost principle. It is difficult to estimate the theoretically ideal cost as a basis of support. Underwriting the return to specialised (family-supplied) resources at (lagged) market-determined prices can be viewed as a way of providing a surplus for investment (a necessary incentive for growth in poor countries.) Wherever cost data are generated by regular sample surveys the full cost principle has proved to be administratively workable (as in India). Under certain circumstances the cost principle may entail a lower treasury cost than the parity principle. (It is interesting in this connection that the cost principle has been accepted recently in the U.S. Food and Agriculture Act of 1977 as an alternative to parity.) The coverage of full average cost provides downward price stability or insurance against the risk of a price-decline below cost in the sense most meaningful to the farmers, particularly the small farmers in poor countries. The cost variance problem can be handled for practical purposes by choosing the sample deciles whose average cost is to be covered.

Thus on balance the cost principle can be used as the least unsatisfactory basis for price support. While the support price is a guaranteed minimum, entailing "passive" purchases by the government when the market price goes below it, many governments engage in "active" purchases of grain for running a concessional subsidized grain supply system, or building up public sector stocks. These purchases need to be made in principle at the going market price even if it is much above the support price. If
direct redistribution of income is not feasible and the low-income population of a poor country would suffer unacceptable cuts in food consumption at market-clearing prices, the operation of a concessional (subsidized) food supply system, to serve this population and the associated dual pricing, becomes a second-best necessity, though it has been criticized as a distortion. But the subsidy must be financed from the general revenues and not by forcibly reducing the price realized by (and thus taxing) farmers only.

In many countries, supporting the prices of many farm products, the inter-product price relatives need to be deliberately rationalized. Otherwise farmers switch resources between products (wheat and rice, cereals and pulses, fine and coarse grains, foodgrains and feedgrains, feed crops and cash crops, crops and livestock etc.) in response to "wrong" signals, generating excess demands and excess supplies in different product markets. This particular problem is often due to the practice of fixing support (purchase) prices for different products one by one, with uncoordinated formulae. The problem can be reduced by fixing a coordinated support price-package for all supported crops. The determination of this package – the consistent price-set – can be guided by the solution of a farm sector general equilibrium model. Operational research on such models to derive consistent administered price-sets deserves priority.1

4. Taxes, Trade and Subsidies

The argument so far has treated price policy in abstraction from the effects of taxation, trade policy and subsidies, on farmers and consumers. Considerable

1Attention may be drawn here to the recent work of IIASA on sector modelling. See K. Parikh and F. Rabar 1981.
empirical work has been done to measure the combined effects of the whole mix of these macro policies in several countries. An excellent summary of the methodology and the main results of this work is available in Scandizzo and Bruce (1980). But the assumptions underlying this methodology, and the policy implications that follow, merit a critical examination in view of the multiple objectives of policy makers in developing countries, as well as the current thinking in the fields of public finance and international economics relevant to these countries. A partial review on these lines is presented in this Section. It will show that many forms of discrimination and trade restriction, prevalent in these countries, are undesirable for agricultural development; but some interventions appear to be fully justifiable.

**Taxation.** In the field of taxation, the basic issue is whether the tax system should discriminate at all against, or in favor of, a whole production sector such as agriculture. Unfortunately, there is a long tradition of classical as well as Marxist arguments for discrimination against agriculture. They add up to the theory that the exploitation or immiserization of agriculture is an inescapable requirement of industrialization. These arguments continue to influence some economists and administrators in developing countries. But all of them appear, on scrutiny, to be invalid.

In the Marxist tradition the main argument for discrimination against agriculture is that accumulation by landlords and usurers—of rent, interest and the output of unpaid serf-labour—constitutes the main initial investible surplus which a revolutionary government should seize and invest in industry. This argument, combined with the general anti-peasant, anti-agriculture bias of
early Marxist thought (Mitrany, 1951), resulted in the collectivisation and "exploitative" treatment of agriculture under the early Russian and East European five-year plans.

In the liberal tradition, the argument for a heavier taxation of agriculture emanated from the dominance of the rental component in agricultural income. Since taxes on economic rent could not be shifted they were regarded as specially desirable. (See Wald, 1959, Ch. 4.)

Another argument which reinforced the rent argument for the taxation of agricultural income was the notion of a perverse supply curve of labour in agriculture. A tax on agricultural labour income was deemed desirable because this perversity would not allow an adverse output effect.

Unless one is a doctrinaire anti-agriculturalist, the substantive point in the Marxist view is rationalisable in the proposition that in the early stages of development a government in search of investible funds, should tax surpluses--excesses of income over subsistence--heavily and progressively. It is logically implied in this view that surpluses should be taxed wherever they happen to be. Since they happen to be with traditional landlords and money-lenders as a result of previous accumulation they have to be taxed there. But if they happen to be with a pre-revolutionary non-agricultural bourgeoisie, or with the post-revolutionary public and private sectors, they have to be taxed equally. The object of developmental taxation must be all surpluses and not agricultural surpluses alone. But all Marxists somehow do not accept equal treatment of farm and nonfarm surpluses.

In considering classical arguments it is necessary to raise the basic question of the validity of tax discrimination between different types of income.
For equity the magnitude of income alone is important; its sectoral origin is irrelevant. Governments, however, do treat different types of income differently. One distinction that has now come to be accepted as valid by the theorists of finance is the one between "earned" and "unearned" income. This distinction is really intended to be an approximation to the economically meaningful distinction between labour income and property income. Discrimination between the two is rationalisable on grounds of equity because labor income Gini is usually less than property-income Gini. If it is accepted, the consequence should be that if there are two equal incomes, one of which has a larger property income component than the other, the former should be taxed more heavily.

Now, on this principle, a case for heavier taxation of agriculture can be derived only if it is true that the property income component of value added in agriculture is always larger than the property income component of value added in non-agriculture. But data do not confirm this expectation. In India, for example, the ratio of the wage bill to value added in large-scale industry and mining averaged 40-42 percent during 1955-1958. (Mukerji, 1965, p. 161.) The ratio of labour income to value added in agriculture estimated from Indian farm management data turns out to be 42 to 53 percent. Therefore the residual share of property income in value added cannot be larger in agriculture than in industry. It follows that heavier taxation of agriculture as such cannot be justified if the intention is merely to discriminate between labour income and property income.

In order, then, to make an argument for discrimination against agricultural income, one would have to go further and argue that as between types of property income, landed property income should be taxed more heavily than non-land property income. If this discrimination is based on the notion that landed property income is absentee income, it is again untenable and iniquitous. For all urban property income from real estate and financial assets, that is, all income except income
from household industry, is necessarily absentee income, whereas the bulk of the income of the small owner-cultivator from agricultural land is directly due to his own labour.

The conclusion to which we are thus driven is that if heavier taxation of property income than of labour income is considered just, all property income, agricultural and non-agricultural, should be similarly treated; and all labour income, agricultural and non-agricultural, should be similarly treated. Absentee property income in the village cannot be regarded as any more or less odious than absentee property income in the city. If one is against citizens having private absentee ("unearned") incomes simply because they happen to have accumulated income-yielding assets in the past, one should be proposing either the abolition of all private property in such assets, or a capital levy on all property, rather than fiscal discrimination only against certain forms of it.

The whole trend of contemporary thinking is to treat all durable productive assets, land and non-land, equally as different forms of capital. The specialty of land as a durable asset is a hangover from the past which still bedevils some fiscal thinking. But it is high time that the hangover disappears. Neither in its productive role, nor in the determination of its capital value and rental value, is land different from any other productive asset. The only component of rent which has a non-capital character in theory is pure site value. But it is nearly impossible in practice to measure and assess it as a separate component of the empirical rent. (See Wald, 1959, pp. 77-78, 80 and 93.)

Moreover, the rigidity of the supply of land for a society as a whole is no longer so categorically distinctive a feature of land now as it was in the 19th century, because modern technology has enormously increased both the
reproducibility and substitutability of the productive power of land.

As for the non-shiftability of taxes on rent, Ursula Hicks has rightly disposed of the generality of the argument: "It was argued that the full effective incidence of the tax would be on the landlord, because an overcharged tenant would move away, and so the tax would have no disincentive effects. This may well have been true in English conditions during the time of the Napoleonic wars and the Industrial Revolution, when Ricardo put forward this analysis. But the Indian peasant had neither the knowledge nor the opportunity to get away from an extortionate landlord." (Hicks, 1965, pp. 104-5.)

In countries where the proportion of the agricultural labour force in the total remains higher than 50 percent and millions of landless households compete for insecure crop-sharing contracts from year to year, it would be untenable to argue that any tax on the landlord would not be shiftable.

There remains the labour supply curve argument. Unfortunately we do not yet have a sufficient number of estimated labour supply curves for various milieus and various classes of farmers. But theoretically, even supposing that these curves have negative slopes, we can build a case for heavier taxation of agricultural labour income only if similarly estimated non-farm labour supply curves are shown to have positive or smaller negative slopes. But if all labour supply curves had similar slopes the case for heavier taxation of farm labour income would not follow. All labour income would have to be treated similarly.

Thus neither the orthodox Marxist nor the classical arguments for discrimination against the agricultural sector stand critical scrutiny.
In fact a sector is neither an income-earning nor a tax-paying entity for fiscal purposes. The whole of the value added in a sector accrues to some individuals, families or firms who are the real tax-paying units. And if a tax system has horizontal equity in the sense that units with equal taxable incomes are taxed equally, and vertical equity in the sense that the elasticity of tax payment with respect to taxable income has some socially acceptable value greater than unity, then the concept of intersectoral equity (or discrimination) used by some economists is operationally unnecessary.

It has been argued that "considerations of horizontal equity do not justify an absolute corporation tax, that is, a tax that goes beyond the objective of extending the personal income-tax to retained earnings." (Musgrave, 1959, pp. 173-174.) If there is no case for an absolute corporation tax, there is evidently none at all for an absolute sector tax.

On grounds of vertical equity, again, if the difference between the tax-income ratios of different income-brackets reflects the socially desired degree of progression, it is immaterial whether the taxpayers in each bracket are farmers, workers, technicians or entrepreneurs.

Every consideration, then, shows up the weakness of arguments supporting heavier direct taxation of agricultural income simply because it is agricultural.

In the field of indirect taxation, discrimination between (a) wage goods and luxuries, (b) ordinary and merit goods, (c) consumption, intermediate and investment goods, and (f) traded and non-traded goods, is accepted as valid under certain conditions. On these principles, foodgrains and most of the farm-produced raw materials which go into the production of wage-goods, should attract no or low domestic indirect taxes. So should farm inputs and small-scale farm equipment.
Unfortunately, these principles too are widely violated and many farm inputs and outputs are subjected to unjustifiable discriminatory taxation. They are also discriminated against in non-fiscal policies.

The main non-fiscal mode of exploiting agriculture is the use of monopoly power in the purchase of farm output at less than competitive prices, and the sale of important inputs (particularly fertilizer and equipment) at more than competitive prices by state marketing agencies, and/or large national and multinational corporations. These monopolistic operations of public and private agencies are fundamentally objectionable from the neoclassical as well as the socialist point of view. They entail a heavy allocative social cost and a grossly inequitable transfer of income from millions of low-income peasants to bureaucrats and local and foreign capitalists. Export agriculture (the marketing of bananas, cocoa and coffee, for example) is particularly afflicted by monopoly power—frequently exercised by state and multinational agencies in cooperation. In fact, there seems to be little difference between state monopolies and private monopolies in their ability and willingness to squeeze farmers—though some socialists do not appreciate this identification of the behavior of the old and new rentier classes. Much descriptive documentation is available of the similar "exploitative" character of both kinds of agricultural marketing monopolies. (For a summary of these see Lappe and Collins 1977). More detailed research is needed to measure the allocative and distributive effects of specific state and private marketing monopolies. But prima facie the effects must be regressive; and opinion needs to be built in favour of maximum pluralism in marketing.
The question of trade taxes and restrictions raises complex issues requiring a separate discussion.

**Trade Policy.** Agricultural and overall trade policy are inseparable. Therefore it is necessary to consider briefly the basic orientation to trade policy which underlies recent research in project and sector analysis.

In much of this research, based on the Paretian paradigm, differences between border prices and domestic producer prices due to trade interventions, and between domestic producer prices and consumer prices due to domestic interventions, are regarded as sources of "distortions."

Interventions which cause these distortions are of course prevalent in OECD as well as developing countries. It has been estimated that in the EEC, the consumer-plus-treasury costs of agricultural interventions in 1968 was $13 billion (or 55 percent of farm GDP). In the U.S. it was 9.6 billion (or 38 percent of farm GDP.) (Johnson, 1973, pp. 50-51.) Currently, farm policy has caused domestic prices in EEC countries to be 1.4 to 5 times the world prices for milk powder, 1.5 to 4 times for butter, 2.5 times for cheese, 2 times for beef and 1.5 to 2 times for grains. (WDR 1981.) Obviously rich countries do not believe in a free-trade--free-market regime which alone would equate border prices and domestic producer and consumer prices. Tariff and quota protection, producer price support and/or consumer subsidies are the general rule in OECD countries. And these policies are likely to continue, with some variations, despite a large and growing number of studies measuring their enormous "welfare costs." There are reasons, often good reasons, why these policies are pursued. They lie in the concern with objectives other than Paretian efficiency. It is necessary to consider these
reasons sympathetically for they have even greater relevance and force in low-income countries than in the developed countries.

The several reasons for producer price support have already been mentioned. In the OECD countries the most important of these is downward price stability as a means of income support for farmers. In the poor countries it is full cost coverage as a means of maintaining producer incentives. Since a free market cannot ensure either downward price stability or full cost coverage, intervention becomes unavoidable.

The reason for food subsidization for consumers was also noted earlier. It is an inevitable second-best policy alternative to a direct redistribution of income.

Given producer price supports and consumer subsidies for these reasons, producer-price and consumer-price differentials will continue to exist.

There remains then the difficult issue of the relation between border prices and internal prices which involves all the questions of trade policy. There is a vast literature on why free or freer trade which eliminates or reduces the difference between external and internal prices is desirable; and also on the circumstances in which trade intervention is justified.

From the point of view of developing countries it is necessary only to reiterate that an orthodox free-trade bias is inherent in most of the current project and sector analysis. Like the OECD countries the low-income countries cannot accept this analysis without qualification because of its monistic preoccupation with static efficiency, and the neglect of other objectives. When these other objectives and some structural features of poor economies are kept in view many major arguments exist for first-best and second-best trade interventions (tariffs or export taxes).
Whenever the border price of a product is used as a criterion price in project or sector analysis, a free trade bias is built into the analysis. No domestic activity would pass the test of such analysis unless it can produce at a cost lower than the border price, or generates an acceptable IRR (say ≥ .1) at the border price. The inputs of labour, capital, foreign exchange may be shadow-priced but the free-trade bias of output pricing remains.

The free-trade bias is essentially a bias for cheapness (minimization of cost per unit of output or maximization of product per unit of resources) which is the sole concern of Paretian optimality.

Shadow-pricing of inputs does qualify this monism in favour of objectives other than cheapness (such as fuller employment) but it still ignores the objective of long-run self-reliance—the establishment and expansion of productive capacity in key sectors on domestic territory—to which all governments, including the present rich-country governments, implicitly attach a significant independent weight in their objective function. They are prepared to sacrifice considerable cheapness for the sake of self-reliance.

If immediate cheapness were the main criterion of choice, W. Europe and/or the U.S.A. should greatly reduce or discontinue the production of many farm products and textile products, shoes, cars and certain types of electronic goods. But employment and/or self-reliance objectives prevent them from doing so.

In chronic labour surplus countries the employment argument for tariffs applies of course with greater force than in the OECD countries. For in the OECD countries, tariffs only protect existing employment; in labour surplus countries they may be required to generate net additional employment for the unemployed.
The weight attached to long-run self-reliance, too, cannot be less in the ex-colonial countries than in the OECD countries. The sector(s) in which a high degree of self-reliance is considered critical by policy makers are of course different in the two sets of countries. They may include crude oil in the West, food and/or capital goods and/or defense equipment elsewhere. But in some fields self-reliance is regarded as vitally important in most countries; and trade restrictions are invariably used to promote it. (Some countries may of course attach no value at all to self-reliance.)

Besides (1) the employment and (2) self-reliance arguments, there are at least three theoretically well-established sets of arguments for trade taxation: (3) the terms of trade arguments, (4) the infant-industry/learning by doing/external economies/high technology arguments, and (6) the defense against foreign trade-barriers arguments. (See Corden 1974 for a recent welfare analysis of these arguments.)

The terms of trade argument justifies trade taxation as a first-best policy whenever a country faces less than infinite foreign demand elasticities. In so far as poor countries sell low-elasticity goods and early growth tends to worsen their terms of trade they can legitimately impose export taxes.

In certain conditions trade taxation as a defense against foreign trade-barriers is also a first-best policy.

For employment generation, or self-reliance in key sectors, or infant industry promotion, trade taxes are second-best or worse; wage or industry subsidies are better. But if, as in poor countries, subsidy costs are high, or collection of non-trade taxes costlier than the collection of trade taxes, trade taxes may be the preferred alternative.

Thus the field of theoretically legitimate trade intervention in developing countries is quite extensive. And the evaluation of trade policies in poor countries cannot fairly proceed with a simple, free-trade-biased methodology.
The better approach would be multiple-objective programming with structural constraints specific to each country.

The use of consumer and producer surpluses as measures of welfare in the current methodology is also subject to basic theoretical limitations. The practitioners of the methodology recognize these difficulties. They can do very little about them for want of data or other reasons. Still, strong categorical judgments are made about policies in developing countries on the basis of the surplus methodology. It would be enough to recall a few of the well-known basic difficulties. (See the well-known survey paper by Curry, Murphy and Schmitz (1971).

There is, first, a fundamental inconsistency between recognizing the key characteristic of backwardness as the pervasive fragmentation of labour and capital markets and then using the ordinates of supply curves estimated from crude aggregate production or sales data as measures of the true opportunity costs of resources.

Second, only the integration of areas under zero-income effect demand curves can be valid for welfare analysis. But in low-income countries the proportion of income spent on agricultural output is so high that agricultural price changes have substantial income effects. Therefore, the integration of the ordinates of ordinary demand curves would measure changes in consumer welfare with large, unknown errors.

Third, the distribution of gains/losses between producers as a group and consumers as a group is of much less interest to policy makers than distribution between rich producers and consumers, and poor producers and consumers. Conventional welfare analysis sheds very little light on distribution of gains between income brackets in the absence of disaggregated demand and supply
Finally, the general equilibrium effects of quantity and price changes, in a sector as important as agriculture in developing countries, are ignored by partial analysis.

For all these reasons, although the numerical measurements of welfare gains and losses due to agricultural policies using crude demand and supply elasticities are interesting, it would be premature and misleading to derive strong judgments from them.

Once again, a much better approach would be multiple-objective programming, with some of the objectives specified as inequalities in the constraint system.

Subsidies. The need for food subsidies was noted above.

The question of the choice between input subsidies and product price support is controversial. There are strong arguments for both. (See Krishna 1967.) Product price supports (on a full cost basis) are essential in any case as a general incentive to stimulate the growth of the output of selected commodities in developing countries. If input subsidies are added, they only increase the treasury cost.

Input subsidies are considered to be necessary to accelerate the diffusion of particular inputs. But then if every important input is subsidized, the total cost tends to become excessive. And if inputs are in short supply, subsidies accrue only as rents to some marketing agents; the majority of farmers continue to pay high market-clearing prices. Therefore, it may be desirable to subsidize only credit linked to the purchase of modern inputs at market prices. And credit subsidies (and/or quotas) may be reserved on grounds of equity only for small farmers, or landless households.
buying productive assets or inputs.

4. Equity

In the general thinking on income distribution two major empirical generalizations have held the field: (1) that there is a trade-off between growth and equity due to the negative effect of redistribution on the incentives to work and save; and (2) that during the developmental transition the Kuznets-law operates.

But some country experiences have cast doubt on the generality of both of these beliefs. As regards saving, Mr. Okun has pertinently pointed out that "the nation can have the level of saving and investment it wants with more or less redistribution, so long as it is willing to twist some other dials. For example, any threat that greater progressivity would make saving inadequate could be offset by more federal saving...or more middle-class saving through special incentives.

"In 1929 (in the U.S.) when all federal tax rates were low and barely progressive, the nation saved and invested 16 percent of GNP, in 1973, with all the allegedly onerous 'soak the rich' taxes, it saved and invested the same 16 percent of GNP." (Okun 1975, pp. 98-99.)

This observation on the loose link between progressivity and the saving rate was made in the context of U.S. debates. But it seems to be generally true. Otherwise one cannot explain the average gross domestic saving rates being nearly the same in low-income, middle-income and high-income countries (23, 25 and 22 percent in 1979), with their divergent Gini coefficients, nor can one explain the range of (positive) saving rates as wide as 2 to 32 percent within the low- and middle-income groups, and 11 to 42 percent within the high-income
group. (WDR 1981 p. 142-3.) Obviously the policy environment can make it possible for countries with a relatively low income per capita, and/or a low Gini coefficient, to have a relatively high saving rate; and countries with high income (Gini) to have a rather low saving rate.

For the rural areas some recent studies show that after significant farm income growth has begun, even at low income levels when the aggregate average saving rates are low (5 to 8 percent), the marginal rates can be 3 to 4 times as much; and in regions where new technology brings higher income streams within the farmers' reach, they can quickly raise their average saving rates to 10 to 44 percent. (Krishna and Rai Chaudhuri, pp. 18, 25.) In a Taiwan study the rural marginal propensity to save was found to be between 38 and 72 percent in different years in the 60's; and even for households with less than a hectare, its range was as high as 30 to 60 percent. (Ong, 1972.) Thus it cannot be assumed that redistribution necessarily reduces the saving rate.

Regarding work incentives (again in the U.S. context) Mr. Okun has noted that researchers "have uncovered virtually no significant effects of the present tax system on the amount of work effort of the affluent. Some limited effects of transfer payments have been found on the work effort of secondary earners...in low-income families, but virtually none on primary earners." (Okun 1975, p. 97.)

Little work has been done on redistribution and work-incentives in poor countries. But it is doubtful if large (absentee) landowners, traders and moneylenders, upper middle-class professionals and corporate owners would respond to a real redistribution by working less. If anything, a real land reform may induce large landholders to work and utilise their land more fully for the first time. And at the low-end, real transfers may actually increase
the effective labour input by improving nutrition.

Therefore the neo-classical reservations about the negative effect of redistribution on saving and effort are found to be empirically weak. The effect depends on the total policy-mix.

The Kuznets hypothesis of inequality increasing, and then decreasing, as income per capita grows, has a firmer empirical basis. As recently estimated, the Kuznets curve shows maximum inequality at about 800 ICP dollars (internationally comparable 1970 U.S. dollars) per capita. (Chenery 1979, p. 466.) But, again, the Kuznets curve should be viewed only as a summary of the average historical tendency in the absence of special intervention. Many countries have been and can always be far beyond the curve. In recent decades the cases of Yugoslavia, Korea and Taiwan have been particularly notable for successfully combining growth and poverty reduction.

As Fei, Ranis and Kuo (FRK 1979) have observed on the basis of their uniquely interesting decomposition of the reduction in inequality (measured by Gini G) in Taiwan: "the Kuznets effect is a complex phenomenon that needs to be disaggregated. In its extreme form, it really is relevant only to the non-agricultural sector. In countries where agricultural activity is important—as it is in Taiwan and in most LDCs—growth does not necessarily conflict with equity, even before the turning point has been reached." FRK show in fact that in Taiwan the tendency of nonfarm growth to increase G was overpowered by the tendency of more egalitarian farm income growth to reduce it, so that overall G came down (during 1964-68).

Agriculture thus happens to be the one sector where the Kuznets law need not operate and growth and equity can be reconciled even in the early stage of development if a suitable pattern of growth is chosen.
Since 85 percent of world poverty is estimated to be in the rural areas, it is imperative to fashion a poverty-reducing pattern of agricultural growth. But historical experience also suggests that in the long run the reduction of rural poverty requires a rapid shift from farm to nonfarm activity. For in all countries, at all stages of development, nonfarm income per worker is higher than farm income per worker; and the gap between rural and urban family incomes is eventually reduced only by migration out of rural areas, and/or an increase in the proportion of family income derived from nonfarm activity in farm families.

Thus a twofold equity strategy is indicated: (1) to structure equitable agricultural growth; and (2) to accelerate nonagricultural growth, outside as well as inside the rural areas, and its demand for rural labour, as much as possible.

Equitable agricultural growth essentially requires:

(1) land reform, and

(2) a strong preference for small farmers in the distribution of inputs and credit.

The growth of nonfarm activity requires:

(3) rural works/the provision of infrastructure (water supply, energy and transport) and social services (health and education) for all rural communities; and

(4) the promotion of industry in the rural areas and/or migration.

There is a very broad-based concensus in the development community about these ingredients of an active redistributive policy, particularly in the rural areas of low-income countries. (Vide Chenery 1979; Adelman and Morris 1973; and World Bank AOWP 1975.) Therefore it would suffice to accent very briefly some of these ingredients.
Land Reform. As regards land reform, it is obvious, and has been shown, that the distribution of land is the dominant determinant of the distribution of income, and access to nonland inputs. (See Repetto and Shah 1975.) Gini coefficients of land distribution generally range from 0.4 in Asian countries where land reform has been carried out, to 0.6 and 0.7 in other Asian countries, and in Africa, and 0.8 to 0.94 in Latin America (Berry and Cline 1979). The ranking of their income inequalities is similar. (WDR 1981, p. 183.) (Separate rural income distribution data are not available for most countries.) Redistribution of land is economically feasible without loss of output because of the existence of the "inverse relationship", i.e. the decline in the average productivity of land with an increase in farm size. The evidence on this relationship, estimated with international cross-section data from 41 countries of the developing world, has been summarized elsewhere. (Krishna 1979.) National evidence on it covering 7 Asian, 6 Latin American and 2 African countries has also been presented. (Krishna 1979; Berry and Cline 1979.) Therefore the existence of the inverse relation can hardly be doubted. It implies that a less unequal distribution of a given area of land would increase rather than decrease the productivity of land. This was indeed its effect in post-war Japan, Taiwan and Korea.

But the prospect for land reform does not depend in the least on the intellectual demonstration of its economic feasibility. It depends entirely on the political power acquired by the rural poor—the small farmers and the landless—through conscientization, unionization and struggle. The national and international intelligentsia interested in land reform (or redistribution of nonland inputs for that matter) have to think of funding and promoting an adequate network of organizations for bringing about the universal unionization
of the rural poor in the shortest possible time. Redistribution in the modern industrial sector has been associated with unionization and struggle; and it is hardly likely to come about without unionization and struggle in the rural areas—though the latter are admittedly more difficult.

If and where land reform is undertaken it is critical for its success that its implementation is not left to institutions dominated by the old oligarchy or a bureaucracy linked with it. It should be entrusted to local committees with at least 50 percent direct representation of the beneficiaries or the intelligentsia sympathetic to them. This was the case in the land reform committees in Japan.

The Small Farm Sector. Preference for small farms in the allocation of nonland inputs seems to be a widely accepted policy: rightly, because a majority of farms in low-income countries are small (50 to 94 percent in Asia) and most of the rural labour force (50 to 90 percent of the total in Asia) is on these farms. In densely populated countries the share of the labour force in agriculture declines slowly; until it does, the small-farm structure is there to stay and the only policy option is to maximize its productivity by means of adequate investment in technological and institutional change. The inverse relationship justifies the investment.

Since credit is the key to the use of modern nonland inputs (assuming that the inputs are available) an equity policy must give to small farms a highly preferential access to credit. "Credit reform" in this sense is a good substitute for land reform, insofar as modern inputs are a good substitute for land. But credit distribution is skewed. "It is common to find 70 percent or 80 percent of small farmers in a given country with virtually no access to
institutional credit." (IBRD 1975, p. 5.) Since institutional credit itself is a small fraction of total rural credit, the small farmers' share in the total can hardly be more than 10 percent except in a few countries.

Three requirements of a credit policy to reverse this situation need to be stressed.

First, at least half, if not more, of institutional credit should be reserved for small farmers. In fact, in principle, large farmers should have no claim whatever at least on the low-interest institutional credit provided by the public sector. In equity, they should be required to draw all their credit needs from their own substantial surpluses (which are usually lightly taxed, if at all) or from fully commercial private credit. This requirement will be fulfilled if public sector credit is reserved only for small farmers. The World Bank has successfully applied the principle of reservation to some of its own lending, as in the case of the Agricultural Credit and Refinance Corporation in India.

The principle of reservation has to be extended to the operation of the whole banking system. For it is plain that, left to themselves, commercial banks, and even nationalized banks, would not lend enough to agriculture, and certainly not enough to small farmers. It is only through a policy of reservation - or fixing percentage quotas for agriculture and for small farmers in the total lending of banks by legislation or executive action - that the share of agriculture and of small farmers in total institutional lending has risen in recent years in many countries. Without compulsion, bankers always prefer the soft option of lending to urban industry and trade.

Second, there is a strong case for bringing rural lending into the mainstream of commercial bank lending in every country rather than keeping it as a small,
inferior subsector, consisting of special institutions. Even if it is true that in some periods and regions commercial bank lending to agriculture may bring lower returns than lending to industry and trade, it is not an argument for the segregation of rural lending into a separate subsector. Rather, it strengthens the argument for pooling rural lending with other lending, because institutions with a large high-return turnover can bear some low-return turnover more easily than institutions forced to specialize in low-return turnover.

Third, in the case of short-term credit to buy modern inputs the expected additional income itself should be the basis and the security of the credit given, and in the case of medium-term and long-term credit for the purchase of assets, the hypothecation of assets and one or two personal securities or group guarantees, rather than landed security, should be acceptable as collateral.

Finally, banks serving small farmers should transplant on to the national scene a principle with which international development banks already try to operate. They do not wait for projects to come from applicant-governments. They send out their own expert technical teams to prepare projects; appraise and process the projects; and then negotiate and deliver the loans. Development banking for the poor in Asian countries will also have to become "borrower-chasing banking" in a similar way. For if poor borrowers knew all the technical possibilities, knew how to prepare feasible, bankable schemes, and how to do the paper-work and the leg-work and the lobbying and the bribing required to get loans, they would not be poor. Therefore, all that needs to be done to get a loan has to be done for them by the lenders themselves.

The integration of credit and intensive technical help is also the only answer to the loan recovery problem. Overdue rates tend to be high in small
farm credit. But it is remarkable that in some well-administered programs, the overdue rates of share-croppers, marginal farmers and small farmers have been found to be lower than those of others. In the West Bengal (India) CADP operation in 20 blocks during 1974-77 as much as 84 percent of total lending was channeled to these categories of borrowers with a strong technical and delivery back-up. Their overdue rate was only 18.25 percent as compared to 45 percent for other categories of borrowers. (See CADP 1978). The overdue rates should, therefore, be regarded in fairness as not an inherent peculiarity of every small-farm lending operation. If the program itself is efficient in raising borrower incomes substantially with adequate technological and input supply support, there is no reason at all why the delinquency of small farmers should be larger than that of large farmers. In fact there is some basis for the presumption that large-farmer delinquency should be higher because they wield greater political influence. They manage to get repeated loans in spite of default because they often control the lending institutions themselves. The small farmers on the other hand have every reason to repay their loans to be able to get new loans; they have no other leverage. Thus the main answer to the repayment problem lies in maximizing the income effect and increasing the structural efficiency of the credit operation itself.

Leakage of credit earmarked for small farmers is also a serious problem. It can only be reduced by direct and adequate representation of small farmers on the boards of banking institutions.

Rural Works. Any concrete list of rural works always contains (1) land, water and forest development projects, (2) the construction component of infrastructure development (water supply, energy and transport) and (3) the construction component of social service development (health and schooling). Each of these activities are clearly productive or essential for raising the productivity of agriculture and decentralizing some industries; and yet somehow they are usually treated as "unproductive". It should be remembered in this
connection that the universal extension of infrastructure and social services to the rural areas was a key factor in bringing about equitable and dispersed agro-industrial growth in Taiwan. Besides being productive, these activities have the merit of being the only activities in which the surplus labour time of small farm and landless households can be quickly given employment and poverty-line income. Thus just as land reform and/or "credit reform" can reconcile productivity and equity in the small farm sector, rural works schemes can combine them for the poorest landless sector. Two problems usually afflict works projects: their bad quality, and misappropriation of funds. But the answers are obvious: the setting up of good, local project formulation bureaus; and vigilance by committees of unionized beneficiaries.

Nonfarm Income. The record of all success cases shows unmistakably that the share of nonfarm income in the income of rural farm families must eventually rise, and migration accelerate, if the rural-urban family income differential is to diminish. By 1967-69 about 45 percent of the income of farm families in Japan and the U.S. was derived from nonfarm sources. (Johnson 1973, pp. 215-16.) In Taiwan the share of rural household income from nonfarm sources increased from 35 to 58 percent during 1964-72 (FRK 1979, p. 92-93.) Such shifts can be regarded as "occupational migration" within the rural areas. Besides such occupational migration, there is geographical migration which eventually reduces the share of the rural labour force in the total to a small fraction (less than 20 percent). The two types of migration together ensure that per capita rural consumption is 80 to 96 percent of per capita urban consumption, even though per worker farm productivity remains only 30 to 40 percent of per capita nonfarm productivity even in rich countries such as U.K., U.S.A., and
Japan. (Johnson 1973, pp.215-16.)

The policy implication of this dynamics is unambiguous. It is essential for equity that nonfarm sources of income be expanded in the rural areas and/or barriers to migration be reduced by subsidizing skill upgradation and information flows.

This brief review shows that an economically rational and feasible mix of growth-cum-equity policies for the rural sector does exist. But equity can rarely be a gift from above. The rural poor will have to secure it with their own organized political power.


Rapporteur's Comments
by Michael Nelson*

The paper opened up a wide ranging discussion of agricultural growth in relation to price versus technology policy, the role of economic analysis in public investment decisions, investment requirements for agricultural development and the underlying need for changes in the power structure if significant advances are to be made with respect to equity. Mr. P. Scandizzo commented on the apparent conflict between the relative importance assigned by the paper to technology policy and Professor T. W. Schultz' thesis from last year's symposium that price policy was at the root of agricultural growth. Referring to the implication that as the capital-output ratio rises profitability of farming goes down, he pointed out that there are substantial difficulties in quantifying physical or financial indicators of the production elasticities of technological progress. Neither technical change nor price policy are costless; the problem is to establish what the costs are in either case. Further, when considering policy it is important to recognize that price changes affect all farmers whereas technical innovations may be quite selective in their impact. Following the same argument Mr. I. Hussain raised the question of how one defines capital investments given factor endowments and the issue of embodied capital in some factors. Mr. T. Davis mentioned the specific question of valuing production inputs, particularly labor.

Mr. Krishna in responding, agreed that the definition of investment is complicated and there is no satisfactory classification. For example, investment in fertilizer production is considered industrial, and in fact, direct investment in agriculture amounts to only about a quarter of such input-related investments. The situation is further complicated by the fact that social investment in rural areas is considered non agricultural. Because of these issues Mr. Krishna maintained that it may be illusory to carry out economic rate of return analysis for projects which provide inputs such as irrigation water, since once having calculated benefits one can manipulate the incremental capital-output ratio (ICOR) of infrastructure, through alternate definitions of capital, to achieve any desired benefit-cost (b/c) ratio. He also concluded that if the b/c ratio is used to justify infrastructure the tendency will always be to favor investment in developed areas e.g. Punjab and Orissa in India.

On the question of technology versus price policy Mr. Krishna added that it is important to distinguish between innovations which are price-responsive and those which are not. Governments have tended to ignore this factor in designing their agricultural research programs. In support of his emphasis on technology policy, he indicated that in general we know which key technical variables influence output, and consequently specification of the problem (technical indicators) should not be difficult. Even recognizing a degree of arbitrariness in choice of technical variables, terms-of-trade variables dependent on border pricing and standard conversion factors which

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affect price policy are even more arbitrary. Accepting that there is room for
debate, the fact remains that the economic return to price policy is unknown
which renders comparison with technology policy speculative.

Mr. T. Hodgkinson asked why private investment in agriculture would
not occur spontaneously in cases where ICORs are low. Mr. Krishna responded
that in such cases under-investment was related to capital market failure as a
result of information lags and misinformation. However, there will be
substantial differences in ICORs according to stage of development of agricul-
ture. Even where ICORs are rising, average costs of production may be
expected to decline thus sustaining the profitability of agriculture.

Mr. H. Binswanger pointed out that some ICORs are related to macro
policies on pricing and tariffs which introduce distortions which depress what
are already low investment levels. Further, he felt that the conclusions from
the paper on correction of terms-of-trade distortions through subsidies were
unwarranted. For instance, a policy of subsidies to achieve given price
relationships may be feasible in India but infeasible within the context of
many African countries.

In reply Mr. Krishna made the point that agricultural and indust-
rial trade policies are inseparable. Under rigorous theoretical assumptions
any difference between border and internal prices represents a distortion. In
practice, neither developed nor developing countries equate these prices e.g.
EEC consumers pay 2-4 times world prices for most foods. The conclusion to be
drawn is that domestic price equality to border prices is an unworkable
paradigm. Primary reasons for trade intervention are employment generation
and increased self-reliance in key commodities; the theoretical underpinnings
rest on (a) imposition of export taxes or tariffs to change the terms of trade
when elasticity of foreign demand is less than infinite; (b) self-defense when
all other countries impose trade barriers; and (c) the infant industry
approach. By accepting border prices as the basis for project analysis we
build a free-trade bias into b/c and sector work. Neoclassical theory can
only handle the static efficiency situation. There are limitations on welfare
analysis; e.g. policy makers are not interested in distribution of gains and
losses between consumers as a class and producers as a class. Thus, it is
essential to discriminate and disaggregate consumer and producer surplus. He
argued for specification of multiple objectives by policy makers from which
implicit weights and shadow prices could be estimated.

Mr. P. Scandizzo expressed reservations on a number of the above
points. He said that while there may be some limitations on welfare analysis
using Marshallian demand curves to approximate consumer or producer surplus,
the constraints were not significant. Furthermore he maintained that b/c based
on border pricing simply recognizes the opportunity costs created by trade
opportunities and does not imply a free trade bias. Mr. C. Bruce concurred
with this position – if border prices are rejected what criterion will be used
to assess welfare gains and losses?. He also raised questions on the
efficiency tradeoff of a self-reliance policy, the viability of the infant
industry approach and the arbitrary nature of weights used in multi-objective
analysis.
The issue of technology policy was raised by Mr. C. Lewis within the context of value-added before crop leaves the farm vis a vis after leaving the farm. He cited the case of the Food Corporation of India (FCI) where there were high transaction costs in government procurement and distribution. What investment parameters would be appropriate to such cases? Mr. Krishna concurred that creating FCI is a high cost way of providing food at concessional prices. In addition, where there is state intervention on a significant scale there is risk of inefficient monopoly and potential for it to engage in commodity speculation, although neither apply in the case of FCI.

Mr. J. D. Von Pischke inquired about the bases for the recommendation that 50% of institutional credit be reserved for small farmers. How are decisions reached on how much credit should be reserved for agriculture? Do such decisions incorporate risk and the opportunity cost of capital? Are incentives such as interest rates used to direct credit away from unproductive activities? He observed that in a number of instances technical assistance appears to be the standard response to questions of unsatisfactory credit recovery rates, and that low interest rates tend to produce concentration of loans in the hands of the rich. Mr. Krishna suggested that credit needs could be approximated through linear programming analysis. Commercial banks would clearly use interest rates to account for risk and ration credit. However, with public credit the interest rate is not the critical issue to small farmers, who will re-lend at the market rate if the public rate is lower; rather, it is physical rationing of credit. Since credit is a vehicle for achieving policy objectives it is essential that it be pooled nationally rather than condemning specialized agricultural lending institutions to bankruptcy.

Part of the discussion focussed on the equity issue. Mr. M. Cernea asked if the reference in the paper to organization of the rural poor, applied to organization within the existing production system or to restructuring of the system. Mr. B. Abbai raised the question of whether the reference to development of countervailing power in hands of the rural poor is what is likely to happen, or what should happen. In answering, Mr. Krishna clarified that he is referring to the organizing of rural groups for bargaining purposes and not to development of cooperatives by the state which are captured by the oligarchy. Relevant change in power relationships do not result from legislation or good intentions and are not within the purview of international organizations. He suggested that in countries with freedom to organize, there is evidence of grassroots movements which, if they were to multiply, eventually could put pressure on the bureaucracy to deliver a degree of equity.

Addressing the issue of investment requirements and planning, Mr. P. Hopcraft stressed the distinction between public and private investment. A great deal of private investment, frequently made in kind, goes into on-farm infrastructure, and recognition of its role should enable formulation of more relevant price policy. A major constraint in formulation of relevant policy is government planners who have very little understanding of the production system for which they plan. Following this theme
Mr. S. Reutlinger suggested that when economists provide advice to policymakers they can agree on interpretation of efficiency in micro terms, but on non-efficiency goals their role is unclear. Where there are multi-objectives single goal tradeoff analysis may be useful. However, he expressed concern over the relevance of macro concepts in formulating policy recommendations.

Summarizing his position Mr. Krishna contended that border pricing is a convenience for project analysis and such analyses should be extended to use domestic prices also. He accepted that in considering investment it is axiomatic that both public and private sources must be included. Nevertheless, it must be recognized that in general we have poor data on private investment e.g. labor capitalization, and labor coefficients don't exist for many countries. There is a "natural" division in the role of public and private investment in capital formation — in the early stages of development a large proportion must be public. One must focus on the procedures for investment allocation and management, where technology policy is critical, and a planning body of some sort must guide the process, whether the source of investment be public or private. In order to understand the mechanisms of micro and macro response to technology and price interventions, some macro modeling is probably unavoidable.
SESSION II

FEEDING MANKIND in the 1980s:
THE ROLE of INTERNATIONAL AGRICULTURAL RESEARCH
Feeding Mankind in the 1980s:
The Role of International Agricultural Research

N.E. Borlaug*

Introduction

It is a pleasure to participate with the World Bank staff and invited guests in the Third Annual Agricultural Sector Symposium. In an important way, the efforts of this institution and of the individuals here today will make a significant difference in improving the lot of mankind in the years ahead.

My remarks today focus on the magnitude of the job ahead in feeding the world's people, and the role international agricultural research can and must play in support of developing country efforts to feed their people in the 1980s and beyond.

Feeding the world in the 1980s--the tasks ahead

Depending on your assumptions, world population will increase over the 1975 level of 4 billion people by 20, 30, or 40 percent by 1990. This means in absolute terms, that over a 15-year period, there will be 1 to 1.5 billion more mouths to feed. Again, depending on population growth rate assumptions, by the year 2020, 2030, or 2040, there will be twice as many people on the earth to feed as in 1975.

What do these population projections imply for food production? In 1975, about 3.3 billion tons of food of all kinds were harvested. Of this total, 98 percent came from the land and 2 percent from the ocean and inland waters. Of the total harvest from the land, about 81 percent was of plant origin and the remainder of animal and bird origin. Cereal grains as a group, which include wheat, rice, maize, barley, sorghum, oats, rye, and millets, constituted the largest and most important single group of foods of plant origin. The cereals are grown on approximately 50 percent of the total arable land of the world, and directly contribute 52 percent of the calories to the human diet worldwide and approximately 62 percent of the calories to the diets in the developing world.

In 1979, world cereal production amounted to 1.55 billion tons of grain. To help visualize this amount of grain, let's imagine it as a World Pan-Equatorial Grain Highway that encircles the earth at the equator. In

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1979, this highway of grain was approximately 17 meters wide, 2.5 meters deep and a little over 40,000 kilometers long. Since 1979, world population has increased by approximately another 160 million people. As a consequence, in order to provide the same per capita grain as in 1979, the world's farmers by 1981 had to produce enough grain to reconstruct the World Pan-Equatorial Highway I, for we consumed it in its entirety in 1981, plus produce sufficient additional grain to begin construction of a new World Pan-Equatorial Highway II of the same dimensions, 17 meters wide and 2.5 meters deep, which now is some 2,000 kilometers long. During the 1980s, in addition to reproducing the first highway each year, the second highway must continue to be constructed at a cumulative annual rate of approximately 1,000 kilometers per year in order to maintain 1979 per capita production levels, recognizing that for millions of people, these per capita grain consumption levels and the equity in distribution were inadequate. Such projections mean that, in 40 to 60 years from now, world food production must be increased by an amount at least equal to the increase in production that has been achieved since the discovery of agriculture, about 12,000 years ago, up until the present time. That is the magnitude of the food production challenge that faces mankind.

Fortunately, the efforts of world farmers, particularly the cereal producers, over the last two decades have kept the rate of growth in grain production ahead of aggregate world population changes. However, I believe that there can be no lasting solution to the world food-hunger-poverty problem until a more reasonable balance is struck between food production and human population growth. The efforts of those on the food production front are, at best, a holding operation which can permit others on the demographic, educational, medical, family planning, and political fronts to launch an effective and humane attack to tame the population monster.

For too long, agricultural scientists have left the impression with the general public and political leaders that the growing worldwide demands for food can be coped with in the indefinite long-term future. I cannot understand those futurologists whose main preoccupation seems to be to prove that new technology will forever disprove the Malthusian thesis. Even if new breakthroughs in science and technology do permit us biologically to feed twice or three times the number of people as are on the earth today, I am deeply concerned that we are taking mankind to the brink of
disaster in hopes that a scientific miracle will save the day. The demographic changes of this century have already exacerbated human misery and the degradation of our environment. Indeed, for those concerned with endangered species, I would submit that human demographic changes, more than rising incomes, are the greatest environmental threat to the planet Earth in the years ahead. Indeed, if this unrelentless growth in human numbers goes on unabated, Homo sapiens will no doubt end up as an endangered species itself.

We have to realize that science alone cannot solve the food problem. Despite the fact that we have the technology to produce sufficient food, many countries of the world simply do not now have the necessary educational and organizational base and the physical and economic infrastructure to keep pace with the growing food demands generated by explosive population growth, even where the biological potential exists to significantly increase food production.

I do not want to give the impression that the efforts of scientists and other engaged in agricultural development activities the last 50 years have not been significant. The application of science to agriculture has been of immense value to mankind. What would be the cost to mankind if we attempted to turn back the time clock to employ the technology of the 1930s and 1940s to provide the food needs for the current world population of 4.3 billion? I recently calculated for the United States the additional cropland area needed for 17 of the major crops to produce 1980 harvests if 1940 yield levels still prevailed. The additional area needed would equal 177 million hectares, equivalent to the land of all of the states east of the Mississippi River, excluding Illinois, Wisconsin and Michigan. Viewed in another way, had the 1940 yields persisted today, it would have been necessary either to have plowed up approximately 75 percent of the permanent U.S. pasture lands or to have converted 60 percent of the U.S. forest and woodland area to cropland. In reality, since the pasture lands and forest lands have much lower levels of potential yield than the land now in crop production, it would have required converting a much larger percentage of these lands to crops than is indicated above. Moreover, had this approach to expanding crop production been pursued rather than primarily increasing yields per acre on the land currently under crops it would have unquestionably resulted in greatly accelerated soil erosion--by both, wind and water--and widespread destruction of habitats for wild life and of areas for recreation. Because of the application
of improved technology, the United States has only
needed to expand the area devoted to the 17 major crops
by 3 percent in order to expand production 2.5-fold
since 1940.

In many parts of the developing world, the ap-
plication of new technology--improved varieties, agron-
omic practices and irrigation--has also resulted in
spectacular production increases. Permit me to use the
example of wheat, the crop with which I am most familiar.
Wheat production in the developing world has increased
at an average annual rate of 4.6 percent per year over
the last two decades, 2.1 percent per year faster than
the rate of aggregate population growth over the same
period. Improvements in yield levels have accounted for
more than half of the expansions in total wheat produc-
tion achieved in the developing world over this twenty
year period. If 1961-65 yield levels still prevailed,
the developing country wheat area would have to be
twice as great today as in 1961-65 to achieve 1978-80
production levels.

Through the application of improved technology
over the last two decades, wheat production has tripled
in India, more than doubled in China and Turkey, and
doubled in Pakistan. Combining only India, Pakistan and
Turkey, average annual wheat production increased from
23.9 to 59.7 million tons between 1961-65 and 1978-80,
an increase in annual production of over 35 million
tons. The increased wheat production in these three
countries alone is sufficient to provide an additional
240 million adults with 65 percent of their annual
carbohydrate needs.

Increasing Food Production Through Increasing Yields and
Cropping Intensity

During the 1980s, mankind will not be able to cope
with the world food production challenges unless
per hectare crop yields are greatly increased in the
developing world, especially in the densely populated
nations. Let me highlight some of the interconnected
problems which must be overcome if we are to accelerate
agricultural production in the developing world.

Soil Fertility--Without doubt the single most important
factor limiting crop yield on a worldwide basis is soil
infertility. The lack of one or more of the essential
plant nutrients is the result of the joint effect of
natural weathering followed by leaching, tie-up in soil
of plant nutrients, erosion, and extractive farming
practices. Virtually all traditional farming systems
are highly extractive. They are essentially "mining"
operations whereby each year crops are harvested and
little or none of the crop residue or animal wastes, which would partially restore soil fertility, are returned to the soil. The exceptions are the Chinese, Japanese, and Koreans, who have done an excellent job of maintaining a moderate level of fertility by the use of organic wastes. Soil fertility can only be restored in nutrient-depleted land by the application of the right kind, organic and/or chemical, and proper amounts of fertilizer. Since the proper kind and amount of fertilizer required to restore fertility will vary with soil type, climate, and crop, such recommendations can only be determined through research.

Until soil fertility is restored, improvements in cultural practices and varieties will improve crop yields only marginally. Many political leaders and economic planners fail to understand or are unwilling to recognize the necessity of making large investments in fertilizer factories, which is the first step toward restoring soil fertility and setting the stage for increased crop yields and production. There are some organic gardening enthusiasts who insist that the wide use of organic fertilizers could satisfy all our fertilizer needs. It is true that organic manures are very effective for growing six beautiful high-yielding tomato plants, six lovely rose bushes, or a small vegetable garden in one's backyard. But it certainly doesn't follow that the same procedure can be effective for producing the food needed to feed 4.3 billion people in a land-hungry world.

The amount of composted organic animal manure (1.5 percent N on a dry weight basis) that would be needed to produce the 47 million metric nutrient tons of chemical nitrogen used in 1978 would be about 3.2 billion tons—quite a dung heap and quite an aroma—were it available. This volume of organic material is equal to twice the weight of current world cereal grain production and would require a 2.9-fold increase in the world animal population, with all the additional grain and pasture feeding implications that such an increase would require, in addition to the transportation costs associated with distributing these organic fertilizers with such a low nitrogen concentration.

Yield Potential of Crop Varieties—Traditional or land race crop varieties have generally evolved on nutrient-depleted soils. They have a low genetic grain yield potential and have unfavorable grain-straw indices (ratios of 30% versus 48 to 53% for the semi and double dwarfs). When soil fertility is restored through the proper use of fertilizer, traditional varieties respond poorly. They have structural, physiological and patho-
logical weaknesses that become manifest under medium- to-high soil fertility levels. They grow tall and have weak straw which lodges badly. They are vulnerable to many epidemic diseases, such as rust fungi, when they are grown on fertile soil that gives rise to dense stands; this modifies the microclimate within the grain field and creates an environment more favorable for the pathogens. Once soil fertility is restored, it is necessary to develop and distribute a series of high-yielding, disease-resistant crop varieties with acceptable agronomic and industrial (consumer) quality characteristics. Such varieties provide the farmer with the genetic capability to utilize more effectively and more completely the improved soil fertility conditions to increase grain production substantially with only modest increases in straw production.

Agronomic Practices--In traditional agriculture, where lack of plant nutrients limits yield, agronomic practices generally receive little attention. The traditional farmer has learned from experience that he can do little to increase crop yields by solely manipulating cultural practices. Consequently, seedbeds are often poorly prepared, resulting in patchy stands with poor spacing between plants. Little attention is given to conserving moisture (rainfall) or to using irrigation water efficiently. Inadequate attention is given to weed control because weeds apparently are not highly competitive with the crop plant, as they too are suffering from plant nutrient deficiencies.

Once soil fertility has been restored, if the new opportunities for large increases in grain yield are to be taken advantage of, it becomes necessary to employ good seedbed preparation, proper seed rates and the correct dates of sowing for each of the improved varieties, proper conservation and management of soil moisture, and proper control of weeds. Under improved levels of soil fertility weeds become aggressive and highly competitive; unless they are controlled either mechanically and/or chemically one will harvest more weeds than food grains.

Control of Diseases and Insects--In low-yield traditional agriculture it is only in unusual years that ecological conditions are sufficiently favorable for pathogens and insects to produce seriously destructive epidemics and infestations. When these conditions do occur, however, the losses are very severe, for there are no organized disease or insect control programs to advise and assist the farmer. In most years, however, the pathogens and insect pest species, like the host plants, are all struggling for survival under difficult and unfavorable environmental conditions. The situation
in intensive agricultural systems changes dramatically. Fertilized soils and improved agronomic practices result in the development of thick lush stands of crops. The ecology within these fields then becomes very favorable for pathogen and insect pests. Therefore, disease- and insect-resistant varieties must be used to minimize the risks of crop losses. Moreover, an integrated control program must be adopted insofar as possible, including crop rotations, proper dates of planting, biological control, and the regular monitoring of the pest population combined with the timely application of pesticides when necessary, in order to reduce crop losses to acceptable economic levels.

Availability of Production Inputs--The continued unavailability to farmers of production inputs is still a nagging problem in many developing countries. It is still necessary to establish more effective networks to distribute seeds of improved crop varieties, fertilizer, herbicides, insecticides, and fungicides down to the village level if crop production is to be improved. The timeliness of distribution, appropriateness of the products being distributed, and price are all of primary importance. Too often such issues become hopelessly entangled in a web of bureaucratic inertia.

Government Economic Policies Affecting Agriculture--Whenever an attempt is made to provoke change in a primitive agriculture, more effective technological recommendations which include improved crop varieties and agronomic practices must be developed to overcome the inherent defects and weaknesses in the traditional agricultural system. The improved technology must be checked for validity and demonstrated widely on thousands of farms. Once effective technologies have been developed and widely demonstrated with positive results, then they must be married to sound economic government policy that will encourage adoption and thus result in increased production. Without such a marriage, the benefits from agricultural research can never be fully realized.

Research and Extension Programs--Agricultural research and extension programs in most developing nations are weak and lack sufficient integration between the research and extension process. They are handicapped by a shortage of trained people, inadequate budgets, and the low prestige associated with agriculture. Despite the fact that 50 to 85 percent of the total population in most developing nations are involved in farming, agriculture occupies the lowest rung on the socio-economic ladder. Consequently, many of the most talented young people with a rural background want to forget about the hard
work and low income associated with agriculture. They consequently seek careers in medicine, dentistry, law, chemistry, engineering, or business.

It is impossible to transform traditional agriculture into modern agriculture without the assistance of a large group of well-motivated and well-trained scientists and technicians. Experience in a number of countries where I have worked, in which research and training programs were initiated when there were very few trained people, indicates that it takes 20-25 years to identify, train, and provide research experience for a sufficiently large number of young scientists and technicians so that a national research institute can be organized and staffed effectively to produce large and continuing impacts on production. Moreover, there is the further problem of keeping these research organizations viable and functioning effectively. Some withstand the adverse effects of inadequate funding, poor physical facilities and equipment and remain effective. Others collapse and wither into ineffective bureaucracies. Outstanding skillful scientific and political leadership in key top positions is essential in keeping research organizations viable.

Role of International Agricultural Research

Let me now turn to the role that international agricultural research can and must play in stimulating food production in the developing world during this decade. Most of my comments will focus on the role of the international agricultural research institutes, relatively new organizations on the agricultural research scene, which were created to help increase food production in the developing world.

The international agricultural research centers are an outgrowth and have drawn many of their organizational principles from successful bilateral commodity-oriented cooperative research efforts pioneered by the Rockefeller Foundation in the 1940s and 1950s. The Cooperative Mexican Government-Rockefeller Program, with which I was associated from nearly its establishment in 1943, was the first such international agricultural research venture. Its wheat research and production program became the model for many of the subsequent international programs in agricultural research. The organizational principles which guided the Cooperative Mexican-Rockefeller Program during its 20-year life span are worthy of mention. They included the following:
(1) A commitment to recruit and keep the best trained and motivated international staff available, and to give this staff sufficient resources and freedom to devote their energies fully to research program objectives. Continuity of program leadership proved to be directly related to research progress and its impact on increased production.

(2) An orientation to work within the public sector on a cooperative basis with national agencies with complete and free exchange of research materials and information.

(3) An emphasis on commodity-oriented research activities across disciplines directed toward raising the productivity of basic food crops and a policy of getting results of proven value into use at the earliest possible moment.

(4) A commitment to strengthen national research capabilities through an intensive training component designed to develop a group of competent enthusiastic, dedicated indigenous agricultural researchers and production specialists. Once the scientific leadership of the project could be assumed by trained and experienced local scientists, the foreign counterparts were to gradually retire from active participation in direct project operations.

The success of the Rockefeller Foundation's first project in Mexico, and of similar programs in other countries, led the Rockefeller Foundation, in partnership with the Ford Foundation, to establish in 1960 the International Rice Research Institute (IRRI) in the Philippines. This was followed by the International Maize and Wheat Improvement Center (CIMMYT) in Mexico, and two other centers concerned with improved food production in humid tropics, the International Center for Tropical Agriculture (CIAT) in Colombia, and the International Institute for Tropical Agriculture (IITA) in Nigeria. By 1969, the establishment and support of these four international agricultural research institutes had cost the two foundations roughly $40 million, and IRRI and CIMMYT had produced important breakthroughs in rice and wheat production through the development of high-yielding broadly adapted varieties and improved crop management practices.
The increasing requests made by national governments and development assistance agencies to the first four international centers for assistance led the two foundations, now joined by the World Bank FAO, and UNDP, to develop a new mechanism whereby a broader spectrum of international research activities could be financed to meet the food production challenges facing the developing world over the years ahead. In 1971, the Consultative Group for International Agricultural Research (CGIAR) was organized to bring together governments, public and private institutions, international and regional organizations, and developing country representatives to support the network of international agricultural research centers and programs.

This network of international agricultural research centers (IARCs) has expanded considerably since 1971. Today, there are 13 international centers and programs financed through the CGIAR. Eight of the IARCs have a commodity orientation, and work on over 20 of the world's major food crops. Some of these institutes concentrate their research on tropical and subtropical production areas; others are more concerned with semi-arid and arid regions. Two centers, both located in Africa, are livestock-oriented research institutes that focus on African livestock diseases and production systems. One center is concerned with world food policy issues and another with management issues related to developing country agricultural research systems. Finally, the International Board for Plant Genetic Resources was established in 1974 to conserve irreplaceable sources of valuable genetic material represented by the primitive cultivars of crop species and their wild relatives.

Relationship of IARCs to National Programs

The mandates of the IARCs call for them to orient their research, training, and technical assistance activities toward increasing the absolute availability of world food supplies, with particular emphasis on food production in the developing world. IARC research activities are to concentrate on those critical aspects of food production in the developing world that are not being adequately addressed elsewhere, which offer the potential of widespread benefits for food security, either regionally or globally, and which address the problems of producers in low-income, food-deficit countries.
To use the terminology of my economist friend and colleague, Don Winkelmann, the IARCs were created to be producers of intermediate goods and services. These products include research output, such as improved germplasm; the development of more effective and practical procedures for tropical and subtropical research activities; training and national staff development activities; consultation assistance; and information services.

Given the fact that IARCs are not national agricultural research enterprises, the effectiveness of their products for helping to increase production in the fields of developing country farmers is almost wholly dependent on the transmission and adaptive capacity of national agricultural research, extension, and production organizations coupled with wise stimulatory economic policy in the developing world. The strengthening of national capacity, in turn, depends in large measure on the sustained determination of national governments to promote agriculture and to recognize in resource allocation the critical importance of public services in support of food production. In the final analysis, only national programs should carry the responsibility for formulating technologies and recommendations for their farmers. The IARCs, with properly focused research, training, and technical assistance programs can, of course, help to facilitate national action. However, the IARCs cannot be a substitute for strong and effective national research enterprises.

Developing country (national) programs today are at very different stages of development. Some have a relatively good human resource base and research infrastructure. The relationship of these more advanced national institutes with the international centers is more on a collegial basis. The provision of improved germplasm, collaboration on specific research problems, and some training and consultation assistance are the primary requirements of these national programs. Other national programs have yet to develop a firm research base, and look to the IARCs for greater amounts of research support, training, technical assistance and consultation services. Finally, a considerable number of national programs face such severe human resource and research constraints that they rely heavily on the IARCs for all types of assistance and services, including the deputing of IARC staff to work directly within a national research enterprise. The international centers must be sensitive to these variations in national research capacities and must tailor their programs and services accordingly.
I would like to make several additional points about the relationships between international agricultural research institutions and national research enterprises in the developing world. First, it has been my experience that as national programs strengthen, they tend to increase rather than decrease their interest in expanded research collaboration with the IARCs, and find the products of the IARCs, particularly improved germplasm and new research procedures, to be of greater value to national research efforts. In effect they find themselves in a better position to more effectively exploit the potential benefits of the products and information of the IARCs.

Second, it is erroneous to view the development of national program research capacity as a constantly improving evolutionary process. Unfortunately, more often there is an ebb and flow in national research capacities. I have seen a number of national programs move towards self-sustaining performances only to be stymied or decimated by bureaucratic restrictions, resignations, transfers, promotions, budget restrictions, or political reorganizations. In far too many developing countries, particularly the densely populated ones, I have also seen that when a scientist reaches a senior grade, he prefers the status quo, the known, rather than risking a "secure" position through supporting new research initiatives and their application which involve greater risk-taking.

These realities provide a strong justification for viewing the IARC network as a permanent dimension of the world's agricultural research system. They also imply that the range of IARC activities must continue to change as national programs strengthen over time, and that the IARCs must continue to assume leadership in exploring new scientific frontiers which may lead to future research breakthroughs on the world food production front. Indeed, the international centers, perhaps uniquely, are in a position to engage in research activities of widespread utility which would not be adequately funded in the context of a national research enterprise, but which can be justified at the international level.

Nevertheless, in the years ahead, it is vitally important that the IARCs do not lose sight of their purpose: to conduct mission-oriented research to increase food production in the developing world. By mission-oriented research I mean the organization and application of research resources toward specific and concrete objectives, e.g., to increase the quantity, quality, and dependability of crop production in the developing
world. Much of this research is of an applied nature, and draws on the existing stock of scientific knowledge to solve specific problems. Such research should not be viewed as second-class research, nor incapable of adding to the frontiers of knowledge in a particular scientific discipline.

Several examples in wheat research illustrate this point. In the Mexican Government-Rockefeller Cooperative Wheat Program in the 1940s, in order to cut the normal time needed to develop and release improved varieties from 10 to 5 years, we decided to grow two breeding cycles per year, shuttling successive breeding cycles between an irrigated, sea-level environment in Sonora in the northwest corner of the country, and the cool, rainfed highland plateau around Toluca near Mexico City at 2650 meters altitude. The materials planted in November in Sonora and harvested in early May were transferred to Toluca for immediate planting. Selections at this site were in turn harvested in November and sent back to Sonora for immediate planting. When we initiated this breeding procedure, we also had a hunch that, in addition to cutting the time needed to develop improved varieties, we would be able to do a better job of selecting disease-resistant lines, since both environments were conducive to epidemics of rust and other foliar diseases.

It soon became apparent that not only were we achieving our intended objectives, but that some of the superior lines we were selecting had outstanding yield potential under both of these widely differing environmental conditions as well as daylight insensitivity achieved by using two different dates of planting with quite different day length periods. This shuttle breeding methodology was highly unorthodox at the time. I vividly recall a visit by one of my former major professors at the University of Minnesota about five years after we initiated our shuttle breeding procedure. When my professor learned that the breeding sites we were using differed in latitude by 10° degrees and in altitude by 2,600 meters he was horrified to think I was engaged in such idiotic things and said to me, "Norman, apparently you failed to even learn the first lesson I taught you in the first elementary plant breeding course you took with me." Fortunately, by that time, we had seen that this highly controversial procedure was resulting in the rapid development of broadly-adapted, high-yielding cultivars with excellent disease resistance—all critical elements for enhanced yield stability—than was possible through conventional breeding.

We soon saw another benefit from developing broadly-adapted varieties. Since the seed production and distribution programs in Mexico were not very well organized
and efficient, they were unable to handle the multi-
plication and distribution of a large number of varie-
ties, each only adapted to local eco-niches. In con-
trast, our broadly-adapted varieties, capable of superior
performance across a wide range of environments, helped
to circumvent many of the problems we were encountering
in the existing seed production organization.

The next problem we faced in our wheat improvement
efforts was that our varieties tended to grow too tall
when optimally fertilized for grain production, and
often severely lodged near maturity. After a fruitless
eight-year search for sources of dwarfism, we obtained
from Dr. Orville Vogel of the USDA posted at Washington
State University, some early generation progenies from
a cross he had made between Brevor, a local winter
wheat variety, and Norin 10, a Japanese dwarf wheat
variety. This material was crossed extensively with our
broadly-adapted and disease-resistant Mexican material,
and set the stage for dramatic increases in yield
potential, first in Mexico, and later throughout the
world. Although our interest in dwarfism was to circum-
vent lodging, it soon became evident that the new
semidwarf varieties had a 40 to 80 percent higher
maximum yield potential than ever observed before, even
in the absence of lodging.

The point I want to make from these two anecdotes
is that the "Princess of Serendip" is usually the
Patron Saint of scientific progress. Throughout my
career, I have seen that, while looking for one thing,
I stumbled onto something else, in some cases much more
significant that what I was looking for in the first
place. This is the nature of research. The fact that
the discoveries we made in wheat improvement had such
significant impacts on world food production can be
directly attributed to our applied research orientation
that led to their development. We were interested in
solving the most pressing constraints we saw to in-
creased food production. If conventional science of-
fered a solution, we used it. If the problem was such
that conventional scientific wisdom didn't provide a
solution we explored the unknown, sometimes employing
unorthodox methods. The guiding principle in setting
our research priorities was always to attack the most
pressing production problems first, and as each major
problem was overcome, move on to the next most limiting
factor. This research orientation should continue to
guide the work of the international centers and national
research enterprises in the future.
IARC Program Priorities During The 1980s

All of the crop-oriented IARCs have been charged with similar mandates to help increase the quantity, dependability, and quality of food production in the developing world for their respective crops. A variety of research avenues, some conventional and some unorthodox or novel, should be pursued in the 1980s to achieve these common objectives. However, I must caution that a considerable portion of the research funds currently available to IARCs must continue to be devoted to stand guard over the crop improvement gains already made.

As an example of the importance of maintenance research to defend the gains already made, consider the average life of an improved wheat variety. Despite the fact that a breeder has incorporated a good level of disease resistance, say to a rust fungus, in a newly-released variety, this resistance can be lost through mutations of the rust pathogen within 3 to 5 years. Only occasionally does a variety remain effective for 8 to 10 years after widespread commercial production. This biological reality requires that breeders continually develop new varieties which combine different sources of disease resistance, and thus can become replacement's for today's commercial varieties. At the same time, they must continuously strive to increase the yield potential of the forthcoming varieties above those of the best present commercial varieties.

It is an axiom of experience in plant breeding research that if you stop you regress. The natural enemies of our crops continue to be evolutionary and active. Rusts and other pathogens will continue to mutate, insects will develop resistance to chemical and genetic controls through mutations, and environmental policies will continue to affect the components of agronomic practices. These considerations enhance the importance of the IARC services and research activities, such as their germplasm bank units and international germplasm development and testing networks.

I would like to clarify, however, that I don't think that the IARC plant breeding institutes should be seen as having the global responsibility for collecting, preserving, and cataloguing all possible germplasm of primitive land races for their crops. Such collection efforts are important but are better suited to other organizations created specifically for this purpose. Rather, the IARC germplasm collections should be viewed as working collections to support active breeding programs around the world.
The germplasm undergoing improvement at the IARCs and in developing country national programs are living collections of an immense amount of genetic diversity. Through the extensive international testing programs coordinated by the IARCs, this broad range of genetic diversity is constantly distributed and evaluated by thousands of scientists at thousands of testing sites around the world. Indeed, the advent of international testing networks, pioneered by the Cooperative Mexican-Rockefeller Foundation Program, and subsequently more fully development by the international centers, began a new era in plant breeding. Before the creation of international nurseries, many breeders were reluctant to release early generation and advanced lines to fellow scientists for fear that new varieties would be named and released without proper recognition of their efforts. Distribution of materials to other scientists was generally delayed until the variety had been named in the breeder's own state or country.

International testing ushered in a new willingness to share early-generation materials and un-named advanced generation lines, provided that due recognition was given to the breeder and institution responsible for developing the material. This, broad-scale sharing of material, in turn, greatly increased the introduction of new germplasm with much greater genetic variation into national programs and helped to break down psychological barriers which had tended to isolate the efforts of individual plant breeders. International testing also provided a vehicle for breeders to obtain data on their best materials at hundreds of test sites around the world. In one year, information could be obtained on the performance of individual materials under various production environments and disease situations that would have taken 20 years, if ever, to generate had individual breeders relied on their own resources.

Over the last 20 years, the IARC-coordinated international nurseries have served as a unifying thread to bring together the work of thousands of scientists and hundreds of organizations worldwide. As a result of this collaboration, hundreds of high-yielding, input-efficient varieties with good yield dependability have been released and put to use in farmers' fields around the world. I am concerned that there are forces at work which are trying to limit the plant breeding work of the IARCs and to place greater monopoly control over plant genetic resources. Such trends could have disastrous consequences for plant breeding research, especially on self-pollinated crop species in the developing world. I strongly believe that improved plant genetic resources should be viewed
as a global treasure available to all nations and
scientists to be exploited for the good of mankind. I
am opposed to any legal, political or economic arrange-
ments which would unfairly restrict the free exchange of
germplasm in the years ahead. I am concerned that the
spread of varietal patenting arrangements within the
developing world will lead to higher costs in the
development of high quality seed. I cannot abide by the
notion that monopoly control of genetic resources will
advance plant breeding research in the developing
world, at least not in the foreseeable future.

Two other issues have come into focus during the
last decade which further complicate and adversely
influence our attempts to increase food production over
the next several decades. These are: 1) the environ-
mental issue and 2) the energy issue.

Agricultural Research and the Environmental Issue

The environmental issue has evolved from public
concern mostly in the developed world about the adverse
effects on the environment of modern high-yielding
agricultural technology. This technology employs the
use of insecticides, fungicides, herbicides and fer-
tilizer, which are essential for protecting our crops
and for increasing production. The fear is based on the
presumed adverse effects of agricultural chemicals on
the environment, especially on public health and the
survival of wildlife. The concern has already led to
some ill-advised legislation that has banned the use of
certain chemicals which, in turn, has had adverse
effects on health and/or food production in some countries.

The environmental movement, undoubtedly well-
intentioned, but badly-informed, is fostered, controlled
and popularized by relatively small, well-organized
groups of elitist environmentalists and neo-ecologists.
They play on the public's fear by employing propaganda
campaigns to convey the idea that civilization is on
the verge of being poisoned out of existence by the
reckless and unnecessary use of agricultural chemicals.
The leaders of this campaign seem to imply that the
world can, and should, go back to producing its food
with pre-World War II technology. They ignore the fact
that the agricultural production technology of 1930,
which was adequate to produce the food for a world
population of less than 2 billion, is completely inad-
equate for the production of food for the present
population of 4½ billion. If we attempted to employ the
methods of 1930 to produce the food for today's popula-
tion, we would plunge the world into famine, and into
social, economic and political chaos. Moreover, it
should be pointed out that the environment in which our
food is produced is, in fact, an environment that is
hostile to our food crop plants. Most of our modern crop plants would be unable to survive (and certainly unable to produce any reasonable yields) without the modern husbandry of today's agricultural man; and without a stable food supply, civilization would collapse.

CIMMYT, as well as other crop-oriented research centers, attempts to develop integrated crop protection technology to minimize losses. Major emphasis is devoted to the development of high-yielding varieties with genetic resistance to the major disease and insect pests. Agronomic practices such as crop rotations, proper dates and rates of sowing to minimize disease and insect problems, and mechanical control of weeds are also employed to minimize danger of losses from pests. Pesticides should only be employed only when necessary, and when employed, they should be used with proper controls and caution.

It is my belief that much of the confusion, misunderstanding and litigation that has evolved in the past over the use of chemicals in agricultural production could have been avoided if suitable educational programs had been developed to explain to the non-rural public the complexities and difficulties of protecting our crops, together with an explanation of the precautions that are taken to protect human health and safeguard non-target wildlife species. Such an educational program must emphasize that the vast tracts of primeval wilderness of the past are gone forever—victims of the encroachment of so-called civilization. If the vestiges of primeval wilderness that still remain are to be preserved, then more collective efforts of all sectors of our societies must be concerned about increasing the productivity of the land now being used to produce our food and fiber, while, at the same time, slowing demographic growth to manageable rates.

**Agricultural Research and the Energy Issue**

If the world's food needs are to be met during the next several decades, it will be absolutely necessary to increase greatly the production and use of chemical fertilizers. Large increases in the use of fertilizer will be essential to increase crop yields on the nutrient-depleted and infertile soils of the developing nations where yields are at present very low.

Prior to 1950, many agriculturists believed that soil nitrogen could be maintained at levels capable of producing high grain yields by employing legumes in rotations with cereals, supplemented by the use of animal manure and green manure crops. This situation changed drastically in the early 1960s because of dramatic technological improvements in nitrogenous
fertilizer production. The development of large centrifugal compressors and the use of better catalysts greatly increased production. A single large centrifugal compressor replaced 20 to 30 reciprocal compressors and permitted the establishment of large, more cost-efficient 1,000 to 1,500 ton per day ammonia factories—greatly reducing the cost of production. This reduction in the price of ammonia soon stimulated the consumption of nitrogenous fertilizers and led to major increases in crop production throughout the world.

The consumption of nitrogenous fertilizers in the USA increased from 900,000 to 10.7 million nutrient tons per year from 1950 to 1980. During the 1960s and the 1970s, the use of nitrogenous fertilizer skyrocketed everywhere, first in the developed countries, and by 1970, its consumption also had increased spectacularly in such developing countries as India, the People's Republic of China, Pakistan, Taiwan and South Korea. This spectacular growth in the use of nitrogen fertilizer dramatically contributed to increasing grain yields on the small farms in developing nations. It facilitated the rapid adoption by farmers—small and large—of high-yielding, fertilizer-responsive semidwarf wheat and rice varieties. It catalyzed double and sometimes even triple cropping on the same piece of land, thereby bringing millions of small subsistence farmers into a market economy for the first time.

It is highly unlikely that another spectacular change in nitrogen fertilizer production technology, such as occurred during the early 1960s with the introduction of the centrifugal compressor, will again come to our rescue to reduce production costs and thereby compensate for the large increases in prices of gas and petroleum (or coal). Moreover, the capital investment costs of nitrogenous fertilizer factories has increased greatly in the past decade.

Despite these increasing costs, the installation of new nitrogen production capacity has kept pace with demand in recent years. Still a serious problem, however, is the low operating efficiency of many developing country fertilizer plants. Many plants operate at only 60-70 percent of rated production capacity. These low efficiency rates are due to many factors including inadequately trained manpower, weak maintenance programs, lack of spare parts, power failures, and problems in raw materials supply. The achievement of higher production efficiency rates can help to reduce fertilizer costs in the years ahead.
Recognizing the long-term trends for higher prices for nitrogenous fertilizers, expanded research efforts are needed to develop substitute sources of nitrogen and to increase the economic efficiency of utilization of nitrogenous fertilizers (as well as other fertilizers, whose prices have also increased substantially in a large part because of increase in transportation costs). On the industrial research front, the International Fertilizer Development Center (IFDC) is attempting to modify conventional nitrogen fertilizers, such as urea, so as to produce slow release formulations which will improve nutrient uptake efficiency.

On the fertilizer use side, much more can be done to improve efficiency. For example, often unnecessarily expensive complex fertilizer formulas are used which include expensive nutrients to which there is no yield response. In other cases, poor yield responses to fertilizers are the result of an improper balance of nutrients. For example, phosphorus or nitrogen when used alone on some soils provide only marginal yield increases, but when used in combination with one another, show a strong interaction and result in a large increase in yield. In still other cases, errors are made in the time, and/or rate of application of the fertilizer or in improper placement. Grain yield responses to fertilizer application are often affected by poor stands of plants, competition from weeds, and improper conservation of soil moisture prior to planting. It is my contention that the weakest link in increasing cereal production in virtually every developing nation is in agronomic-production research. If this can be corrected, it will greatly contribute to increasing cereal production in many developing nations.

There is also renewed interest in re-establishing the use of leguminous crops, which produce food and/or forage, and at the same time fix substantial quantities of nitrogen when employed in crop rotations with cereals. Wherever economically feasible, green manure crops should also be encouraged in crop rotations. Unfortunately, these practices take valuable scarce cropland out of food production for at least one cycle, which is generally not feasible in food-deficit, densely-populated "land hungry" nations.

In the long run, one can dream, as I did in my Nobel Lecture eleven years ago, that ingenious scientists will some day succeed in developing highly efficient nitrogen-fixing symbionts, whether nodule-forming or inhabitants of the rhizosphere of cereal, which are capable of fixing a substantial proportion of the nitrogen required to produce moderate levels of
grain yields. Such dreams currently offer some hope of becoming reality within the next several decades because of advances of research on several of the biological nitrogen fixation fronts. In recent years, researchers have shown that *Azospirillum* species inhabit the roots and/or rhizosphere and fix considerable amounts of nitrogen in a number of tropical grasses. These are sometimes also present in the roots of maize, sorghum, and wheat.

The increasing cost of nitrogenous fertilizer has also brought a renewed research interest in improving the efficiency of a number of biological nitrogen fixation systems that have in the past played important roles in fixing atmospheric nitrogen for crop production. Among the systems that are being given expanded research attention are: 1) the nodule-forming species on the roots of legumes, 2) the floating fern-blue green algae system (*Azolla* spp-*Anabena* spp) in paddy rice, 3) the free-living algae and bacteria that are active in the rhizosphere of rice roots, and 4) the system involving beneficial root fungi, such as mycorrhiza, that live in contact with plant roots and improve the nutrient uptake of the host plants.

In the last couple of years, I have read reports of some, in my judgment, over-enthusiastic optimists who predict that within this decade, new techniques in genetic engineering which involve inter-generic cell fusion and DNA transfers will revolutionize our cereal crop plants and help reduce the expenditures for nitrogenous fertilizer. Several of the IARCs, including IRRI, ICRISAT, CIAT, and a number of other research institutes, are engaged in research to improve the efficiency and potential of biological nitrogen fixation. Certainly, the information generated to date merits additional intensive research to improve the efficiency of nitrogen fixation to a level where it can provide a considerable part of the total nitrogen requirements for the cereal crops. I must caution, however, that it is unlikely that there will be more than 5 to 10 percent of the additional total world nitrogen requirement needed for agriculture that will be forthcoming from these approaches for at least the next several decades.

Although there are several interesting leads in the CIMMYT and sister IARC research programs which indicate that some progress can be made through genetic research in increasing fertilizer efficiency or finding partial substitute solutions to the high cost of nitrogen fertilization, we should not be misled that high yields, the key to feeding mankind in the years ahead, are possible without adequate plant nutrition. When I am asked, which happens quite often, whether
good plant breeders will soon succeed in developing varieties which do not require fertilizer to produce high grain yields, my reply is that this will occur about six months after we have succeeded in producing a race of man that needs no food to grow strong bodies, maintain health, work effectively, and enjoy life.

As you can gather, it is difficult for me to accept the judgment of those today who insist that the world cannot afford to use fossil fuels for the production of nitrogenous fertilizer—absolutely essential to maintain the necessary expansions in food production—while we continue to permit the tremendous wastage of fossil fuels in many other sectors of the world economy. The amount of gas being flared from well heads and refineries in Saudi Arabia in 1975 was estimated to be about 6 billion cubic feet per day. This wasted gas would be sufficient to supply the energy and raw material (for synthesis) for 167 anhydrous ammonia-urea plants (1,000 tons per day), capable of producing 45 million nutrient tons of nitrogen annually—about as much as the total 1975 world consumption of nitrogenous fertilizer. Moreover, vast quantities of gas are being wastefully flared in at least 20 other countries. When I see the world’s continuing profligate misuse of gas, one of the basic raw materials for the production of nitrogenous fertilizers that are so essential for restoring fertility to "worn out" nutrient-deficient low-yielding soils, I lose my patience with those who ask plant breeders to perform miracles.

A Look Ahead on the Agricultural Research and Production Fronts

Today, there is a so great euphoria among some groups of scientists that major benefits will soon be forthcoming from the use of genetic engineering employing new techniques in tissue culture, cell fusion, and DNA transfer to increase the breadth, level and stability of diseases resistance, and also to increase yields in our crop plants. Although great progress has been made by employing genetic engineering techniques with bacteria or yeasts to increase the production of insulin and interferon, there is no evidence at this time that similar results can be obtained with higher plants, and especially with polyploid species such as wheat. It is highly probable that it will be many years—several decades, if ever—before these techniques can be successfully used to breed superior crop varieties. Further, it is a mistake to assume, a priori, that the transfer into our crop species of disease-resistant genes through genetic engineering will necessarily result in anymore durable resistance in the
subsequent varieties than we have been able achieve to date. Remember that pathogens, when faced with extinction, seek to mutate into new races capable of attacking the variety.

CIMMYT, as of now, has not committed itself to initiate research employing genetic engineering to improve its breeding programs. It is, however, keeping its options open by establishing contacts with certain universities where such research is under way. If results look promising, CIMMYT many in the future opt to explore the feasibility of adding such an approach. Meanwhile, there is much that remains to be done, and can be done, to further improve the disease resistance of food crops by employing conventional plant breeding methods.

With world population growth pressures, the significance of raising crop production on the more marginal production areas also becomes more important for future world food production. Some 600 million people live in the semiarid tropics and about one billion people live in developing country agricultural areas characterized by serious biological constraints. The crop production problems of farmers in marginal areas should receive increased research attention in the decades ahead. I must caution that agricultural research alone cannot produce miracle improvements in many of the more marginal production areas. Some of the biological limitations are simply too overpowering for science to overcome. Still, we can put science to work on a number of the problems faced in marginal land areas. Breeding attention should continue to increase on developing crop plants for problem soils, e.g., excessive acidity, alkalinity, salinity, and aluminum toxicity. Similar work is under way for added tolerance to heat, cold and drought stress. Using conventional as well as new breeding techniques I believe varieties can be developed with greater yield potential and stability for many of the marginal lands areas.

At CIMMYT, two major breeding approaches are being pursued to develop improved varieties for the more marginal production conditions. One involves conventional breeding procedures in search of genetic variation within a particular crop species for added tolerance or resistance to particular stress problems. As an example, wheat researchers have identified materials with greater tolerance to acid soil conditions with aluminum toxicity characteristics. This tolerance has been incorporated into advanced lines which are capable of much higher yield levels on the millions of hectares of land afflicted by these soil-stress problems. Actually, these so-called aluminum-tolerant varieties are, in some cases, more correctly labeled phosphorus-efficient
varieties, i.e., they possess a greater capacity for phosphorus uptake in soils which tie-up more of the available phosphorus.

Wide crosses between plant species are another method being explored to transfer useful genes for added tolerance to stress problems into our crop species. Triticale, a hybrid cross of wheat and rye, is an example of such research efforts which resulted in the development of a new crop species. Triticale now has similar yield levels to the best bread wheats in optimum production environments. Biologically, it probably has an even higher maximum genetic yield potential than bread wheat due to its greater production of total dry matter. Its strong comparative advantage over wheat, however, is most evident in marginal production areas with acid soils, sandy soils, and cool temperatures. In such environments, triticale has shown up to a 200 percent yield advantage over the best wheats available today. Consequently, this new crop offers increased food production potential for a number of important marginal land areas.

Research to cross domesticated species with wild relatives is another promising research avenue which may lead to the development of improved varieties adapted to marginal land areas. Generally, such wide cross research involves breaking down natural barriers between plant species in order to introduce useful genes from alien genera into domestic crop species. We have identified a number of wild species with greater tolerance to salinity, particular diseases and insects, and temperature and moisture stresses than we have found to date within the germplasm of the major crop species. Successful introgression of these desirable genes can lead to crop cultivars with greater tolerance to environmental stresses. New techniques, such as tissue culture and those being developed in the new frontiers of genetic engineering, offer potentially great payoffs and merit added research resources in the years ahead. In the meantime, we cannot neglect the more conventional areas of plant breeding research, since they represent the major line of defense today on the food front. We must be careful not to drain research resources from activities with a proven track record just because high-powered salesmen-scientists are getting broad and, I believe, premature press coverage on their claims of "miracle" breakthroughs in plant breeding research.

Permit me to close my remarks by saying I believe if the proper emphasis is given to agriculture and if sound financial policies are established and continued to encourage it, food production can be increased fast enough to keep pace with the growth of the Population
Monster over the next doubling of the world population, be it 40, 60, or 80 years. During this period, most of the world's food production will continue to come from the same species which now supply our food needs. Fortunately, we still have a large unexploited yield production potential manifest by the big spread in yield between the maximum yields being harvested by the best farmers and the average yields harvested for the same crop on the majority of farms in the same country. The yield in many of the developing nations, where most of the land is still being cultivated with primitive traditional methods, is very low. It is in these areas of the world that excellent opportunities exist for increasing yields and thereby expanding food production. We must help the developing nations of the world to exploit this potential if the food needs of the world are to be met. On the other hand, we must also continue to work aggressively to raise average yields per hectare in the developed nations where yields are already high. In such areas, additional increases will be more difficult to achieve as the maximum genetic yield potential for each crop species is approached.

Nevertheless, I am optimistic that, from a scientific point of view, we have the knowledge to double the current level of the world food production in the next 40 to 60 years. To achieve these production increases and to distribute the food equitably will require the sustained and focused support of governments and international development assistance agencies. The task will not, and cannot, be achieved without massive new investments in the agricultural sectors of the developing countries, particularly in the areas of water resource development and fertilizer production.

In closing, I would like to quote Drs. Andrés and Jean Mayer, who succinctly state the challenge facing agricultural scientists, and indeed, mankind in the coming years: "Few scientists think of agriculture as the chief, or the model science. Many, indeed, do not consider it a science at all. Yet, it was the first science—the mother of science; it remains the science which makes human life possible; and it may well be that before the century is over, the success or failure of science as a whole will be judged by the success or failure of agriculture."
CHAIRMAN'S COMMENTS

by

S. R. Freiberg*

Dr. Borlaug has presented a stimulating and thought-provoking paper. He presents a broad picture of International Agricultural Research as compared to previous speakers. In 1980, at our first Agricultural Sector Symposia and the one last year, each had four speakers on Agricultural Research but their topics were more narrowly defined. Thus, Dr. Krantz, ICRISAT and Dr. Okigbo, IITA spoke about farming systems research, Dr. Sanchez talked about soils and rainfed agricultural research based on his experiences at CIAT and in Peru. Dr. Herdt of IRRI talked on rice research technology; Dr. Willey, ICRISAT and Dr. Watson formerly of the Rubber Research Institute spoke about multiple cropping; Professor Bunting of Reading University on High Yielding Varieties Technology and Energy Costs and Dr. Odhiambo from the International Center of Insect Physiology gave us a paper on Pest Management Research. Now, we have been given an overview of international agricultural research and how it has contributed to and may continue to contribute to solving agricultural production problems in the developing world.

Dr. Borlaug started out by telling us about the race between population increase and world food supplies. He points out that half the world's arable land is planted to cereal crops and that 81% of our food is from plant origin and only 19% from animal and bird origin. Perhaps that is why he stresses crop research and says little about animal research. He then presents the factors which affect increased yields and cropping intensity; these being soil fertility, crop improvement, improved agronomic practices; pest control, availability of production inputs and Government agricultural economic policies.

The role of the Internal Agricultural Research Center is then discussed and a brief history of the IARC's is given beginning with IRRI in 1960. The relationship between the International Agricultural Research Centers and the National Research program in the developing countries is then described and stress was given to tailoring the services of the IARCs to the countries' research needs based on their stage of agricultural research competence. It certainly is generally true, as Dr. Borlaug points out, that as the national research programs improve their capabilities, there is a concomitant increase in their interest in collaboration with, not only the IARCs but also other research organizations.

There clearly is a need for the IARCs to keep their goals focused on increasing the supply of improved germ plasm to permit a steady stream of genetically improved materials for testing in developing countries under different agroecological conditions. As pointed out, this is essential to

*Agriculturalist, EMENA Projects Department
stay ahead of the inevitable breakdown in resistance to diseases and insect attack. The IARC-coordinated international nurseries serve as important links to the research efforts of the developing countries. This needs to be continued as well as serving as training centers for developing country agricultural research scientists and extension subject matter specialists.

Dr. Borlaug states that the increased cost of fertilizers and especially nitrogen fertilizer has affected the expansion of HYV use because of their dependence on increased fertilizer use when compared to local varieties. He is more optimistic than I am that nitrogen-fixing organisms can be found to do the same for cereals as they do for legumes and some tropical grasses. I think a more immediate impact can come from crop rotation or intercropping with legumes. I do agree that genetic engineering seems remote as a means of altering cereal crop plants in beneficial ways, but maybe they can alter rhizobia species which will nodulate on cereal crops and fix atmospheric nitrogen, but that also seems like a long way off. Certainly, research on more efficient utilization of fertilizers makes sense. Perhaps timed release fertilizer has a role to play. As a result of the new techniques of applying herbicides directly to weeds between row crops using rope wicks, there may be a similar means for future application of nitrogen to cereal crops and possibly combined with research on more fertilizer efficient varieties.
Rapporteur's Comments
by
Paul Marko *

Third Annual Agriculture Sector Symposia: Dr. Borlaug's address, concluding remarks by Chairman Freiberg, and questions from the floor.

The Chairman made the following comments:

That, in past symposia, specific topics related to cultural practices needed to improve crop yields such as soil improvement, farming systems, multi-cropping and the use of improved crop cultivars, had been the subject of the speaker's address.

The present address by Dr. Borlaug was an over-view of the role of the various agricultural sciences and their application to the dominant issues of world food production; i.e., population, sources of yield improvement, etc. Dr. Freiberg agrees with Dr. Borlaug on these issues and sees the need to give special emphasis to the following topics in the future:

(a) increase the collaborative research work of the IARCs, with national research programs;

(b) increase the pool of available quality germ plasm in major food cultivars;

(c) improve the exchange of international nurseries;

(d) increase the efficiency in use and production of nitrogenous fertilizers;

(e) study the role of improved crop rotations;

(f) stimulate basic genetic research of direct application to world food production in institutions of higher learning, and such topics as Rhizobia production.

(g) to provoke in all institutions of applied research a special consideration for more effective use of all inputs affecting the biological systems of production.

* Agriculturalist, AGR
Questions from the floor to Dr. Borlaug:

Jose Olivares, AGR

Question: You mentioned the improvements of conventional systems of plant photosynthesis. What is the potential for chemical photosynthesis?

Response: This type of research should be undertaken by universities. It does not have a role at present in the IARCs.

Monty Yudelman, AGR

Question: You have mentioned the Princes of Serendip. Could you elaborate on what the role of the Princes has been in your own work?

Response: I used this to illustrate the need for an open mind for those carrying out research and funding it. But, I can give you a concrete example from my work in Mexico. In the early 1940s, wheat production in the north of Mexico was limited uniquely, or so popular belief had it, by the wheat plant being susceptible to stem rust. We began an intensive conventional plant breeding program to select for resistance. In order to accelerate the process two crops a year were grown in the north at higher latitudes, and in the central plateau at lower altitudes. In the selection of germ plasm from these nurseries the phenomena of day length insensitivity was detected which gave our wheats greater adaptability. After we had selected stem rust resistant germ plasm, these varieties were incapable of remaining erect in situations of better soil fertility, so we started re-selecting incorporating genes for shorter straw, making the varieties more resistant to lodging and therefore responsive to fertilizer. As the farmers' demand for the varieties grew, weaknesses in the capacity of local institutions to multiply seed in quantity and of the desired quality, were revealed. What I am trying to point out is that starting with the simple research objective of breeding for stem rust resistance, we encountered many unforeseen challenges and made discoveries that tended to improve not only the disease resistance of the plant but also its cultural practices and the support industries for wheat production. However, we had to establish an order of priorities as each of these unforeseen opportunities presented itself. We were selective.

Delbert A. Fichett, EMNVP

Question: Would you comment on the role of the private sector in the Third World, especially its role as regards input distribution and its impact on stimulating the adoption of the higher yielding varieties.

Response: There seem to be great fears of the use of private sector to stimulate agricultural development, especially in Africa and Asia and to some extent Latin America .......... The public sector management in the Third World of fertilizer production is a limiting factor, many of the fertilizer plants are not run efficiently and the cost of this valuable input is sometimes higher than imported sources .......... An area where the private sector could provide dis-incentives in the Third World, and this depends on the established capacities
of the private sector in each country, is the free exchange of germ plasm. If current trends to Plant Breeder Rights and accompanying legislation continue in the developing countries, this free exchange will be interrupted.

John Lindt, ASP

Question: We read in the development literature about special requirements for improved varieties, that they require more fertilizer than the unimproved varieties, that given equivalent situations, the unimproved varieties under stress will out-perform improved varieties.

Response: This kind of misinformation abounds in the context of the development literature; but show me a human that does not require good nutrition to achieve his growth and development. The same is true of plants; to obtain their yield potential they require the best available circumstances. Improved cultivars will yield, as well as unimproved cultivars, in all conditions, but when these conditions improve, the improved varieties will make more efficient use of nutrients and achieve their genetic yield potential.

William Jones, EAP

Question: I remember an incident we experienced together in the field of Pepe Nieto in 1951 in Mexico. The subject of the eventual ban on DDT use was discussed. You mentioned the consequences of this ban in the developing world. Have your predictions come true?

Response: The incidence of malaria is on the increase, which a selective use of DDT would have prevented - the present situation was foreseeable even then. Some recent research from the International Vegetable Center in Taiwan indicates that DDT breaks down in the soil and there is no soil build-up of the chemical by its continued use. I think the key concept in the use of pesticides or any agricultural chemicals is to be selective and used according to recommended dosage. Its the same with a doctor's prescription. If one takes the medicine as prescribed, there are no after effects, and the disease has been successfully treated in the majority of cases. One family of agricultural chemicals of great benefit to the production of food in the world are the herbicides. Again, used as prescribed and selectively, they are a powerful tool.

Dr. Ian Graham-Bryce, Director East Malling Research Station.

Question: You have mentioned the potential of genetic manipulation in your paper. However, you seem to see it at the level of basic university-inspired research for the present. I would have thought this might be something that the IARCs could use in a more applied way especially on perennial crops. For example, the ability to manipulate ploidy and improve the sterility of grass species would seem highly useful to the work of the IARCs. Are these the right objectives to be pursuing for genetic engineering?

Response: All these avenues of genetic engineering need to be pursued, and there are subjects within genetic engineering that may have more immediate implications for the applied work at the IARCs. One example being the variation in genetic information contained by various cells in potato varieties; there is a lot to be learned. However, with the great budget constraints that the
IARCs are experiencing, the most difficult of their history, the proper place for this kind of research at present is in the universities. We cannot under-estimate the difficulties the IARCs will have in the coming years due to cuts in their budgets. We recently had enormous problems to raise US$100 million from the international community for the budgets of all international centers for the next fiscal year. Yet, if one takes the contribution of just one such center and its genetic improvement program in wheat - CIMMYT Mexico - these investments pay rich dividends. The wheat crop produced in one year in India using almost exclusively germ plasm from the CIMMYT nurseries had a value on world markets of US$4 billion.
SESSION III

CURRENT STATUS and FUTURE POTENTIAL of AGRO-CHEMICALS and THEIR IMPACT on CROP PRODUCTION
CURRENT STATUS AND FUTURE POTENTIAL OF AGROCHEMICALS
AND THEIR IMPACT ON CROP PRODUCTION

I.J. Graham-Bryce*

INTRODUCTION

The essence of agriculture is to engineer that a few plant species, which have been selected as man's crops predominate and flourish in environments where under natural conditions they would be only minor components of complex ecosystems or even completely absent. This can only be achieved by suppressing other plant species, which by definition are weeds in these circumstances, and by preventing losses to consumers other than man or his livestock, namely pests and diseases.

The struggle against competitors is thus an inseparable component of the concept of agriculture and throughout the history of crop production various approaches to combating this competition have been pursued. Among these, the selective poisoning of the offending organisms by chemicals has been recognized from the earliest times to offer logistic and other advantages. However, although a wide range of materials has been evaluated over the centuries (see, for example, Smith and Secoy, 1981) toxicants potent enough to be effective in practice were not readily forthcoming. In the brief period of only thirty-five years since the second world war the situation has been abruptly transformed: modern synthetic and evaluation techniques have provided a stream of highly effective pesticides, some having properties which must hitherto have seemed unattainable. These include systemic translocation within plants and high degrees of selectivity, for example, between cereals and grass weeds (propionate amide herbicides) and between beneficial and harmful insects (pirimicarb aphicide); these two highly desirable properties are combined in the case of systemic fungicides which control pathogens living in intimate association with the plant. Table 1 shows a few of the more important milestones to illustrate this remarkable outpouring of invention.

* Director, East Malling Research Station, England and formerly Head of the Insecticides and Fungicides Department, Rothamsted Experimental Station, England.

1/ Unless otherwise indicated the term pesticide is used generically to indicate chemical crop protection agents including insecticides, fungicides, herbicides, nematicides etc.
Table 1

Some major advances in synthetic crop protection chemicals.

<table>
<thead>
<tr>
<th>Approximate Year of Introduction</th>
<th>Product</th>
</tr>
</thead>
<tbody>
<tr>
<td>1930</td>
<td>Dithiocarbamate fungicides</td>
</tr>
<tr>
<td>1942</td>
<td>DDT</td>
</tr>
<tr>
<td>1945</td>
<td>Hormone weedkillers (2,4-D; MCPA)</td>
</tr>
<tr>
<td>1945</td>
<td>BHC</td>
</tr>
<tr>
<td>1945</td>
<td>Systemic organophosphorus insecticides</td>
</tr>
<tr>
<td>1948</td>
<td>Cyclodiene insecticides</td>
</tr>
<tr>
<td>1956</td>
<td>Carbamate insecticides</td>
</tr>
<tr>
<td>1956</td>
<td>Triazine herbicides</td>
</tr>
<tr>
<td>1958</td>
<td>Bipyridylium herbicides</td>
</tr>
<tr>
<td>1967</td>
<td>Benzimidazole systemic fungicides</td>
</tr>
<tr>
<td>1975</td>
<td>Photostable pyrethroids</td>
</tr>
</tbody>
</table>

There is every sign that this creativity is being maintained (Yeo, 1979) although the increasing costs of development and the diminishing market opportunities due to the availability of satisfactory materials from previous successes (see later) may result in a decrease in the rate at which new commercial products are introduced.

The very widespread use of the chemical agents discovered in this period of advance has brought great improvements in yield and quality. It has also greatly improved understanding of their advantages and limitations. Awareness of these limitations, which may include unfavourable toxicological properties, inappropriate persistence or mobility in the environment and capacity to select resistant strains of pest has led to a welcome revival of interest in alternative methods. However, it should be stressed that the use of chemical pesticides remains a most effective, economical and flexible approach, capable of much further development. In view of the remorseless increase in world population and ever increasing pressure on food supplies it is essential that the potential of this approach is fully realized and that everything possible is done to continue seeking improved materials and methods of use.

**PROFILE OF THE AGROCHEMICAL BUSINESS**

The impact of the discoveries discussed above has been dramatic. World output of synthetic pesticides increased from 100,000
tonnes in 1945 to 1 million tonnes in 1965 and nearly 2 million tonnes in 1975 (Green, Hartley and West, 1977). Over the 30 years to 1977 proceeds expanded approximately sixfold to \$7.7 \times 10^9\) at 1977 prices (Yeo, 1979). The current world recession has caused some decrease in the rate of expansion, but this is expected to be temporary and it is confidently predicted that the five-year period 1978-83 will show an average growth rate of 4-5%. Inevitably forecasts thereafter are rather more speculative but similar growth rates are envisaged (NEDO, 1981). This greater usage does not necessarily imply greater tonnages of chemical, as new discoveries are generally significantly more active and therefore applied at lower rates.

There have been some major changes in the balance between different types of pesticide during this period of growth. Figure 1 shows that insecticides were dominant in the 1950's but were overtaken by herbicides in the early 1970's. This balance can be related to the relative consumption in different regions (Table 2).

<table>
<thead>
<tr>
<th>Region</th>
<th>Share of Market, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>North America</td>
<td>34</td>
</tr>
<tr>
<td>West Europe</td>
<td>24</td>
</tr>
<tr>
<td>East Europe</td>
<td>14</td>
</tr>
<tr>
<td>Japan</td>
<td>12</td>
</tr>
<tr>
<td>Remainder</td>
<td>16</td>
</tr>
</tbody>
</table>

Thus the figures reflect the fact that herbicides are dominant in developed countries (for example they account for about 70% of the UK market) where their potential for labour saving is particularly advantageous. This factor is less significant in tropical developing countries where the severity of insect attack may also be much greater, hence there is a greater dependence on insecticides. As would be expected, the market in developed countries is much nearer to saturation; significantly lower annual growth rates in West European and North American consumption are anticipated compared with the global figure of 4-5% cited earlier. These regional differences in growth rates may go some way to redressing the present distribution of usage. Nevertheless, it is a matter of concern that developing countries still account for less than one fifth of the world consumption of crop protection products despite their large area, serious pest, disease and weed problems and faster population growth. There are also undoubtedly enormous unsatisfied demands for pesticides in the USSR and China.

This last comment is reinforced by a consideration of the principal pesticide market opportunities in terms of crop and damaging
organism (Table 3). For reasons to be discussed below, the agrochemical industry is concentrating increasingly on such major outlets and a substantial proportion of these potential markets is located in developing countries, the USSR and China.

Table 3

Principal Pesticide Market Opportunities
(Estimated 1979 end-user value; from Braunholtz, 1981)

<table>
<thead>
<tr>
<th>Product Type</th>
<th>$ million</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maize herbicides</td>
<td>1050</td>
</tr>
<tr>
<td>Cotton insecticides</td>
<td>975</td>
</tr>
<tr>
<td>Fruit and vegetable insecticides</td>
<td>900</td>
</tr>
<tr>
<td>Fruit and vegetable fungicides</td>
<td>860</td>
</tr>
<tr>
<td>Soybean herbicides</td>
<td>760</td>
</tr>
<tr>
<td>Rice insecticides</td>
<td>420</td>
</tr>
<tr>
<td>Maize insecticides</td>
<td>360</td>
</tr>
<tr>
<td>Cotton herbicides</td>
<td>350</td>
</tr>
</tbody>
</table>

NATURE OF THE AGROCHEMICAL INDUSTRY

The period since the advent of the first modern synthetic pesticides has been potentially very profitable for the agrochemical industry, but this profitability has been associated with high risks and a need for substantial investment in research. Typically, the industry spends about 7% of proceeds on research and development, with a further 2-4% on technical service, figures well above the average for the chemical industry as a whole. The costs of bringing new products to the market have risen sharply, to a large extent because of the costs of meeting regulatory requirements, and the break-even period before the initial investment is recovered has lengthened (see later).

These trends have concentrated the industry into the hands of relatively few major manufacturers who can bear the investment cost, maintain a broad enough R and D effort to compensate for products which fail at a late stage in development and justify the wide range of expertise needed to evolve successful products. The number of major producers of active ingredients has declined to about 25 in the face of these pressures. A further slow reduction is anticipated although operating conditions are not expected to change markedly in the 1980's. In most cases agrochemical production forms part of a much larger general chemical business; there would appear to be advantages if this includes pharmaceuticals, presumably because this increases the range of candidate chemicals available for screening and gives benefits from shared toxicological expertise. These producers are concentrated in those developed countries with a strong chemical tradition and industry (Table 4).
Table 4


<table>
<thead>
<tr>
<th>Country</th>
<th>Percentage of Value, 1977 $ million</th>
</tr>
</thead>
<tbody>
<tr>
<td>USA</td>
<td>41</td>
</tr>
<tr>
<td>Japan</td>
<td>13</td>
</tr>
<tr>
<td>France</td>
<td>13</td>
</tr>
<tr>
<td>W. Germany</td>
<td>6</td>
</tr>
<tr>
<td>UK</td>
<td>5</td>
</tr>
</tbody>
</table>

(Switzerland also produces a significant proportion of total world output but comparable detailed figures are not available).

It should be added that Table 4 does not give a full picture of export activity which differs significantly from production. For example, in 1977 the UK's share of world exports was 13%. Typically world demand for a product is initially satisfied from a single large-scale plant but formulation and packaging may be undertaken locally because of transport costs. Pressures for technology transfer to developing countries are however causing a reappraisal of this policy and local manufacture of active ingredients in smaller, more flexible plants may become more common in future.

PROCEDURES FOR DISCOVERY AND DEVELOPMENT OF PESTICIDES

As a result of intensive research, much is now known about the physiology and biochemistry of target organisms. Nevertheless, most leads to new pesticides are still discovered in industry by the traditional method of examining the effects of candidate compounds on test species in high-throughput screens. The candidate compounds may be analogues of established pesticides, natural products, structures based on study of potential target processes or materials produced for totally different purposes such as dyestuffs. They may come from within or outside the company undertaking the tests. The most valuable leads may arise from novel compounds synthesised for other purposes. For these reasons the process is known by the somewhat misleading term "random screening." It has been developed into a highly efficient process and worldwide as many as 200,000 compounds are evaluated annually by the various major producers (Corbett, 1980). As the agrochemical business has become more competitive and development costs have risen, greater attention has been given to the commercial target setting on which such screens are based. The result has been an increasing concentration on the major potential markets discussed above, at the expense of crops and problems which may be very important locally, but are minor in global terms.
Once a lead has been discovered, attempts must be made to determine the most active structure within the identified chemical class. Various sophisticated techniques (quantitative structure-activity relationships or q.s.a.r.) have been developed to help with this process of lead optimization. In general these attempt to define the way in which the electronic, hydrophobic and steric properties of substituent groups influence the activity of a parent molecule. Recent progress with such approaches is reviewed by Verloop (1981).

Compounds successful in preliminary screening are taken forward for further glasshouse and subsequently field trials leading to worldwide evaluation and eventual release as new products. Early in this development toxicological and environmental studies are started and these extend in complexity and depth as the compound progresses towards introduction. Minimum requirements for registration now include: acute and long term (2 year) toxicity studies on mammals, fish, birds and possibly other nontarget organisms; carcinogenic, teratogenic and reproductive studies for at least 3 generations in selected species; metabolic studies in plants and animals together with investigation of metabolites; residue measurements in crops, meat and milk; measurements of persistence and redistribution in the environment; studies of effect on soil-borne organisms and microbial processes in soil; investigations of possible effects on wildlife. Requirements of regulatory authorities have proliferated markedly in recent years, largely in response to public opinion. The investigations needed to meet these requirements now account for a substantial and increasing part of the costs of introducing new chemicals (see Table 6) and there is concern that this is restricting the development of potentially valuable products (see, for example, Goring, 1975).

When the evaluation of efficacy and side effects has confirmed that the compound has a good chance of commercial success, but well ahead of the final decision to proceed, the development of appropriate formulations and production processes must be started as this work can take 2-3 years to complete. The various strands of the overall development finally come together at the date of launch, but the candidate product can fall at any of the commercial or regulatory hurdles up to this point, giving no return for all the investment and resources devoted to its development. These costs of development have now increased to something like $20 million per marketable product and discounted cash flow considerations show that this investment is typically not recouped for some 12 years or more. Such figures, together with the timescale for development of 5 to 8 years emphasize forcibly the risks involved in the agrochemical business and the consequent need for a substantial organization and financial backing. They also demonstrate that agrochemical companies must now be confident of receiving a substantial sales income, of the order of $30 million annually (1981 prices) to justify the investment in developing a product. This brief analysis explains the increasing concentration on major markets and resulting dangers that so called minor uses will be neglected. The definition of minor in this context should be seen in perspective: even a commodity such as potatoes may now come into this category.
and others such as temperate cereals may be becoming only marginal. A further implication is that to be viable agrochemical companies must now operate on a global scale. Any further increases in the costs of development, for example additional regulatory requirements, can only exacerbate this trend unless alternative financing arrangements are evolved.

Tables 5 and 6 summarise the different activities involved in the commercial development of a new pesticide.

### Table 5

**Generalized pattern of commercial pesticide development (adapted from various sources including Braunholtz, 1981; Green et al, 1977)**

<table>
<thead>
<tr>
<th>Year</th>
<th>Activity</th>
<th>No. of Compounds</th>
<th>Survival rate</th>
<th>Accumulated cost $M</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Synthesis, screening</td>
<td>12,000</td>
<td>1:100</td>
<td>5</td>
</tr>
<tr>
<td>2</td>
<td>Glasshouse trials</td>
<td>120</td>
<td>1:6</td>
<td>6.5</td>
</tr>
<tr>
<td></td>
<td>Initial field trials</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Field trials</td>
<td>20</td>
<td>1:5</td>
<td>7.0</td>
</tr>
<tr>
<td></td>
<td>Initial toxicology</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Field evaluation</td>
<td>4</td>
<td>1:2</td>
<td>9.0</td>
</tr>
<tr>
<td></td>
<td>Toxicology</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Formulation and process development</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5-7</td>
<td>Worldwide evaluation</td>
<td>2</td>
<td>1.2</td>
<td>20.0</td>
</tr>
<tr>
<td></td>
<td>Toxicology, environmental studies</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Formulation and process development</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Production, Promotion, Patent and registration</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Table 6

**Approximate distribution of research and development costs for introduction of new pesticide.**

(Adapted from Braunholtz, 1981)

<table>
<thead>
<tr>
<th>Activity</th>
<th>Percentage of total cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Synthesis and screening</td>
<td>25</td>
</tr>
<tr>
<td>Glasshouse and field testing</td>
<td>20</td>
</tr>
<tr>
<td>Safety and environmental studies</td>
<td>25</td>
</tr>
<tr>
<td>Process development and formulation</td>
<td>20</td>
</tr>
<tr>
<td>Patents, administration etc.</td>
<td>10</td>
</tr>
</tbody>
</table>
CHARACTERISTICS OF EXISTING AGROCHEMICALS AND SCOPE FOR IMPROVEMENT

In view of the wide range of chemical agents now available and the extensive experience of their use, we should now be well placed to make a balanced appraisal of their characteristics and the scope for further advance. In any such review it is instructive to compare existing products with the specification of an ideal treatment (Graham-Bryce, 1975a). Such a specification would include:

- high activity against the target species at cost-effective rates of application
- selective action against the target organism
- persistence not longer than required for the intended biological effect
- efficient transfer from the point of application to the target organism without risk of contaminating non-target areas
- properties unfavourable to concentration along food chains.

The essential requirements are efficacy and safety. The extent to which existing materials meet this specification and directions of future development will be discussed briefly under five headings: activity against the target organism, biological availability, durability of effectiveness, selectivity and compatibility with other control measures. These various aspects are inter-related but some separation is essential for ease of discussion. It should be noted that improvements can be attained both by discovering better chemicals and by using them more effectively as a result of modifications in formulation or method of application.

Activity against the target organism. Since the beginning of this century, and particularly during the period of heightened activity since the second world war, the flow of new discoveries has resulted in a progressive increase in potency of several orders of magnitude for all major classes of chemical agent: insecticides, fungicides and herbicides (Figure 2). The latest advances, represented by deltamethrin, triadimefon and DPX 4189 represent astounding levels of activity compared with previous standards, that of DPX 4189 being particularly remarkable as this herbicide is active via the soil at the rates shown. Nevertheless both biochemical considerations and circumstantial arguments (Graham-Bryce, 1975a) suggest that the limits of activity have not yet been reached so that even more potent compounds may be expected to emerge from either high-throughput screening or fundamental biochemical and physiological studies.

As a result of the progress illustrated by Figure 2, effective treatments are now available for most classes of damaging organisms. There are, however, notable exceptions. Table 7 lists some important examples.
Table 7

Classes of damaging organism for which satisfactory chemical control agents are not yet available

Pests
- soil-borne insect pests
- nematodes

Pathogens
- viruses and related organisms
- bacteria
- soil-borne pathogens

Weeds
- volunteer crops
- perennial weeds in growing crops

The reason for the lack of effective agent in these cases is not necessarily that the organisms concerned are intrinsically less vulnerable to chemical attack. Inaccessibility to applied treatments or requirements for selectivity may be the cause; these factors are discussed below. For controlling these classes of organism it is usually necessary to adopt non-chemical approaches, although there is increasing interest in indirect chemical methods such as suppression of symptoms or promotion of naturally occurring defence mechanisms in plants.

Biological availability and delivery to the target organism. With the ideal pesticide application system, each individual damaging organism would receive a just-lethal dose and no toxicant would reach unintended recipients, thus maximizing both efficacy and safety. In practice most present methods of applying pesticides are extremely inefficient: Only a small proportion of the applied dose reaches the intended target while the remainder enters the environment without contributing usefully to crop protection. This is illustrated by Table 8 which gives the proportion of the applied dose taken up by the receiving organism or calculated as required to eliminate a damaging infestation if applied directly to the individuals in the population.

Table 8

Utilization of crop protection chemicals (from Graham-Bryce, 1977)

<table>
<thead>
<tr>
<th>Pesticide</th>
<th>Method of application</th>
<th>Receiving Organism</th>
<th>Efficiency of utilization, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dieldrin</td>
<td>seed treatment</td>
<td>wheat bulb fly larva</td>
<td>0.002</td>
</tr>
<tr>
<td>Lindane</td>
<td>foiliar spray</td>
<td>capsids on cocoa</td>
<td>0.02</td>
</tr>
</tbody>
</table>
Chlortoluron  soil treatment  grass weeds  0.02
Dimethoate  foliar spray  aphids on field beans  0.03
Ethirimol  seed treatment  barley (for mildew control)  2.2
Disulfoton  soil incorporation  wheat (for aphid control)  2.9
Lindane/ Dieldrin  aerial spraying of swarms  locusts  6.0
Paraquat  spray  grass weeds (total cover)  up to 30

All such estimates must be subject to considerable reservations and high levels of utilization cannot be expected in many crop protection situations, especially with prophylactic or protectant treatments. Nevertheless the figures suggest that there is substantial scope for improvement.

In considering how such improvement might be obtained, it should be recognized that the requirements are very demanding; crop protection treatments are applied at extremely small rates into environments where they are subjected to powerful redistribution and weathering effects, caused by physical processes and by chemical and microbial degradation. As increasingly potent compounds are discovered and rates of application decrease, there is a corresponding increase in the significance of these processes. This argues for giving greater attention to the physicochemical properties that determine response to such processes (Graham-Bryce, 1981) and hence govern movement in the environment and biological availability.

The initial placement and release of the active ingredient are, however, dependent on the formulation and application system: substantial advances are in prospect on both these fronts also. In the case of sprays, traditional methods involve diluting the active ingredient in a relatively large volume of water (usually greater than 200 litre ha⁻¹) and pumping through hydraulic nozzles. This causes the liquid to break up unsystematically into drops which may vary in size from 1-1000 microns in diameter. This wide size range is likely to contain drops both too large and too small. Large drops can be very wasteful while at the other extreme small drops do not impact efficiently and are liable to drift and possibly cause environmental contamination. There has, therefore, been much interest in the improvement of spraying systems and in recent years, significant progress has been made. In particular the development of rotary atomizers has permitted a much better control over drop size, leading to the concept of controlled droplet application or CDA (Bals and Merritt, 1975).
The optimum drop size, composition and density for a particular control problem depends on complex interactions between the biological characteristics of crop and damaging organism and the physicochemical properties of the active ingredient and formulation. For many purposes, however, effectiveness increases with decreasing drop size. When combined with CDA, this allows a considerable decrease in the total volume applied, thus achieving the additional advantages of ultra-low volume (ULV) methods, which are essentially economic and logistic in reducing transport of materials. These advantages are particularly beneficial in the tropics where availability of water may be a major problem. However, the risks of contamination by airborne drift increase with decreasing drop size so that the requirements for efficacy and safety appeared to be in direct conflict. Recently a very interesting means of resolving this apparent conflict has appeared: the electrostatic charging of spray drops. The basic concept is not new; it has been recognized for many years that the pattern of initial retention of particles can be significantly altered by giving them a high electrostatic charge. There have been various attempts to exploit this principle to improve drop capture, but in the past the necessary equipment has been too cumbersome and expensive. Modern techniques have, however, made possible the development of practicable systems. Electrostatically-charged droplets can be produced from a rotary atomizer (Arnold, 1979) giving significant improvements in deposition. A more radical innovation is the electrodynamic system devised by Coffee (1979) in which both the formation and projection of the droplets is achieved electrostatically as well as their charging in a low-energy system which contains no moving parts. Again deposition and coverage are greatly improved and a very favourable distribution between the upper- and under-sides of receiving leaves has been reported. If they fulfill their promise these new methods will transform application technology and greatly improve efficiency of utilization.

Efficiency and economy of usage can also be greatly influenced by the timing of applications which ideally should be carefully matched to the critical point of population growth. There is currently much interest in the development of predictive and monitoring systems, for example those for insects based on pheromone traps, and in the establishment of economic thresholds. These are essential components of supervised control and integrated pest, disease or weed management approaches, discussed further below.

The problems of delivering the toxicant efficiently to the target are particularly acute for soil inhabiting organisms. The difficulty of transferring an effective dose to minute targets widely distributed within a medium through which movement is retarded by adsorption and by the tortuous nature of the pore system and in which the chemical is degraded by chemical and microbial processes will be readily apparent. It is this inaccessibility which largely accounts for the prominence of soil inhabiting organisms among those listed in Table 7. For these reasons there is keen interest in discovering insecticides, nematicides and fungicides translocated downwards in
plants; there is a notable lack of such products in contrast with the relative abundance of downward translocated herbicides.

Durability of effectiveness. Any long-term approach to crop protection should embrace not only the discovery of potent control agents and their efficient application, it should also ensure that these agents remain effective when used repeatedly. In practice the transience of chemical treatments due to the emergence of resistant strains of pests or pathogens is probably their greatest shortcoming. The problem has become progressively more serious throughout the world; resistance to insecticides has now been detected in some populations of almost all species of medical, veterinary or agricultural importance and resistance to fungicides is proliferating in pathogens. The first cases of resistance to herbicides in weeds have been reported in recent years.

Because resistance genes persist within populations, the only practicable way of dealing with established resistance has been to switch to a different chemical which may in turn select other mechanisms of resistance. The range of possible replacement compounds may thus be reduced very rapidly as a result of this sequential development of resistance, particularly in the case of insecticides which come from very few chemical classes so that there are already dangers of exhausting all available compounds with some pest populations (Sawicki, 1975).

It is therefore essential to devise pesticide management strategies which will delay or prevent the development of resistance. Such strategies should in principle be based on two inter-related components: knowledge of the genetic and biological characteristics of the population being treated, which condition the response to selection, and understanding of the selecting characteristics of the pesticide, including the mechanisms of resistance it selects and their cross-resistance patterns. Ideally such information should be obtained before the compound is introduced into practice or at an early stage in its use, but this raises formidable experimental problems and there is, as yet, no agreement on procedures.

Where a full analysis of the factors determining resistance is not possible, it is necessary to fall back on enlightened empiricism and adopt what appear to be reasonable strategies. The key to such strategies must be to reduce the selection pressure or to impose a multiple treatment in which individuals resistant to a particular compound will be eliminated by another component. Alternation of different pesticides or mixtures of different materials seem obvious ways of exploiting these principles. In favourable cases it is possible to find compounds to which there is no cross-resistance or even negative cross-resistance, whereby individuals resistant to one compound have a heightened susceptibility to another: In adopting this approach it is important to recognize that differences between pesticide classes in selecting characteristics do not necessarily parallel differences in mode of action. There is a further difficulty that certain widespread
resistance mechanisms, such as delayed penetration into the organism, or enhanced metabolic attack by oxidation or hydrolysis, have a very general applicability and may affect a broad range of compounds from different chemical classes.

The development of effective strategies is likely to raise further complex technical and policy questions. Thus it may be desirable to complement the use of pesticides with alternative chemical or non-chemical methods. It is also very desirable to establish monitoring procedures to detect the onset of resistance at the earliest possible stage so that the selecting agent can be withdrawn. To make such strategies effective, they must almost always be practised on a regional scale within which all those applying pesticides must co-operate. The potential organizational and political difficulties will be obvious.

Once resistance has become established, there is usually nothing that can be done to restore effectiveness. In a few cases, however, it may be possible to counteract resistance caused by an enhanced degradation mechanism through the application of a synergist which suppress the relevant metabolic process. For example, Miyata et al (1979) were able to overcome the resistance of many organophosphorus insecticides in the green rice leaf hopper by simultaneously applying Kitazin, a systemic organophosphorus fungicide active against rice blast, which inhibits the esterases involved in the insecticide resistance. Such simple solutions are, regrettably, rare and a co-ordinated approach employing several methods is normally necessary. Strategies to counter resistance are reviewed by Sawicki (1981).

Selectivity. While no doubt the need for treatments which would not harm unintended recipients was recognized from the earliest considerations of chemical approaches, the importance of selectivity and its many ramifications have become increasingly apparent with experience of the use of modern synthetic products. Selectivity has various aspects which vary in importance according to the type of pesticide and the use to which it is being put. With herbicides, safety of the crop is obviously of particular concern. This also tends to apply in the case of fungicides, reflecting the very intimate association of fungal diseases with the host plant. For insecticides, selectivity between mammals and insects has required especial attention; this is largely a consequence of the fact that currently available insecticides come from a very limited range of chemical classes, the organochlorines, the organophosphates, the carbamates and the pyrethroids, all nerve poisons having a basic mode of action to which mammals are also vulnerable. The problems of resistance have also highlighted the importance of selectivity in favour of beneficial arthropods which include pollinators as well as predators and parasites. These latter natural enemies provide a means of controlling the population which acts indiscriminately on both resistant and susceptible individuals.
Selectivity can be achieved either by arranging that a much larger proportion of the toxicant reaches the target than reaches non-target organisms by adjusting placement and timing of applications or formulation (ecological selectivity) or by using compounds intrinsically more toxic to the target organism (physiological selectivity).

There are large differences in the physiological selectivity shown by different compounds; for example Table 9 provides data for representative insecticides, expressed in terms of median lethal doses.

**Table 9**

Selectivity of insecticides between pests and mammals  
(from Graham-Bryce, 1976)

<table>
<thead>
<tr>
<th>Insecticide</th>
<th>LD50 to rats mg kg⁻¹ (oral)</th>
<th>LD50 to insects mg kg⁻¹ (topical)</th>
<th>Ratio rats: insects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aldicarb</td>
<td>0.9</td>
<td>10 (aphids)</td>
<td>0.09</td>
</tr>
<tr>
<td>Disulfoton</td>
<td>8.6</td>
<td>7.5 (aphids)</td>
<td>1.1</td>
</tr>
<tr>
<td>Parathion</td>
<td>3-6</td>
<td>0.9 (houseflies)</td>
<td>5</td>
</tr>
<tr>
<td>DDT</td>
<td>118-250</td>
<td>10 (houseflies)</td>
<td>18</td>
</tr>
<tr>
<td>Carbaryl</td>
<td>850</td>
<td>4 (mosquitoes)</td>
<td>212</td>
</tr>
<tr>
<td>Dimethoate</td>
<td>200-300</td>
<td>0.7 (houseflies)</td>
<td>357</td>
</tr>
<tr>
<td>Malathion</td>
<td>1400-1900</td>
<td>18 (houseflies)</td>
<td>917</td>
</tr>
<tr>
<td>Bioresmethrin</td>
<td>8600</td>
<td>0.2 (houseflies)</td>
<td>43,000</td>
</tr>
</tbody>
</table>

While the selectivity of some extensively used compounds makes it necessary to take special care in handling and application, other compounds such as bioresmethrin are outstandingly safe. The approach to the discovery of pyrethroids of this type is based on extensive knowledge of the molecular features determining their toxic properties (Elliott, Janes and Potter, 1978). Most other cases of favourable selectivity have been obtained by chance. However, toxicological properties are the outcome of three interacting processes: transport to the site of action, metabolism of the applied molecule during passage to the site and ability to disrupt the vital function at that site. Much is already known about the underlying physiology and biochemistry and in principle there is no reason why sufficient understanding of the three processes in different organisms should not be acquired to make possible the deliberate design of selective chemicals (Graham-Bryce, 1975b). The resources required would be considerable, but there would seem to be reasonable prospects of success if the effort required was considered justifiable.

An even more fundamental basis for selective action is attack on biochemical or physiological processes present in the target class of organism but absent in non-target. With insect/mammal selectivity, metamorphosis provides obvious opportunities and has received much
attention leading to new classes of juvenile hormone and insect growth regulator insecticides (Menn and Henrick, 1981). More generally the problems of resistance and selectivity have played a large part in stimulating interest in alternative chemical agents such as those controlling insect behaviour. The use of pheremones as attractants in traps for monitoring pest populations so that pesticide applications may be timed more precisely in relation to the incidence of damaging levels is now well established; attempts to employ them for controlling pests by mass trapping or disruption of normal behaviour have proved less immediately successful but it seems certain that this technique will find an assured place within the armoury of control measures (Baker and Longhurst, 1981).

Compatibility with other control measures. Experience of the practical use of modern pesticides and the awareness of their potential limitations such as resistance and inadequate selectivity has led to widespread recognition of several general principles: the need to consider any control agent in relation to the life history and population dynamics of the damaging organism; the need to treat noxious organisms not as individuals but as members of populations; the need to recognize that the objective of crop protection is to protect crops and not to kill damaging organisms. Such principles are incorporated within the now universally accepted concept of integrated pest, disease or weed management which combines all ecologically acceptable methods in an attempt to give durable, effective and safe crop protection. A further important concept is implicit in the integrated approaches; the need to regard chemical control as just one of the checks which can be imposed on the development of a damaging infestation. It follows that chemical agents, conventional or novel, should be fully compatible with other approaches.

Certain of the requirements for this compatibility have already been discussed, for example selectivity between pests and natural enemies is essential to preserve the contribution of biological control. Detailed consideration suggests many other less obvious possibilities; for example it is possible to identify chemicals which enhance natural defence mechanisms in resistant host plants, such as phytoalexin elicitors. Further analysis of the components of partial resistance in host plants can suggest types of action which would best complement the way in which the plant exerts its control over the population. In the case of powdery mildew on apple, for example, such an analysis by Dr. M. Jeger (discussed by Graham-Bryce, 1981) suggested that antisporulant activity could be particularly valuable.

CONTRIBUTION OF AGROCHEMICALS TO INCREASED CROP PRODUCTIVITY

The importance of crop losses due to pests, diseases and weeds needs no emphasis. Quantifying these losses, even for one pest on one crop in a localized region is difficult, requiring careful experimentation and investigation. Nevertheless various very
informative estimates have been made (see review by Gough, 1977). One of the most widely quoted is the formidable survey by Cramer (1967) who estimated that global losses amounted to something like one third of the value of the growing crop distributed between weeds 9%, diseases 12% and insects 14%. In keeping with comments in earlier sections of this paper, losses were greater in tropical developing countries than in temperate developed countries. Table 10 shows some selected examples from Cramer's survey.

Table 10

<table>
<thead>
<tr>
<th>Crop</th>
<th>Potential Production</th>
<th>Actual Production</th>
<th>Loss</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cotton</td>
<td>17</td>
<td>11</td>
<td>6</td>
</tr>
<tr>
<td>Maize</td>
<td>339</td>
<td>218</td>
<td>121</td>
</tr>
<tr>
<td>Rice</td>
<td>439</td>
<td>232</td>
<td>207</td>
</tr>
<tr>
<td>Wheat</td>
<td>351</td>
<td>266</td>
<td>86</td>
</tr>
</tbody>
</table>

While it seems self-evident that pesticides can make a major contribution to improving crop productivity and quality, assessing the extent of this improvement is equally difficult. Under experimental conditions, pesticides can be shown to greatly increase yields, but extrapolating to practical conditions over many sites and seasons is clearly fraught with difficulties. Nevertheless the beneficial effects of agrochemicals will be considered below for two contrasting situations: cereals in the UK, representative of relatively large scale farming under temperate conditions in the developed world, and small scale holdings in the tropics, with particular reference to cotton. These situations will be discussed in the light of the factors discussed in earlier sections of this paper.

Cereals in the UK

Cereals are the most extensively grown arable crops in the UK. They are very vulnerable to seedling diseases and provide one of the most clear cut early examples of the benefits of routine application of pesticides: the introduction of organomercurials in the 1930s resulted in a progressive and substantial reduction in losses due to these diseases and an improvement in seed health (see Gough, 1977). Organomercurials have been routinely applied to cereal seed in the UK for many years. Further improvements were obtained in the early 1950s when the effectiveness of soil applications of lindane against wireworms was established. Subsequently it was found that rates of application could be decreased about 20-fold by applying the insecticide to the seeds. Insecticidal seed treatments against wheat bulb fly also proved very effective; Strickland (1969) estimated that
treatment seed in this way could save the equivalent of 34,000 ha of wheat (then worth about £3.3 million) in years of severe attack.

In the case of weeds, the introduction of the phenoxyalkanoic acid herbicides for controlling broad-leaf weeds in cereals marked the beginning of the modern era of weed control and their application to cereals at the seedling stage rapidly became standard practice. In early experiments in the 1940s Blackman and Roberts (1950) demonstrated yield increases of over 20% in cereal crops following the use of the new synthetic materials. By the late 1960s, however, following widespread use the situation had changed markedly. Analysis of many trials by Evans (1969) suggested that application of these herbicides gave no overall benefit and he concluded that there would be little disadvantage if these treatments for broad-leaf weeds were applied less routinely. Table 11 from Gough (1977) is based on Evans's (1969) survey.

Table 11

<table>
<thead>
<tr>
<th>No. of sites</th>
<th>Yield (cwt grain acre(^{-1}))</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Unsprayed</td>
</tr>
<tr>
<td>Spring barley</td>
<td>187</td>
</tr>
<tr>
<td>Winter wheat</td>
<td>75</td>
</tr>
</tbody>
</table>

Nevertheless farmers are likely to require much persuading to withdraw a proven treatment; the attractions of applying an insurance treatment for what is in practice a relatively low payment are likely to outweigh the potential modest cost saving.

It should be noted that grass weeds and wild oats remain a serious problem fully justifying the application of herbicides. Gough (1977) quotes yield increases in the range 14-44% from controlling wild oats in cereals in the UK and total cash benefits from herbicide treatments against wild oats and blackgrass of over £27 million.

Cereals were, however, traditionally regarded as relatively low-value crops which could not justify expensive crop protection treatments in contrast to, for example, fruit. In the mid 1970s, however, farmers' attitudes to the control of pests and diseases altered dramatically principally as a result of two factors: changes in the economics of grain production and the advent of several very effective new pesticides, notably systemic fungicides for controlling foliar diseases (Graham-Bryce, Hollomon and Lewis, 1979). With greatly increased prices it became possible, using high yielding varieties to achieve net profits of up to £250 ha\(^{-1}\) for winter wheat and £175 ha\(^{-1}\) for spring barley (1978 prices). This provided a considerable
incentive to increase yields which, in the absence of additional land, could only be achieved by better management or increased inputs such as seeds, fertilizers, and machinery. With the resulting high input costs, farmers seemed anxious not to risk even small crop losses and were increasingly prepared to use the new insecticides and fungicides available to control pests and diseases. Furthermore the five year period over which input costs rose so rapidly included three years of particularly heavy aphid attack (1975, 76 and 77).

These various factors have had considerable effects on pesticide use. In 1974 1.4 million ha of winter wheat were grown in England and Wales. Nearly all the seed was treated with organomercurials to control soil- and seed-borne diseases as discussed above. Only 1% of these crops were subsequently sprayed to combat stem and leaf diseases. Approximately 20,000 ha were treated against wheat bulb fly and 3,000 ha for wireworms. A further 31,000 ha were sprayed against aphids. By contrast, in 1977, the area of winter wheat had declined to 1.02m ha. Seed was still treated with organomercurials but in addition the proportion of crops sprayed with fungicides had increased to 15% and approximately half the crop (490,000 ha) was sprayed with aphicide, mainly with the selective aphicide pirimicarb, although broader spectrum insecticides, demeton-S-methyl and dimethoate were also used. In 1976 aphid infestations were particularly severe and even more aphicide was used; in 1978 and 1979, however, there was little need for aphid control. Carbendazim, often mixed with dithiocarbamate, to control Septoria and tridemorph, to control mildew, were initially the most frequently used fungicides on wheat. However, a wider choice of mildewicides, the introduction of benodanil and oxy-carbacin to control rust, and the development of the broad spectrum fungicide triadimefon, have contributed to the more extensive use of fungicides.

Although most barley (1.94m ha) is sown with seed treated with BHC and organomercurials, additional insecticide use is limited to some 1% of the crop which receives aphicide. Fungicide use, however, has increased substantially since 1970 (Table 12) when 3% of crops were treated with the mildewicides ethirimol or tridemorph.

Table 12

<table>
<thead>
<tr>
<th>Year</th>
<th>% Crops treated</th>
<th>% Crops treated with Ethirimol</th>
<th>% Crops treated with foliar sprays</th>
</tr>
</thead>
<tbody>
<tr>
<td>1970</td>
<td>3</td>
<td>10</td>
<td>7</td>
</tr>
<tr>
<td>1972</td>
<td>17</td>
<td>14</td>
<td>11</td>
</tr>
<tr>
<td>1973</td>
<td>25</td>
<td>26</td>
<td>21</td>
</tr>
<tr>
<td>1974</td>
<td>46</td>
<td>25</td>
<td>16</td>
</tr>
<tr>
<td>1975</td>
<td>41</td>
<td>16</td>
<td>26</td>
</tr>
<tr>
<td>1976</td>
<td>42</td>
<td>15</td>
<td>19</td>
</tr>
<tr>
<td>1977</td>
<td>34</td>
<td>16</td>
<td>34</td>
</tr>
<tr>
<td>1978</td>
<td>50</td>
<td>16</td>
<td></td>
</tr>
</tbody>
</table>
As more mildew fungicides became available, use increased and half the crops are now treated. Greater emphasis on winter barley has led to some increase in other stem and foliar diseases, notably eyespot and has given impetus to the increasingly widespread use of triadimefon which has a wider spectrum of disease control.

The less widely grown and lower value cereals, oats (0.14m ha), rye (0.01m ha) and maize (0.03m ha) receive far less insecticide or fungicide; cereal cyst eelworm (*Heterodera avenae*) can cause serious losses locally in oats but soil nematicides are too expensive to apply to this crop on a field scale.

It is of interest to examine the yield benefits resulting from the increase in pesticide use outlined above.

Estimates of direct losses caused by the main species of cereal aphid (*Sitobion avenae* infesting the ears of winter wheat and *Metopolophium didhodum* attacking the flag and upper leaves) range from 6-13% depending on when treatment is applied. Indirect losses due to barley yellow dwarf virus (BYDV) which is transmitted mainly by *Rhopalosiphum padi* probably account nationally for a further 5-10%, though individual fields, especially in the south and west, may suffer much greater damage.

At present, other pests, including wireworm, wheat bulb fly, blossom and saddle gall midge, thrips and slugs together cause additional minor losses on a national scale, though any one of these pests may be serious locally.

Table 13 gives the estimated annual average losses caused by the more important diseases of wheat and barley for 1972 and 1977.

Clearly losses vary considerably from year to year; weather is an obvious factor in this but the varieties grown and the region of the country are also important and, locally, losses may be more severe. Yield reductions exceeding 15% may occur where conditions favour mildew development and losses in wheat frequently exceed 10%. Brown rust of barley is more common in the southern half of the country than in the north and significant yellow rust epidemics seldom occur in wheat growing outside the extensive cereal growing areas of East Anglia and the East Midlands. Leaf blotch of barley, glume blotch and leaf spot on wheat are all more important in the wetter areas of SW England and Wales.

Thus, with the total cereal crop valued at about £1,000m annually, it is likely that pests and diseases together cause at least £50-£100m worth of pre-harvest damage. Additional losses during storage, including a deterioration in malting quality, may result from damage sustained in the field.
### Table 13

Estimated annual average losses in 1972 and 1977 caused by the more important diseases of wheat and barley

(From: Graham-Bryce, Hollomon and Lewis, 1979)

<table>
<thead>
<tr>
<th></th>
<th>1972</th>
<th></th>
<th>1977</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Loss/ha</td>
<td>Loss Value @ £50/tonne</td>
<td>Cost of Spraying/ha</td>
<td>Loss/ha</td>
</tr>
<tr>
<td></td>
<td>% crop</td>
<td>Approx. av. yield</td>
<td>5.0 tonne/ha</td>
<td>% crop</td>
</tr>
<tr>
<td><strong>WHEAT</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mildew</td>
<td>2.4</td>
<td>5.90</td>
<td>£4.50</td>
<td>1.4</td>
</tr>
<tr>
<td>Septoria</td>
<td>7.4</td>
<td>18.30</td>
<td>-</td>
<td>0.1</td>
</tr>
<tr>
<td>Yellow rust</td>
<td>1.2</td>
<td>3.00</td>
<td>-</td>
<td>negl.</td>
</tr>
<tr>
<td>Eyespot</td>
<td>-</td>
<td>-</td>
<td>£19.80</td>
<td>0.8</td>
</tr>
<tr>
<td><strong>BARLEY</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mildew</td>
<td>8.5</td>
<td>5.00</td>
<td>£4.50</td>
<td>3.6</td>
</tr>
<tr>
<td>Leaf blotch</td>
<td>1.4</td>
<td>1.60</td>
<td>to</td>
<td>0.3</td>
</tr>
<tr>
<td>Brown rust</td>
<td>1.1</td>
<td>1.20</td>
<td>£19.80</td>
<td>0.4</td>
</tr>
</tbody>
</table>
While pesticide application has given clear benefits, these must always be weighed against possible adverse side effects, such as the dangers of resistance and of damage to beneficial insects.

**Small-scale holdings in the tropics**

It has already been stressed that losses in tropical agriculture due to pests, diseases and weeds can be severe; in particular pest problems are usually far worse and infestations develop more rapidly in warmer climates. Also, although there has been less incentive to use herbicides for labour saving than in developed countries, the multiple cropping and intercropping systems frequently adopted in small scale holdings are very labour intensive, and the costs of hired labour are rising. Interest in the use of herbicides is therefore likely to increase. The need for pesticides to improve crop yields is manifest, but as Table 2 implies, relatively few third-world farmers use them. This cannot be generally attributed to a lack of awareness of their advantages; for example, a survey by Croxford (1980) indicated that small-scale farmers in Guyana were quite willing to adopt modern techniques when the benefits could be seen. There are however several other factors relating to availability of materials and economics which limit the adoption of modern chemical methods.

An obvious difficulty is that subsistence farmers rarely have the capital to purchase traditional spraying equipment or relatively expensive chemicals produced in Europe, Japan and N. America (see Table 2). Where credit is available, it is usually restricted to cash crops.

A technical problem which has a major importance that might not be obvious at first sight is the availability of water for spraying. As has been pointed out above, traditional methods of spray application require substantial volumes of water; an appropriate supply may not be available or may be at a distant borehole or stream necessitating tedious and time-consuming transport to the field. There is an inevitable tendency to neglect spray schedules or to apply at lower volume rates than required for effective control. Furthermore, most small manual hydraulic sprayers are very cumbersome and tiring to operate. They require regular maintenance, but spare parts may be impossible to obtain. It can well be argued that it is the problems of application as much as factors associated with the products themselves which have limited pesticide use in developing countries. In this connection the advances in CDA, ULV and electrostatic spraying described above are potentially of immense significance and promise to improve greatly the practicality of pesticide application in third-world agriculture. Good control of cotton pests has been obtained with volume rates as low as 0.51 ha\(^{-1}\) using electrodynamic methods. (Matthews, 1981).

With such low volumes there is the further potential advantage that the manufacturer can provide the pesticide formulation
ready-to-use in a sealed package. This is the philosophy of the bozzle concept (Coffee, 1981), an extension of the electrodynamic system in which the plastic nozzle and the pesticide container are provided in an integrated unit. Such a unit offers benefits both in terms of safety and through the assurance that the preparation of the sprayed formulation and its dispensing are entirely in the hands of the manufacturer; this prevents any possibility of errors or individual adjustments by the operator and should therefore ensure a more reliable performance.

There are, of course, other factors which make pesticide treatment under tropical conditions difficult. For example, the potential rapid attenuation of spray deposits by intensive weathering from sunlight, high temperatures and tropical rainstorms can place far greater demands on persistence and effectiveness than under temperate conditions. Such considerations underline the impressive success of modern pesticides, applied at low rates. There is predictably less quantitative information to document this success under tropical conditions than in temperate agriculture in developed countries. Probably the fullest information relating to small-scale enterprises concerns cotton.

Insect attack is frequently the main factor limiting yield and more than one quarter of the global use of insecticides is on cotton. It was also on cotton in a developing country (Peru) that some of the most severe problems of unwise multiple use of pesticides, particularly resistance, first became apparent.

The beneficial effects of pesticide application under tropical conditions in Malawi have been carefully investigated and fully described by Gower and Matthews (1971). A comprehensive pest control programme was assembled under the general direction of an Extension Officer, with assistants given responsibility for particular areas. This responsibility covered all aspects of cotton production, including education of local farmers who were trained to spray their own cotton when monitoring indicated this to be necessary. Quantities of chemicals used and costs were recorded for about 2,000 farms. The records demonstrated very substantial benefits from spraying, illustrated by the results in Table 14.

Table 14
Effects of pesticide treatment on cotton yields in South Malawi (from Gower and Matthews, 1971)

<table>
<thead>
<tr>
<th>Year</th>
<th>Unsprayed</th>
<th>Sprayed</th>
</tr>
</thead>
<tbody>
<tr>
<td>1965</td>
<td>484</td>
<td>1111</td>
</tr>
<tr>
<td>1966</td>
<td>215</td>
<td>925</td>
</tr>
<tr>
<td>1967</td>
<td>142</td>
<td>1117</td>
</tr>
<tr>
<td>1968</td>
<td>142</td>
<td>1092</td>
</tr>
<tr>
<td>1969</td>
<td>289</td>
<td>1090</td>
</tr>
</tbody>
</table>
The adoption of pesticide spraying greatly stimulated cotton production in East Africa; the increased yields re-established the crop in areas where attack by pests had rendered it unprofitable. Gower and Matthews found that both yields and profit margins increased progressively with increasing numbers of sprays over the range which they studied (Table 15).

### Table 15

Relationships between yields, profit margins and numbers of sprays for cotton in Malawi.

(from Gower and Matthews, 1971)

<table>
<thead>
<tr>
<th>Number of sprays</th>
<th>Yield (kg ha(^{-1}))</th>
<th>Margin (£/ha)</th>
<th>No. of farms</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-7</td>
<td>742</td>
<td>29.8</td>
<td>783</td>
</tr>
<tr>
<td>8-10</td>
<td>1078</td>
<td>45.2</td>
<td>997</td>
</tr>
<tr>
<td>11-12</td>
<td>1293</td>
<td>53.4</td>
<td>497</td>
</tr>
<tr>
<td>13</td>
<td>1368</td>
<td>61.2</td>
<td>128</td>
</tr>
</tbody>
</table>

The benefits of insect control have been particularly emphasized in this example and in considering crop protection in tropical developing countries generally. Disease control is clearly also most important, but there are few quantitative studies of benefits in small-scale farming systems. Nor should the potential advantages of weed control be overlooked, despite their relative limited use on small farms at present. The results in Table 16, obtained by Wijewardene (1978) show that the use of herbicides can give very substantial reductions in the labour required for weed control compared with mechanical methods; when added to the improvements in efficiency from application of insecticides by rotary atomizer rather than conventional hydraulic sprayer the overall benefit is dramatic.

### Table 16

Manpower requirements for conventional field preparation, manual weeding, and knapsack spraying compared with zero tillage (herbicide spraying) and insecticide application by rotary atomizer for maize and cow-peas under savannah conditions.

(from Matthews, 1981 after Wijewardene, 1978)

<table>
<thead>
<tr>
<th></th>
<th>zero tillage</th>
<th>conventional</th>
</tr>
</thead>
<tbody>
<tr>
<td>Field preparation</td>
<td>Herbicide spray 4</td>
<td>Slash and burn 180</td>
</tr>
<tr>
<td>Weed control</td>
<td>Herbicide spray 4</td>
<td>Hand hoeing 280</td>
</tr>
<tr>
<td>Insecticide application</td>
<td>Rotary atomizer 2</td>
<td>Knapsack 20</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>10</strong></td>
<td><strong>470</strong></td>
</tr>
</tbody>
</table>
Other examples of the benefits of herbicide application in small-scale farming come from rice growing in Peru. Ennis (1967) reported that yields of rice were increased by 34% (transplanted crop) and 68% (direct-seeded crop) through application of the herbicide propanil. The same herbicide increased yields in the Philippines by 43%.

These selected examples demonstrate clearly that pesticide treatment can greatly increase productivity and profitability in small-scale farming. While careful appraisal of benefits and risks should be undertaken in each case, there is therefore every incentive for expanding the use of pesticides and for overcoming the logistic, administrative and application problems inhibiting their wider adoption.

**EDUCATION AND EXTENSION**

Modern agricultural methods are technologically demanding, and the benefits of new materials and techniques can be fully realized only if appropriate steps are taken to make potential users fully aware of their advantages and how to employ them. The need for this dissemination of information is nowhere greater than in the case of crop protection methods which are becoming increasingly complex. The need for improved education in crop protection has often been emphasized in relation to increasing production in developing countries. Thus Ennis (1970) estimated that approximately 1500 additional crop protection extension specialists in multidisciplinary teams would be needed if pesticide programmes were to be expanded by 50% in Asia, Africa and Latin America. However the need is by no means confined to developing countries. Powdery mildew is the most important cause of yield loss on barley, the most widely grown arable crop in the UK. However, when agrochemical companies introduced systemic fungicides for controlling mildew they found that many farmers were unaware of the importance of mildew and had not observed how extensively it affected their crops. It was necessary to educate them about the nature of the disease and the benefits of controlling it before they could appreciate the value of the product being offered!

The need for an informed farming community is made greater by the trend towards more considered application of pesticides in order to safeguard long-term effectiveness and minimize harmful side effects. An essential component of the resulting supervised and integrated control approaches is the concept of decision making based on monitoring and forecasting of infestations. In many cases such forecasting can be done only shortly before treatment is needed. To be effective such warnings must be effectively disseminated to farmers, who must have the knowledge and the will to interpret and act on them properly. The inescapable requirements for education and extension in this context will be obvious.

In practice these requirements are met by extension and advisory services in the public sector and by representatives from
agrochemical companies; the mutual advantages of complementary activity by the two groups are increasingly recognized, especially in a period of financial stringency. While there are obvious benefits from personal contact between adviser and farmer, warning schemes generally must depend on centrally disseminated information. In developed countries the need for speed and flexibility has led to increased use of modern communication techniques: radio, telephone answering services, telex and teledata systems.

As decision-making approaches become more specific and sophisticated, however, there is a greater need for farmer participation and on-farm decisions. Advances in automatic sensing of meteorological conditions and micro-computer analysis of the data obtained may have a large impact in this connection. Several agrochemical companies are involved in the development of on-farm decision-making systems; examples include the risk model introduced by Bayer which indicates the appropriate course of action on the basis of answers to a series of questions and the 'Wheatrace' system developed by ICI.

A note of warning should, however, be sounded. Lewis (1981) in reviewing monitoring to aid pesticide use commented that farmers respond to the welter of advice which may be available in various ways. Some do not seek up-to-date information on pests at all, others spray routinely and yet others accept advice but do not act on it. Such comment prompted Steele (1981) to question whether there was a danger of developing over-elaborate schemes which most farmers would be unable or unwilling to exploit and of pursuing a pesticide mystique without reference to practical realities of the farmers' ability.

There is a complementary need for specialist knowledge among suppliers of pesticides; this has led to increased interest in licensing schemes for suppliers and practitioners such as the British Agrochemical Supply Industry Scheme (BASIS).

RELATIONSHIPS BETWEEN PUBLIC SECTOR AND INDUSTRY

Reference was made to the complementary roles of industry and public organizations in education and advice in the last section. More generally, the impressive progress in chemical methods of crop protection has depended heavily on productive interplay between the two sectors across the whole range of activities involved in discovery, development and implementation. Thus industry looks to public sector and academic research to establish the underlying principles on which new advances can be based and while there may be differences of opinion about specific regulations, industry depends on registration authorities to act as a public watchdog. In certain cases, public sector research has opened up major new classes of pesticide which have been subsequently exploited by industry. A notable example is the synthetic pyrethroid group developed by Elliott and co-workers at Rothamsted Experimental Station (Elliott, Janes and Potter, 1978).
However, there are several trends which suggest collaboration may have to be even closer in the future. The arguments presented in this paper indicate increasing financial pressures on the agrochemical industry which are likely to increase their concentration on major markets at the expense of minor uses. It has also been suggested that there is substantial scope for developing more sophisticated materials (selective pesticides, behaviour controlling chemicals etc) and methods of deployment (resistance strategies, supervised control etc). Many of these advances, however desirable and feasible, would be uneconomic for industry to develop, particularly in the light of the escalating costs of registration. Yet it would seem vital to ensure that the resources, expertise and organization of industry are productively harnessed in pursuing these goals if they are to be attained. One way of achieving this would be for industry to modify traditional policies of marketing pesticides for application on the localized scale of individual fields towards the provision of a complete crop protection service, evolved in collaboration with the public sector. This package approach has been vigorously pursued by Ciba-Geigy with major projects in Indonesia and the Sudan (Bernet, 1981). These initiatives have achieved much, although they have also revealed technical, organizational and political difficulties. Whatever the future of such a package approach, it is unrealistic to advocate courses of action considered to be for the public good without considering how to pay for them.

While, therefore, the potential for technical improvements in chemical approaches to crop protection is still very considerable, it is likely that policy and economic considerations will determine how far this potential is realized, as much as scientific factors.
SUMMARY

During the period since the second world war, crop protection has been transformed by the introduction of a wide range of versatile and potent compounds. Proceeds of the agrochemical industry expanded 6-fold between 1947 and 1977 to $7.7 \times 10^9, with herbicides now the most important category of agrochemical. Usage is dominated by USA and W. Europe, with less than 20% of consumption in developing countries. Development costs now approach $20M per marketable product (much attributable to meeting regulatory requirements) with break-even periods exceeding 10 years. As a result the agrochemical industry is now dominated by large chemical manufacturers who concentrate on major markets at the expense of minor crops and uses. Procedures for the discovery and introduction of new products are reviewed.

The advantages and limitations of chemical approaches and the scope for improvement are discussed in the light of the experience gained with modern synthetic pesticides. The key requirements of chemical agents are efficacy and selectivity. Recently discovered conventional pesticides are outstandingly active and can be applied at rates of 10 g ha\(^{-1}\) or less. Even more potent compounds may be discovered. There remain, however, several important classes of damaging organism (e.g. viruses, bacteria, nematodes, soil-borne pathogens) for which there are no satisfactory treatments; the reasons for this are considered.

The transience of chemical treatments due to the emergence of resistance is a serious concern; strategies for delaying or preventing resistance are discussed. A further deficiency of current chemical treatments is that the active ingredients are used very inefficiently. Typically well under 1% of the applied dose reaches the intended target. Methods of improving utilization are reviewed; in particular the development of controlled droplet application (CDA) and electrostatic spraying hold great promise. Requirements for selectivity between target and non-target organisms and for compatibility with other methods of control are considered.

The contributions of agrochemicals to increased crop productivity are evaluated with particular reference to two contrasting systems: cereals in the UK and small-scale holdings in the tropics with especial reference to cotton. The economics of cereal growing in the UK in recent years have encouraged more elaborate crop protection programmes and the resulting costs and benefits are discussed. Inevitably crop protection in developing countries is generally less elaborate; there is clear evidence that the potential benefits are very substantial but attaining these will depend on logistic and organizational factors as much as on the effectiveness of the chemical agents. More generally it will be necessary to tackle important policy questions if the full scientific and agricultural potential of chemical approaches is to be realized. Various relevant organizational and educational issues are cited and discussed.
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Figure 1. World proceeds from agrochemicals (1977 prices at end-user level) Data from Yeo (1979)
Figure 2. Application rates for representative crop protection chemicals plotted against the date of their introduction to illustrate the progressive increase in activity since the beginning of this century. Rates indicated are representative values from the range employed in commercial practice for each compound. (from Graham-Bryce, 1981)
CHAIRMAN'S COMMENTS
by
J.K. Coulter*

The Chairman thanked Dr. Graham-Bryce for his excellent talk on a subject that covered a very wide field. He recommended the paper to his colleagues in the Bank as an excellent review of the state-of-the-art. He said that the paper appeared to him to provide a very balanced discussion of a subject which was often debated with emotional overtones.

In his presentation Dr. Graham-Bryce emphasized the current trends towards linking crop protection measures with other aspects of crop production in integrated crop production systems. He drew attention to the increasing potency of pesticide materials over the last four decades. He pointed out that most pesticide sales are in developed countries with the developing countries consuming only about one fifth of the total production. The high costs of and substantial time period required for research and development of a new material, resulted in pesticides being very largely produced for major market outlets at the expense of minor uses, many of which were in LDCs. He went on to discuss problem areas affecting the present efficiency of pesticides, notably build up of resistance and inefficient application methods and formulations and discussed briefly some ways in which these limitations may be overcome in the future. On the topic of improving application efficiency mention was made of the low volume controlled droplet application equipment and of systems which produce electrically charged spray drops. Reference was made to the data in the paper on estimated global losses from plant pests, diseases and weeds in order to demonstrate the potential value of control procedures. The speaker closed his presentation with a brief discussion of why small farmers in LDCs presently make little use of pest control techniques in spite of demonstrated benefits from their use. In order to promote increased usage he stressed the need for both public and private sectors to play a part.

The Chairman drew attention to some points which appeared to link the paper to those of the previous speakers Dr. Borlaug and Dr. Krishna. Dr. Krishna had emphasized the need for better technology and Dr. Borlaug had drawn attention to the need for inputs of agro-chemicals. He had emphasized the role of fertilizers while Dr. Graham-Bryce had shown the benefits that could be obtained from the proper use of other agro-chemicals. Plant breeding could help deal with some of the pest problems but any kind of improved agriculture would still require inputs of agro-chemicals. The paper and particularly some of the tables raised interesting questions about the role of these substances in the developing countries. Thus there appeared to be very little use on the "poor man" crops such as cassava and

* Agriculture Research Adviser, AGR
millet. The cost of development of the order of $20 M made it highly unlikely that specific substances could be developed for the smaller markets. Another aspect of concern was the fact that soil borne pests, particularly nematodes, were likely to become more important as tropical agriculture intensified and these appeared to be the most difficult to deal with in developed agriculture. Nevertheless there were some very interesting developments which were of great interest which seemed capable of delivering much smaller qualities of active chemicals much more efficiently.
Rapporteur's Comments
by
J. C. Collins*

The Chairman opened the meeting for questions and a participant from OED inquired when it was expected that applicators such as the electrodyn might become available to farmers in developing countries. In reply, the Speaker said that, in his view, the past emphasis on developing more active pest control chemicals will begin to change and that in the future increasing emphasis will be placed on better application technology and on properties other than intrinsic activity. However, it must be realized that introduction of Ultra Low Volume spraying techniques with a much more efficient usage of chemical could significantly affect the future sales of an agricultural chemical company and that such companies were naturally cautious about policies for introducing such equipment until the probable effects on future markets and sales are fully evaluated. Recently released results of trials in South America with the electrodyn were favorable and it seemed likely that ICI would have hand held applicators ready to introduce in Latin America shortly.

A participant from Latin America Region questioned why greater use was not made of pesticides in developing countries stating that in his view price was an important factor. Agricultural subsidies in developed countries permitted higher profit margins for the farmer thereby making increased use of inputs for higher production more attractive. Import duties and lack of competition could tend to raise prices of pesticides and equipment in developing countries to levels higher than in developed countries. He questioned whether one could lower the regulatory requirements for pesticides in LDCs to make these markets more attractive. Dr. Graham-Bryce agreed that promoting pesticide use in LDCs was a problem and that it was difficult to find solutions. If we believed that regulations were right in developed countries one could hardly consider relaxing them in LDCs. In any case, because of public concerns about the environment, it was unlikely that any substantial reduction in pesticide controls would materialize in the future. In his view some form of enlightened subsidy from public funds may be necessary to achieve the desired increase in pesticide usage and to promote improvements which are uneconomic for industry. The introduction of such subsidies, possibly in the form of aid, might provide a means of developing products for minor uses in LDCs but would require political acceptance in both developed and developing countries.

A questioner from South Asia Region suggested that the move away from single crops and towards traditional mixed cropping systems for small farmers in developing countries would exacerbate the problem of increasing use of pesticides because commercial developers of new pesticides would not find this a particularly interesting field. He asked how one might promote research to develop materials particularly

* Irrigated Field Crops Adviser, AGR
suitable for such LDC situations. Dr. Graham-Bryce replied that one should not expect agricultural chemical companies to be philanthropists and should not be too critical of their emphasis on developed country markets in their R&D operations. Regulatory requirements and the need to recover development costs within patent life create pressures on these companies and one needs to find a way to support research and development for desirable though uneconomic objectives through use of public funds. As environmental and toxicological testing now represent a major R&D cost for new materials, it might be possible for public funds to be made available to support environmental and residue studies where a material was particularly suitable for LDC usage.

A participant from West Africa Region asked whether there were any new developments in the field of improved application techniques which would be suitable for tropical tree crops. Dr. Graham-Bryce said that tree crops presented a particular problem in situations where large tractor drawn equipment could not be used. In general, it was necessary to use air assistance to achieve good penetration of the spray. Electrostatic systems being developed were unlikely to be adapted for tree crops use for sometime. A promising line of future development in the longer term, however, was systemic compounds having potential for upward movement from the soil through the root or downward movement following an application to the foliage. Much current research was aimed at development of downward moving materials.

A speaker from Latin America Region inquired whether problems of improper use of pesticides materials in Latin America should be blamed on the manufacturers who in his view were generally scrupulous or on their agents who were less so. He said that while one could get laws regulating pesticide usage promulgated it was then unlikely that anything further would happen. He asked how Bank staff should respond in these situations. Dr. Graham-Bryce said that there was obviously a great need for training of both users and suppliers in developing countries which might be encouraged by the Bank and there seemed often to be advantages to be derived from some sort of licensing of suppliers within a country.

Another guest speaker at the symposium, Dr. Borlaug, asked how the present attitude of the general public in Europe to world environmental issues compared with attitudes 10 years ago. Dr. Graham-Bryce said, he thought they had not changed much but that perhaps it would be unwise to expect balanced reactions from the public on emotive issues about which they were often not in a position to be well informed.

Participants in the follow-up session raised various questions to which Dr. Graham-Bryce replied as follows:

(a) There were obviously inherent difficulties in adapting developed country technology to LDC small-scale farming situations because of the differences in production systems;
this could apply for some perennial crops. This limitation should be recognized in trying to extend such developed country technologies. He felt that the cost relationships in LDCs were a further factor. Price incentives were necessary to increase pesticide usage in any situation. Nevertheless there must be locally suitable technology as well. He did not think that farmer attitudes were a particular limiting factor to pesticide introduction.

(b) In reply to a question on the efficacy of furadan he said that this material had a nematicidal effect and was also efficacious against soil pests. Some systemic activity was reported. The material does have significant and useful activity in spite of the experience cited by a questioner. To supplement sales information provided by manufacturers, it might be necessary to conduct trials for the particular local conditions concerned. On the performance of the electrodyn equipment he said that there were likely to be requirements for developing suitable formulations; the equipment itself had been demonstrated to give a good deposition of very uniform droplets.

(c) Replying to a question whether there was any scope for local manufacture of pesticide materials, Dr. Graham-Bryce said that certain materials such as the synthetic Pyrethroids needed highly sophisticated chemical technology for their production but that other products requiring only simple manufacturing techniques could be produced in localized small-scale plant. A question was asked as to whether advanced technology pesticides such as the synthetic Pyrethroids were necessary in LDCs to which Dr. Graham-Bryce replied that in many cases new materials offered clear benefits; where for example, the choice lay between using the pyrethroids and the alternative organochlorine insecticides there seemed to be every reason to go for the pyrethroids in view of the recognized disadvantages of the organochlorine materials.

(d) In looking towards likely future developments in the pesticides field of which account might be taken by Bank agriculturists in developing projects to come into production in the 1990s Dr. Graham-Bryce noted the following:

(1) Significant advances are likely in conventional toxic-acting pesticides such as systemics with enhanced capability for translocation within the plant.

(ii) With disease control materials considerable advantages were likely to be gained through development of chemicals which either prevent the expression of disease symptoms or prevent invasion by the disease
organism rather than materials which kill the pathogen directly.

(iii) While some development will take place in the use of pheromones for control, this is likely to be limited in scale and similarly only modest advances are likely to occur in development of microbial pathogens such as *Bacillus thuringiensis*.

(iv) Another area which seemed to have high potential was the use of growth regulators to modify host plant resistance to disease organisms and pests.

(e) With regard to future plant breeding activities for pest and disease resistance Dr. Graham-Bryce said that it was difficult to breed varieties to incorporate a large number of desirable characteristics at the same time. Thus, it was necessary to establish an order of priority for the desirable features which the plant breeders should attempt to develop. For example, in certain cases pests can be relatively easily controlled with chemicals so that it would be better for the breeders to aim for disease resistance where control of disease by chemical means was comparatively more difficult.

Discussion followed on what might be the Bank's role to encourage development of appropriate pest control materials and techniques for LDCs while recognizing that at present the LDCs get on only the residual of R&D activities aimed primarily at the developed countries. To get solutions to problems in LDCs which would represent relatively minor usage of a technology, the Bank might use its influence to assist potential LDC customers to negotiate with agricultural chemical companies for research to be undertaken in the particular field. Such involvement might however, require the Bank itself to increase its expertise in the pest control field and there seemed to be a consensus that Bank agriculturists were presently very out-of-date in this subject and had little access to pest control expertise when faced with day-to-day problems. It was suggested that CPS Agriculture should make an effort to up-date Bank agricultural staff on pest control developments, develop training opportunities and increase the availability of specialist expertise. The possible need for individual visits to research stations and agrochemical companies was suggested and the importance of funds being available to permit use of expert consultants when the need arises was stressed. It was further suggested that a guideline might be needed on Bank policy on the use and financing of agricultural chemicals, a directory of information sources for use when particular expertise needed to be located to resolve a problem, and also guidance on how one might go about strengthening national pest control programs as part of the Bank's institution building activities in the field of agriculture in general.
SESSION IV

WATER MANAGEMENT IN TRANSITION: LESSONS from CENTRAL THAILAND
INTRODUCTION

This paper will present a case history of conditions in a region where irrigation has been practiced for over 90 years and where great changes have taken place since the first World Bank financed project was begun 30 years ago. The period 1976 to the present has witnessed a transition from a time when water supplies were plentiful to a permanent condition of relative scarcity. This situation and the actions which have been and still are being taken as a result may be of interest in other countries.

THE SETTING

Topography

The Chao Phraya River basin drains an area of some 180,000 km² in central Thailand. The basin is the largest watershed in the country and the Chao Phraya is a river of central importance as the traditional water transportation link from the interior to Bangkok. Three topographic regions are represented in the basin. In the north, and on the eastern and western margins of the basin, are mountainous areas with elevations reaching 2,500 m above sea level. Agriculture, aside from forestry, is confined to narrow valleys in the mountainous region. The central one-third of the basin is a gently rolling plain lying at elevations between 130 m and 20 m above sea level which is subdivided by the Ping, Yom and Nan rivers. These rivers join to form the Chao Phraya River near the southern edge of the central plain. Almost all of the plain is cultivated, and some of the most productive of the traditional rice-growing areas are here. The southern third of the basin forms the delta of the Chao Phraya River. Ground elevations range from 20 m above sea level down to sea level. Distributaries of the Chao Phraya River, the Suphan (Tha Chin), Noi and Lopburi rivers, flow through the delta with a fall of about 7 m over a distance of 180 km to the sea.

Climate

Traditional agriculture in the basin is dominated by the rainfall pattern of the monsoon climate. On the major agricultural areas, the average annual rainfall is from 1,100 to 1,400 mm/yr. Ninety percent of that rainfall

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occurs between May and October. In the Chao Phraya plain, where the average rainfall is about 1,200 mm, as little as 800 mm has fallen in some years, and in others as much as 1,800 mm has been experienced.

Rice is the principle indigenous crop in this basin. Soils are generally suitable for rice cultivation, and the crop is very manageable with the heavy wet season rainfall. Varieties adapted to local growing conditions have evolved with particular specialization in the deeply flooded parts of the delta. Historically, rice was also a crop with an assured market and it was government policy as early as the 1890's to increase production for export.

**Origins of Irrigation Development**

Irrigation was first undertaken to increase production in the wet season. It has been estimated that, on average, reasonably good crops can be obtained by using rainfall alone about 3 years out of 5, and that in the remaining 2 years serious losses occur due to delayed or inadequate rainfall. Historically some lands favorably located with respect to the river received a more or less assured supplementary supply of water through inundation during the river flood. The first irrigation works in the delta area were developed to extend the benefits of inundation flooding from the rivers to larger, more distant areas. This form of development was pursued in halting fashion from 1890 to the early 1950's.

Much of the area which was supplied by these projects was, at the time, very sparsely populated. Development in the first half of this century was therefore accompanied by settlement of much of the delta area. Access to new land in this manner has been a very important feature of Thai society until very recent times.

Direct control of water diversion from the Chao Phraya River was achieved by construction of a barrage at Chainat together with distribution canals to carry the diverted water throughout the area of the upper or northern section of the greater Chao Phraya project. These works were constructed under World Bank loan 36TH. The barrage was built in the period 1952 to 1956 and the canals were completed early in the 1960's. Ongoing projects for adding to the network of distribution canals and providing drainage facilities then followed. These works were the first concrete steps taken to modify the irrigation system to permit the effective use of water for dry season irrigation.
Present Irrigation System

The main elements of the Chao Phraya basin system as it now exists are illustrated in Figure 1. In the 1960's and 1970's, two large storage reservoirs were constructed at Bhumibol dam on the Ping River and at Sirikit dam on the Nan River. The total areas irrigated now amount to 686 000 ha in the northern part of the Chao Phraya delta, and 729 000 ha in the southern part. Land consolidation, a form of intensive development providing land leveling, farm supply and drainage ditches, and rationalization of farm boundaries, is currently being implemented on 90 000 ha of the northern delta. Along the Nan River, the Phitsanulok-1 Project is under construction. This project will serve 110 000 ha, with a complete irrigation and drainage system, including some degree of land leveling. Other small projects and informal irrigation under local initiative along the tributaries of the Chao Phraya River serve an additional 139 000 ha. Thus the gross total area under irrigation in the basin (including that under construction at Phitsanulok) now amounts to some 1 664 000 ha. Of this total area only about 12 percent (the land consolidation areas and the new Phitsanulok project) have been constructed with facilities for complete water control. The degree of water control possible in the older systems varies widely but over much of the area only partial control can be achieved. A large part of the low-lying southern part of the Chao Phraya delta is equipped only with major perimeter canals which serve to both supply and drain land which traditionally grew only long-stemmed "floating" rice. Many of the older canals in the northern part of the delta are equipped to distribute water to areas where the final distribution is by overland flow from field to field. These are not able to provide any degree of control.

Objectives of the Basin Study

World Bank loans were instrumental in implementing most of these works. In addition, loans were concurrently made for related development in the river basin for hydroelectric power, inland water transportation, and water supply projects. About 20 percent of the electricity supply for the country is generated at Bhumibol and Sirikit dams. There was concern that competition for use of the water resources might arise and that there would be a need for trade-offs, especially between the power and irrigation interests, as time went on. Therefore a comprehensive analysis of the use of water in the basin was undertaken in conjunction with the development of the Phitsanulok Project. The objectives of this study were stated in 1976 as
FIG. 1- PROJECT LOCATION MAP
- to collect relevant existing data and establish a data collection program for supplementary data required

- to identify conflicts in dry-season water use currently existing or likely to arise in coming years

- to identify and carry out detailed studies of technical options for resolving water use conflicts

- to develop methodology for resolving particular conflicts in water use and establishing guidelines for overall allocation of water among competing uses

- to formulate guidelines for operating the water systems

- to identify development priorities in power, irrigation, salinity and pollution control and navigation.

The Meklong River basin was included in the study because development in that basin is proceeding along parallel lines to that of the Chao Phraya, and because there is some possibility of exchange of water between these adjacent basins through diversion works.

ANALYSIS OF WATER USE

Overall Water Balance

In general terms, the water balance of the Chao Phraya River basin can be understood as follows.

The average annual rainfall in the basin is approximately 1,300 mm/yr. Part of this amount is immediately available to agriculture, an unknown part replenishes the groundwater supply, and part is returned to the atmosphere by evaporation and plant transpiration. Rainfall is heaviest in the mountainous areas and somewhat less on the plains. Most of the rainfall throughout the basin is confined to the May to October wet season, but there are differences in geographical distribution from season to season and from year to year.

The groundwater resources of the basin have not been proven or exploited on any significant scale except for domestic water supply.

About one-eighth of the total rainfall in the basin flows through the rivers to the sea. This amounts to a total quantity of some 30 300 $10^6$m$^3$/yr, on average. Historically, the estimated total runoff amounts have varied from a minimum of about 15 500 $10^6$m$^3$ to a maximum of about 48 500 $10^6$m$^3$/yr.
FIG. 2 - ANNUAL FLOW AND REGULATING VOLUME PROPORTIONS
Much of the runoff from the basin derives from the foothills, low-lying plains and delta areas where there is little practical opportunity for storage. Flows through the storage reservoirs at Bhumibol and Sirikit dams amount to about 40 percent of the total basin runoff (12 600 $10^6$ m$^3$ on average). Both reservoirs are very large, and effectively provide full control over that part of the basin runoff.

The approximate magnitude of the five principal uses of water in the basin expressed in $10^6$ m$^3$/yr are as follows.

- Irrigation 19,500
- Power generation 11,500
- Navigation 8,360
- Water supply 590
- Salinity control 5,210
- Total 45,160

Compared with

- total estimated basin runoff 30 300 (15 500 to 48 500)
- runoff regulated runoff from reservoirs 12 600.

These various uses are satisfied by the surface runoff of the basin by using the uncontrolled flood flows as much as possible in the wet season, and by combining the uses of water released from the reservoir to achieve multiple purposes. Thus water released from the reservoirs for irrigation, water supply and control of salinity intrusion in the estuary can also generate electric power and maintain the water depths required for navigation at critical points in the river.

Analysis by Simulation

The analysis of water use in the basin made extensive use of a computer simulation model. The model provided four key features.

- It allowed the mechanics of each kind of water use to be taken into account in some detail.

- It took into account the complex and important interaction between different forms of water use in terms of water movement and, in the case of the electric power system, in terms of electrical interconnections between the various power stations.

It permitted the wide range of variability of conditions imposed by the hydrology of rainfall, evapotranspiration, and river flows to be fully represented.
FIG. 3 - SCHEMATIC DIAGRAM OF WATER MOVEMENTS
- It provided a comprehensive and consistent means of testing options for future development of water resource projects and for changes in the style of water management.

The simulation model represented natural flows in the river channels and the operation of the controlled reservoir storage, month by month, for the hydrologic conditions recorded in the 25-yr period 1952 to 1976. Irrigation water requirements were computed for various parts of the basin using the actual rainfall recorded in each month of the simulation period. Irrigation demand calculations were based on the Penman evapotranspiration equation calibrated for conditions in Thailand.

Extensive field measurements were made as part of the overall study. Control structures in the irrigation system were calibrated and flows were monitored in a large number of areas to establish irrigation efficiencies representative of current management practices. The flow monitoring program also provided information on the effectiveness of irrigation return flows in helping to meet downstream irrigation demands and on the best means to represent the effectiveness of the rainfall in meeting proper requirements in the wet season.

**Operating Procedures**

During the conduct of the study, a number of operating principles and priorities which had previously been generally accepted and understood in practice were established more formally. In particular, a joint committee was formed by which officials of the Electricity Generating Authority of Thailand (EGAT) and Royal Irrigation Department (RID) would coordinate their operational activities. The priorities and operating policies incorporated in the simulation model for the study are the same ones which were agreed by the joint committee and which became the official operating policy of the two agencies. In simple terms, the operating policies give

- the Irrigation Department the responsibility of determining what quantities of water must be released to satisfy all downstream needs, including water supply, navigation and salinity requirements in addition to those of irrigation

- the Electricity Authority the responsibility to provide those quantities of water and also the freedom to exceed the stipulated flows to the extent that it is necessary to meet minimum operating needs and to maintain the reliability of the electricity system.
At times when the reservoirs are nearly full and there is some risk that water may need to be spilled, EGAT have full freedom to generate at high capacities and maximize energy benefits. At times when reservoir levels are very low, and there is a risk that the live storage may be depleted, both agencies are obliged to restrict their water demands in a form of rationing.

Irrigation Versus Electricity

The system studies showed that irrigation and electricity generation are by far the largest, and economically the most important, water uses in the basin. Of the two, irrigation has the most direct interest in management of the reservoirs. The studies simulated the operation of the entire electricity generating system, and it was seen that there is now sufficient flexibility in the electricity system to accommodate a wide variety of patterns of release which irrigation might dictate. At the current stage of development, there is little conflict between these two purposes. On the contrary there is a very large degree of common interest in finding operating practices which would lead to the maintenance of large reserves of live storage in the reservoirs to guard against infrequent sequences of low rainfall and low river-flow years which jeopardize the water supply to the irrigation system. This same requirement is the condition which would assure the maximum long-term energy generation from the hydroelectric stations. The most important findings of the system studies, however, related to conclusions about the limitations on increasing growth of water use which are imposed by the supply of the river basin.

Limitations on Water Use

The system studies were first approached by establishing whether the reservoirs could maintain the water supply needed to serve all uses during periods of low rainfall and river flow. It was found that consecutive years with very low rainfall (as in 1958/59 and in 1968/69) were particularly critical. Although such severe conditions occur infrequently, the reservoirs would empty if the full demand were served. Water demands in 1976 had already surpassed the magnitude which could be served under those conditions.

Various methods of reducing demands during critical periods were attempted. The most satisfactory was to reduce the area of the dry season crop planted when there was not an adequate supply of water in storage in the reservoirs at the beginning of the dry season. This method (referred to as the "dry season area reduction" or DSAR approach), gives the wet season crop priority in the use of irrigation.
water. The wet season crop is the principal source of income to most farmers in the basin and less water is needed to ensure a successful crop than in the dry season.

The DSAR approach was very effective in avoiding reservoir emptying, while continuing to allow increased water use in years when average or even "better than worst" hydrologic conditions prevailed. In the long term, very much greater overall agricultural productivity would result than would be possible if a fixed "safe" level of cropping were adopted. It was also seen that, as new irrigation areas such as the Phitsanulok project are developed, worthwhile overall benefits can be achieved, even though there is an offsetting loss through more reductions in dry season cropping throughout the basin in the most unfavorable years.

There is clearly a limit beyond which further development is not worthwhile. For the water use practices which prevailed in 1977, it seems that it would not be worthwhile to increase target second-crop areas beyond approximately 530 000 ha rice equivalent. The corresponding average annual second-crop production would be approximately 430 000 ha.

Opportunities for Improvement

The system studies led to understanding of the impact of many other factors on overall agricultural productivity. Factors examined included

- the effect of the minimum power generation constraints
- the effect of water supply demand
- the effect of salinity control flow requirements
- the effect of navigation requirements
- the effect of the magnitude of irrigation return flows.

The results could be expressed in economic terms through changes in the long-term average DSAR calculated in the simulation runs.

The most important variable considered in the studies was the set of overall irrigation efficiencies which had been adopted to represent current water management practices. The values had been adopted based on measurements of amounts of water used in 1977 and 1978, on review of facilities and practices at individual projects, replies to
FIG. 4 - AVERAGE SECOND CROP PRODUCTION
questionnaires and discussions with the project personnel. Average overall diversion efficiencies* then being obtained in the wet season ranged from a lowest value of 0.08 to a highest of 0.51 with an average of 0.34. The corresponding values in the dry season ranged from 0.17 to 0.70 with a mean of 0.43.

The highest irrigation efficiencies being obtained in 1977 and 1978 were used as a guide in estimating the "best efficiencies" which may be achieved in the future for each project. It was assumed that operating practices and facilities would eventually be improved in order to achieve best efficiencies and fundamental limitations of some were recognized. The averages of the "best" efficiencies estimated were from 0.46 to 0.55 in the wet season with a mean of 0.52, and from 0.48 to 0.70 in dry season with a mean of 0.54.

The two sets of irrigation efficiencies were used to estimate two limiting rates of agricultural water use in studies of future overall water use in the basin. The results are shown in Figure 4 where it can be seen that more effective water use would have a significant effect on the upper limit to average dry season cropping in the basin. If the "best" efficiencies were achieved the limit on the average total area of dry season crop would increase by about 100 000 ha to 530 000 ha.

The system studies also showed the influence which new projects can be expected to have on water use in the basin. New irrigation projects must be expected to compete with present water uses, particularly with respect to dry season cropping. New projects which include storage on the downstream tributaries of the Chao Phraya River would add to the amount of regulated flow available for use in the dry season, and therefore would allow much more effective increases in dry season crop area to take place. New projects with storage situated upstream from either of the existing large dams will not increase the overall basin supply because those quantities of water are already controlled by the large reservoirs. In effect those quantities of water are already in use by existing projects.

*Overall efficiency of water diverted to the project referred to calculated net crop water requirements

Efficiency = \frac{\text{Consumptive Use} - \text{Effective Rainfall}}{\text{Total Water Diverted}}
FIG. 5 - EFFECT OF IRRIGATION AREA ON POWER PRODUCTION
FIG. 6 - TOTAL ECONOMIC BENEFITS
As a result of the analysis of water use carried out in Phase I of the Chao Phraya-Mekong basin study, the importance and potentially high return of improving water management was recognized. Recognizing that improvements to facilities must be a long-term matter, the recommendations emphasized operational improvements as the best way to rapidly obtain some of the potential benefits. Soon afterward, the projections regarding the need to curtail the magnitude of dry season cropping proved to be correct. However, the move from theoretical understanding to practical action on such a large scale has not been a simple matter.

The Advent of Water Shortages

Water stored in the reservoirs reached seriously low levels in late 1977 and during the dry season of 1978. Efforts were made to reduce the size of the 1978 dry season crop and special efforts were made by RID and EGAT to conserve water. The size of the crop in that year actually increased. In 1979 the crop increased again and, with a good supply of water stored in 1978, a record dry season crop of some 530,000 ha was grown. River flows in 1979 were exceptionally low, and officials faced the upcoming 1980 dry season with the smallest reserve of water since construction of the Sirikit reservoir. The seriousness of the situation was recognized, and the government empowered a special task force in the Prime Minister's office to deal with it on a crisis footing. The areas growing a dry season crop were severely restricted (a total of 230,000 ha was eventually grown), and widely publicized load shedding was invoked in the electricity generating system.

The need for DSAR type management of dry season cropping is now widely recognized, and policies are in place to prevent the degree of crisis which was faced in 1980. However, the agencies are just beginning to address means of more methodical means of controlling water use and to explore policies for allocation of the limited water supply.

STEPS TAKEN TO IMPROVE WATER MANAGEMENT

The analyses, together with the experience of the last 4 years, have shown that while there is now only limited scope for continued development of new areas for irrigation, there are opportunities for very significant increases in productivity through improved management of areas already developed. Since 1979, the Chao Phraya basin study has been extended to seek means of achieving better water management in order to relax the limits imposed on productivity by the finite supply of water available.
FIG. 7 - DRY SEASON CROP AREAS IN THE CHAO PHRAYA BASIN
Improvements in water management come down to two fundamental issues

- to manage the overall magnitude of releases from the reservoirs so that the storage is not depleted in drought years
- to make the best possible use of irrigation water which must be drawn from storage in the reservoirs.

Five general areas of activity have been pursued.

- Technical means of planning the dry season crop under a DSAR format have been developed.
- The operating policies and practices affecting both power and irrigation have been established in the form of principles accepted by both RID and EGAT.
- A program of close examination of water use practices and constraints on individual projects has been initiated.
- A water management system for calculating and balancing water needs in all parts of the basin week by week has been implemented to facilitate a more quantitative approach to water allocation and dispatching.
- Various efforts have been made to persuade the agencies to place a high priority on operations.

The development and application of the Water Management System (WMS) merits some description.

Water Management System

The Water Management System was established to compile, display and record data and to provide predictions of water requirements at various irrigation water control points. It is now the principal support facility available to guide the water operations manager in establishing the quantities of water required from the storage reservoirs each week and in allocating water to each of the 65 main regulators.

The irrigation system is represented in the WMS by an assembly of operations units referred to as "blocks". Each block represents a part of an irrigation project having an area of from 8,000 to 15,000 ha which has distinctive water supply or drainage connections to adjacent areas. There are 106 blocks in the system as it is currently operating. Data on crop types, crop areas and stages and field wetness conditions in each block are reported to the water operations center and updated on the system weekly.
Rainfall at approximately 300 stations is reported and loaded in the system daily. Water level and discharge readings from 25 streamgauge stations, and upstream and downstream observations from 89 regulators, are also updated daily.

The WMS is employed on a routine weekly cycle to produce

- data reports summarizing crop conditions, rainfall, flows and water levels

- calculated irrigation water requirements and return flows for each block for the following 2 weeks. The Penman evapotranspiration equation is used with crop coefficients suitable to the stage of each of the crops in the block and irrigation efficiencies adopted for that block in that season. Current wetness conditions and long-term average rainfall appropriate to the weeks in question are used

- calculated water needs at various points in the system allowing for return flows, forecast sideflows from streams and flow constraints for navigation, salinity control, water supply, etc

- any inherent water deficiencies arising from capacity limitations in the irrigation system

- water requirements from the reservoirs.

The WMS is intended to be modified and updated frequently during use. The computer program structure is arranged to allow the number of blocks and the relationships between them and all the various operating restrictions to be modified without the need for new computer programming.

The WMS has been operated on a weekly basis since July 1979 following a period of commissioning in the 1979 dry season. It has proved to be a valuable guide to the Water Operation Center and is being extended to be used in a similar way for the adjoining Meklong River basin.

THE ONGOING DYNAMICS OF WATER USE

With the rapid expansion of dry season cropping and the events of the last 4 years, it is now widely understood that the limits of water supply in the Chao Phraya basin have been reached. Measures have been initiated to limit dry season water use according to the amount available in storage.
and to make the most effective possible use of water released in the wet season. This is just a beginning. What has been described as a period of transition should really be viewed as one phase on an ongoing dynamic evolution of facilities and practice.

The following are some of the issues which will present a continuing challenge.

Control of Dry Season Cropping

Dry season planning has been carried out by RID since 1978. In recent years the total amount of water available for the approaching dry season has been assessed in November and a target total area adopted for cultivation in the irrigated part of the Chao Phraya delta. Allowance is made for water use in upstream areas not under direct RID control. A schedule of releases from the reservoir is planned with EGAT and the target acreages and locations to be served are announced to the public through RID officials and the Governors of the provinces.

Since farmers are free to make their own decisions, in every year, even in 1980 when the total area was drastically cut back, the area cropped significantly exceeded that planned. Once the crops are growing, every effort is made to supply them with water with the result that RID and EGAT officials have an anxious time every year balancing the risk of irrigation shortage against that of excessively low reservoir levels. One consequence is that production is probably maximized. Very high irrigation efficiencies are observed and farmers are poised to take full advantage of any lucky rainfall in March or April. Another is that the orderly DSAR style regulation of the reservoirs is defeated and there is little chance that the reservoirs will have water stored to cope with a sequence of dry years. Because reservoir levels stay low there is also a loss of power benefits.

Much remains to be done to establish a fair and widely accepted system for allocating and controlling dry season water supplies. In recent years, one group of projects has been given first priority to dry season supply. These are located in the deeply flooded areas of the lower west bank of the Chao Phraya River where traditionally only floating rice crops were grown. Large parts of these projects now grow only one crop—in the dry season—and by doing so, obtain far better yields. Very high irrigation efficiencies are achieved because water is pumped on to the land from the drains. However, the water available directly from rain in the wet season is not used and means of restoring some degree of wet season cropping are being examined.
Limiting Wet Season Water Use

The greatest opportunity for minimizing water releases from the reservoirs is to make the fullest use of rainfall and uncontrolled river flows in the wet season. The water management system provides a means of predicting both water requirements and the expected river flows. At the present time, however, most of the irrigation system is poorly equipped to respond to short-term reductions in demand and it has not been the practice in most areas to reduce irrigation supply in direct response to rainfall. Step-by-step improvement of the system and evolution of operating practices will be needed to achieve general improvement in water use in the wet season.

It can be noted that high irrigation efficiencies and effective use of rainfall are only important when irrigation water is being drawn from storage. For part of the wet season, river flows provide an ample supply and the efficiency of irrigation water use is not a concern.

Changes in Cropping Calendars

Crop calendars have changed rapidly in some areas in recognition of restrictions in water supply imposed by system constraints. Farmers are very prompt to take up new practices which appear to convey advantages. In the Phra Ong Chayanochit project in the southeast corner of the delta, a very early dry season crop is now planted in November making use of water left in the fields from the wet season, and farmers commonly sew high yielding rice varieties by broadcasting. By these means their peak water demands do not coincide in time with those in upstream parts of the supply system.

In the deeply flooded areas of the lower west bank, some areas are beginning to grow a very early wet season crop planted in April to avoid the risk of flood damage in October. The crop is begun using dry season techniques but most of its water needs are met by rainfall. This innovation has forced early scheduling of the dry season crop in this area but may provide a way that full double cropping can be achieved over most the the low area.

It is clear that the initiative for productive changes in cropping practices in response to the new water supply conditions will continue to come from the farmers themselves.
Coordination Between Agencies

The principles of coordination between the two principal agencies concerned with operations are well established. These principles give the responsibilities for reservoir operation jointly to RID and EGAT with each agency able to require some departure from routine when it is necessary. As time goes on, EGAT's operating constraints should be eased as more and more flexibility is built into the expanding electricity system and releases from the reservoirs should be able to more closely match the requirements of irrigation and other downstream uses.

The Importance of Operations

The limit on water supply which is now recognized has very important implications for the organization of irrigation activities in the Chao Phraya basin. For nearly seventy years, development of new irrigation facilities has been a primary interest of the government. The importance of planning and construction has therefore been reflected in the organization of RID and in the choice of careers by young personnel. In the future, for the Chao Phraya River basin at least, the improvement and management of systems which have already been constructed will have the most bearing on agricultural productivity. It is therefore most important that appropriate emphasis be given to these activities.

The Development of New Projects

It is now widely understood and accepted that the water of the Chao Phraya River system is one resource and projects are being evaluated by consultants and funding agencies with this in view. Some schemes are penalized because they compete for water already in use. Others are credited with increasing the regulated water supply in the basin through storing flood waters or through diversion from other basins.

The eventual application of these principles will not be straightforward. The DSAR approach does not set a fixed limit on the size of the target dry season water use. Up to a point some marginal benefits can, on average, be achieved by increasing the target demand. The decision for or against certain new projects on economic grounds may turn on some rather fine points. Some projects may be selected because they are closely aligned to regional development or other objectives of the government.
In time, efforts to reduce water use in existing projects may take sufficient effect to enable some new projects to be justified. It is judged that current rates of water use are approximately midway between those expressed by the 'present' and 'best' irrigation efficiencies used in the 1979 study.

CONCLUSIONS

I suggest that the following conclusions drawn from this case history may be of interest in considering water management in other river basins.

1. **The Merits of Analysis by Simulation**

   The full capability of the river system to meet the needs of various water uses could only be assessed by accounting quite completely for the interactions between uses. The use of a quite complete simulation model was extremely valuable in clarifying the interactions and testing alternative methods of operation.

   If simpler methods had been used the capability of the system would have been underestimated.

   The simulation and their involvement with it played a role in bringing about agreement on policies between the two principal operating agencies.

2. **The Importance of Field Data**

   The importance of direct measurements in the field of flows and water levels, and of cropping data directly from the individual projects cannot be overstated. In this study, a group of three flow monitoring crews was continuously employed.

3. **The Value of the Water Management System**

   Computer based storing, retrieval and manipulation of data is proving to be of great value as a guide to operation of this large system even though the methods available for prediction have inevitable shortcomings.

4. **The Importance of Coordination**

   Close technical coordination between the operating agencies is a most important factor in ensuring that the full capability of the system is achieved. The overall best interest of the country rather than the interests of the individual agencies must govern operating policies.
5. The Innovations by the Farmers

In Thailand the farmers have a great deal of freedom in how they use water from the irrigation system. This causes difficulty resulting from a lack of common interest. However, it also results in great flexibility to find and exploit new crop calendars and forms of cultivation and to achieve very high irrigation efficiencies. In Thailand the farmers' initiative is the principal source of innovation.

6. The Dilemma of Water Allocation

Allocation of scarce water supplies for dry season cropping is a most important long-term problem. Within the limits imposed by the physical system, economic, social or even political grounds must be found for distribution of water when it is available. This problem has not yet been fully dealt with in the Chao Phraya basin.
ACKNOWLEDGEMENT

This paper is based on the experience of carrying out the Chao Phraya-Meklong basin study on behalf of the Royal Irrigation Department of the Ministry of Agriculture and Cooperatives of Thailand. The author takes sole responsibility for the opinions expressed but wishes to acknowledge the work of the many participants in the study, especially that by the personnel of RID and EGAT.
In opening the discussions, the Chairman recalled that at the time when the studies described by the Speaker were under discussion in the Bank, there had been a considerable degree of concern about the complexities and difficulties of the studies, which in the light of subsequent events turned out to be unnecessary. There had also been a lot of discussion on the merits of entrusting responsibility for carrying out the studies to an impartial body rather than to one of the main user agencies. As it happened, the Royal Irrigation Department had done an excellent job of supervising execution of the studies, and cooperation between all interested parties had been good and free of jurisdictional conflicts.

The Chairman observed that the Speaker had emphasized that the studies represented a transitional, albeit essential, phase in the water management process. It was interesting to note that the studies had highlighted the second generation problems of water allocation between systems and within systems, the need for mechanisms to set dry season planting limits and the need for maximization of water resources through better operations by improving physical facilities and by better farmer organization.

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Rapporteur's Comments

by

John C. Stemp*

In discussion after the plenary session, the following questions and comments were made: The first speaker, (South Asia Projects) commented that where irrigation water is limited, farmers located in upstream and downstream portions of an irrigation system are unlikely to have equal access to water. He stated that inequity is minimized where good water control exists or where return flows can be utilised and asked Mr. Cowley what had been the experience in the Chao Phya Basin? Mr. Cowley replied that results from their study were limited to only a few years observations from a small number of sample areas. The magnitude of the inequities in distribution of dry season water were not known. However, observations did show that return flows were used very effectively in the dry season and efficiency levels for the basin as a whole were quite high.

A speaker (Central Projects Staff) asked whether the Basin Study had addressed the question of cost recovery. Mr. Cowley replied that their study did not look specifically at cost recovery. In considering the various users of water in the Basin, they had established that demands of some users, e.g. Bangkok water supply, had to be met irrespective of other demands and their work had focussed on non-economic priorities. No real conflict existed between the two major users - Power and Irrigation.

Another speaker (South Asia Projects) asked whether rice had been replaced by other crops during the 1979/80 dry season when a serious water shortage occurred in the Chao Phya Basin. In reply, Mr. Cowley stated that no substitution for rice had been made in 1979/80 but he understood that this was a possibility for the future. However, another speaker (EMENA Projects) commented that the soils in central Thailand had a clay content of 70 - 80%, suffered from poor internal drainage and were not well suited to crops other than rice. Furthermore, rice cultivation resulted in the destruction of soil structure with adverse consequences for alternative crops. The same speaker pointed out that early irrigation developments in the Chao Phya Basin were based on providing supplementary irrigation in the wet season only and had produced good benefits at the time. This should be remembered when criticism was made of the existing system and efficiency levels. He went on to advocate phased development for such large projects as the Chao Phya Basin.

Another speaker (Latin America Projects) described problems of limited dry season water supply in Colombia where no viable substitute for irrigated rice had been found. Where demand exceeded supply, there had been no alternative to shutting off water supplies to part of the irrigable area. Another speaker (Central Projects Staff) asked whether the simulation model used in the Basin Study had taken into account the farmers' behaviour as water users. Mr. Cowley replied that the model should be regarded as an accounting tool and as such did reflect the current practise of farmers throughout the basin. However, individual farmer behaviour is highly variable and not enough is understood about farmers' reactions in changing circumstances to include this specifically in the simulation studies. Another speaker (Central Projects Staff) suggested that dry season water shortages in the Chao Phya Basin could be alleviated by diverting water from the Mekong River by building the proposed Pa Mong Dam. Mr. Cowley said he knew of no plans to proceed with this project in the foreseeable future but mentioned that his firm

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had just completed a prefeasibility study for a project to divert water from the mouth of the Ing River to the Chao Phya Basin via the Yom River and the Sirikit Reservoir. A speaker (Latin America Projects) asked what recommendations for the future had come from the Basin Study. Mr. Cowley replied that principal recommendations included improvements in operations, the exploitation of ground water and diversion of water from the Mae Klong and Mekong Rivers. Another speaker (East Africa Projects) asked whether the upper basin areas upstream of Bumiphol Dam had been taken into account in the studies. Mr. Cowley stated that allowance had been made for these areas in the study. He added that no control was exercised over irrigation of these areas since they were mostly private schemes. However, in times of water shortage, these areas should be subject to rationing of water together with the downstream irrigated areas.
SESSION V

INTERDEPENDENCE of DESIGN and WATER MANAGEMENT in IRRIGATION PROJECTS
INTERDEPENDENCE OF DESIGN AND WATER MANAGEMENT
IN IRRIGATION PROJECTS

PART 1

By: H. Plusquellec

Deficiencies in water management are significant bottlenecks to improving agricultural production in many of the irrigation projects in the world. It is even more a cause for concern that poor water management and inadequate water supplies have affected several projects which were rehabilitated and that losses due to unsatisfactory operational procedures are still occurring.

This report evolves from a review of recent World Bank publications and reports on water management in irrigation projects (see attached Bibliography). Most of these reports emphasize the relation between the deficiencies in water management of irrigation projects and the inadequacy of institutions, financial, social and cultural constraints. One of the main findings is that the separation of agriculture and irrigation in most governmental systems has led to an excessive concern with the engineering aspects of water development to the relative neglect of management and agronomy. Indeed, until the 1960s irrigation development was associated with the construction of large dams and main canals, but the emphasis was placed on civil engineering and little attention was paid to the management of the system during the design stage. In the next decade, more attention was given to water course management and irrigation techniques at the field level, but water management of the integrated system between the source of water and the farm outlets is still neglected.

In Bank literature, improvement of water management seems to be perceived mainly as a financial or institutional matter. There is, however, still ample room for modernizing the physical infrastructure of

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irrigation projects, as opposed to the vicious cycle of rehabilitation. A few developing and developed countries, mainly in the Mediterranean basin, where water is very scarce have developed a modern water management technology which, in spite of clear advantages, is mostly unused outside the area.

This report provides, first, comments on conveyance and on-farm efficiencies of projects referred to in the recent OED report, "Water Management in Bank Supported Irrigation Project Systems", and then examines the advantages of modern water management technology. We do not intend to suggest that this technology should be transferred blindly to every irrigation project. As a first step, research could be undertaken to explore the technical and economical feasibility of alleviating operation and maintenance problems in irrigation projects by upgrading out-of-date designs still adopted in most projects, towards the highest standards of the current state of the art of hydraulic engineering /1/. The Bank has to play a role in initiating this process because (a) the irrigation agencies and their consultants, if any, are naturally reluctant to change traditional design criteria; (b) the performance of well-managed projects which focus on improvement of agricultural production are not publicized; and (c) the language barriers limit exchange between professional staff across the world /2/.

**Conveyance Efficiency**

Efficiencies of an irrigation system are indicators which reflect closely the quality of water management. However, they should be interpreted cautiously in drawing conclusions on how water management is affected by such factors as design, water charges and maintenance. The comments in the OED on conveyance losses and efficiencies raise some questions. For four projects in Iran, Turkey and Mexico, the conveyance efficiency is estimated at 75% up to 85% for the Seyhan Project. These percentages are quite high for projects with simple and conventional water control structures and it is not clear what part "educated guesses" have played in the determination of these conveyance efficiencies. In comparison, the average system efficiency of 21 US irrigation projects sponsored by the US Bureau of Reclamation is 62% /3/. For three other

/1 This paper deals mainly with the water management and operation and maintenance issues of open channel projects. The O&M issues related to tube-wells, pumping stations, sprinkler or drip irrigation equipment and sedimentation are specific and have their own solutions.

/2 The introduction to the Bank Working Paper No. 458 "Comparative Study of the Management and Organization of Irrigation Projects" emphasizes that the report presents an excellent summary of the English literature on the subject. The four field studies on which this report is based were situated in East and South Asia regions.

/3 Operation, Maintenance and Repair of Selected Irrigation Projects, November 1979. Agricultural and Rural Development Department, Central Projects Staff.
selected irrigation districts in the Western US, the delivery efficiency varies between 60 and 68%; for the South Joaquim District, it reaches 83%. However, for the latter, 90% of the distribution is a closed pipe system.

The reasons for selecting these four projects in the US were that: (i) the systems were relatively well managed, operated and maintained; (ii) water distribution records were accurately recorded in considerable detail; and (iii) the technological levels of the systems studied were considered generally compatible with a developing country's conditions since structures and canals were simple conventional types.

The efficiency of the conveyance system of the Doukkala District in Morocco, /1 including the main canals and distribution system is calculated at 76% for the agricultural year 1977-78. Modern technology is used in this project: the unlined main canal is equipped with downstream constant level gates which adjust the flow to the demand thereby eliminating operational losses, and the 750 km distribution system of aqueducts is heavily equipped with water level control structures and fixed flow distributors. It has been estimated that the overall efficiency rating of these conveyance and distribution canals will improve with time from 76% to about 85% as the system moves towards operating at full capacity since the losses are largely independent of the volume conveyed. However, even though the delivery efficiency of this project is presently only 15% above the average of efficient projects in developing countries, its outstanding success is that the water is delivered in the right quantity at the right time, to all farmers, a target which is not often reached elsewhere. Maintenance and water management problems in this Moroccan District area are essentially at farm level. Farmers do not have a deep-rooted tradition for irrigation; they were previously practicing extensive rainfed agriculture. The progress in production is mainly limited by the rate at which farmers can absorb new technology and the quality of extension services. Similar conclusions on water efficiencies could be said about modern surface irrigation projects in Morocco (Massa, Tadla).

Another interesting example is the contrasting case of the surface irrigation North East Ghor Project in Jordan. The design of this project is of conventional type. The Jordan Valley Authority has been able to achieve a high standard of conveyance efficiency, estimated at 75%, but at the price of an excessive annual budget for O&M. The number of staff (1 for 18 ha as opposed to 1 for 350 ha in Morocco) offsets the difficulties of operating turnouts serving farm units of 4 ha without proper water control. One of the reasons given by the Jordanian agency for this over-staffing is the time required to adjust and check several times a day the settings of the Constant-Head Orifice gates in order to deliver a constant flow to the farms. When maintenance of this ancient equipment is not adequate, or staff insufficient,

/1 Detailed designs were prepared by local and foreign consulting firms on the basis of design criteria and overall concept finalized by the Moroccan administration. Construction of this project started in the early 1950s and was financed from Government funds until the Bank lending program started in 1976 for financing sprinkler irrigated areas.
these gates remain partly open, leading to what is called euphemistically "continuous irrigation" as is so frequently practiced in paddy irrigation projects, even after rehabilitation and land consolidation packages have been implemented.

**Water Use at Farm Level**

The comments of the OED report on "Water Use at Farm Level" are unclear and might bias further judgment on the failure or success of irrigation projects. The report compares field efficiency in different regions such as the Philippines, Mexico and Turkey. For the latter, the report states that efficiency of 60% is surprisingly low compared to 78% in the Philippines during the dry season. It is suspected that these figures are simply not comparable because the definitions of farm efficiency vary from one region to another in staff appraisal reports.

(a) For the projects where paddy is the predominant crop, percolation losses are introduced in the calculations of net consumptive use. What is, in brief, called farm efficiency is the **farm ditch efficiency** which is the ratio between the field application to the cropped area and the volume of water delivered to all farm inlets. This ratio indicates the efficiency of the on-farm distribution systems only.

(b) For the projects where rice is not cultivated and where furrow, border, sprinkler or drip irrigation methods are practiced, **farm efficiency**, as a general rule, means the ratio between the quantity of water placed in the root zone (rainfall deficit i.e. the difference between consumption and effective rainfall) and the total quantity under the farmer's control. This ratio indicates the combined efficiencies of the farm distribution system and water application to the crops.

The FAO Paper No. 24 on "Crop Water Requirements" refers to an ICID publication /1 indicating field efficiency between 0.53 and 0.58 and to USDA sources giving field efficiencies of 0.45 - 0.65 - 0.60 on light, medium and heavy soils respectively. The actual efficiency of 60% reported for the Seyhan Project is the percentage which is generally adopted at design stages in non-rice projects and seems acceptable. On the other hand, an average application efficiency of 70% for the Mexico Rio Colorado seems quite high and the value of 80% assumed in the appraisal report of this project might well be questioned.

**Maintenance**

11. Financial problems are identified in the OED report as the first and most pervasive cause for poor maintenance, followed by lack or shortage of

/1 Irrigation Efficiencies in Small Farm Areas, ICID, 1974
machinery. This is true in many cases, especially where important recurrent costs are nearly unavoidable like, for example, siltation of irrigation networks and reservoirs in Indonesia. But in other cases, these costs are due to under-design or inadequate operation of the systems. An example is the frequent cracking of lining because of rapid variations of water level in canals and failure to provide adequate control structures. Similar conclusions could be drawn for the Dez Irrigation Project in Iran where, at completion, the drain system was entirely silted up. The direct cause was the excess of water application in the over-500 meter long furrows creating severe erosion of light textured soils. The poor operation and maintenance of a system by untrained staff is aggravated in underdesigned projects which did not provide sufficient water level and flow control.

**Water Charges**

Water charges are stipulated in every Bank project as a means for funding O&M costs and a "reasonable" part of investment costs. Covenants to introduce or increase water charges are reported to be breached in most cases. The reluctance of Government to bill farmers for unreliable or inadequate water supplies because of poor design, construction standards or maintenance is quite understandable. However, in most cases where Government takes the necessary steps to comply with covenants dealing with water charges, the farmers have no incentive to save water. In general, the water charges are levied either in the form of annual fees per hectare (Semry Irrigation, Cameroon) or indirect taxes such as the rice premium in Thailand, or the government compulsory paddy procurement and cotton purchase in Burma. Volumetric pricing, which can be combined with a tax covering direct capital repayment is superior in promoting efficient and equitable utilization of water. The pervasive social tensions between head and tail-reach farmers or between powerful and small farmers might be alleviated by application of volumetric water charges. In spite of these advantages, volumetric water charges are applied only in a few gravity irrigation projects in the world /1. The obvious reason is that in most projects there are no adequate devices to measure or release preset flows in a short time. Canal distribution systems are frequently operated by untrained staff with no more than primary school education. It would be illusive to expect them to accurately operate underdesigned farm turnouts to the satisfaction of the water payers. One known exception is the North East Ghor Project in Jordan where this difficulty is overcome by assigning one ditchrider per 13 farm turnouts (see para 8): over-staffing is not a solution and an irrigation district is not a hydraulics laboratory. Installation of measuring devices, requiring frequent readings or frequent adjustments of gate openings to maintain a relatively constant required flow is not a field solution. On the other hand, where the water level in canals varies within reasonable and controlled limits, required flows of water can be satisfied with sill-baffle distributors without test and trial and without further readjustment.

/1 In a few Mediterranean countries (Morocco, Tunisia, Jordan), the price is per unit of volume (cubic meter). In the Rio Colorado project in Mexico, it applies to a flow unit (liter per second per day).
From its review of Bank supported projects, OED has not been able to draw any conclusions on the relationship between the amount of water charges and collection rates on one hand, and the amounts of water used or water efficiencies in the field on the other. From its limited available information, the OED report concluded that there is no clear association between water charges and water use. However, some of OED's remarks on farmers' behavior are not convincing. If farmers in Turkey do not use large amounts of water, although paying a small part of O&M costs, the main reason may be because the farmers, who do not have deep rooted irrigation traditions, are not yet convinced of the benefits resulting from sufficient water application. In the recently completed Sebou Project in Morocco, and in the on-going Lower Medjerda Project in Tunisia, with rainfed conditions similar to Turkey, adoption of irrigation has been very slow. Part of the wheat remains unirrigated; only sugar beet, rice and citrus are irrigated without delay. The OED conclusion that cheap water leads to inefficient water use is certainly correct, but the Ceyhan Project with a 60\% field efficiency in long furrow irrigation is not a convincing example (see para 9). In contrast, two factors play a dramatic role in improving water efficiency in the Jordan Valley /1: (i) the three-year drought between 1976 and 1979 and the extension of irrigated areas resulting in restricted water deliveries; and (ii) the shortage and high cost of hand labor for irrigation.

A better design resulting in lower O&M costs and adequate water supplies can also substantially improve collection rates and recovery rates /2.

Regulation of Water in Irrigation Systems

15. On-farm development programs undertaken in the 1970s in several countries (Pakistan, Egypt, Thailand, Korea) have proved to be successful in improving water distribution and in increasing agricultural production. But this is only part of the picture. Lack of on-farm development is not the only explanation for the underutilization of irrigation potential. The SAR of one project in India /3 concludes that "one of the major constraints to higher yields and the greater utilization of water lies in the deficiencies of the system between the dam and the Government outlet".

Most of the irrigation systems are operated from upstream which is derived from methods used since earliest times on non-regulated rivers: the

/1 See the completion report for the Northeast Jordan Valley Project, (para 6.07).

/2 An interesting administrative procedure to obtain a high collection rate is used in rice monocrop Semry Irrigation, as well as in Morocco in the irrigation projects where industrial crops (cotton and sugar beet) are cultivated with an authoritarian leadership: the water charges are deducted at harvest time from the purchase price of agricultural produce together with the costs of services such as plowing, fertilizers. This procedure results in a very high collection rate.

/3 Gujarat Irrigation II Project, SAR, Volume I.
water is released at the diversion point according to a program of irrigation which is scheduled days or even weeks in advance. Because of the erratic nature of rainfall, both in arid and monsoon areas, and because of the transmission time between the source of water and the different offtakes, it is nearly impossible to adjust exactly the upstream releases to the demand. Consequently irrigation systems are operated either: (i) with excess releases and low efficiency to meet the demand; or (ii) with inadequate water supplies. Some recent SAR reports /1 still mention that the design criteria are such to ensure full command of laterals and outlets on flows down to 40% of full design flow and not for lower flows. This design criteria leads inevitably, both during low demand period and during dry season, to poor water management.

By contrast, a closed pipe irrigation network can be operated in the most efficient way on demand as a water supply system. This would be the ideal solution to deliver water in a timely and reliable way. For evident reasons this pressurized type system solution is not suitable for large scale projects, or at least between the source of water and the sub-district areas of, say, 3 to 4000 ha.

18. In the 1950s, design of open-air irrigation systems emerged in Mediterranean countires to reach the efficiency and flexibility of operation of pressurized systems. The basic concept was to use volumes of storage available in the main canals to meet increases of demand immediately and to store water when demand is decreasing. A canal can thus be operated "from downstream", with the assistance of a centralized transmission system. However, to minimize errors in operation and reduce operating staff, a wide range of equipment has now been developed and used successfully both for existing and new irrigation systems:

(a) constant downstream level automatic gates, simply designed without external source of energy;

(b) different type composite gates controlling the downstream water level within limits of upstream level variations;

(c) a further improvement of the "downstream operation" is the "dynamic regulation" consisting of a quasi-simultaneous manipulation of all regulation facilities and requiring installation of telemetering and telecommand equipment and a central computer.

This equipment was succinctly described in the papers on advances in irrigation technologies presented during World Bank Seminar on Agriculture in January 1981.

/1 Thailand Chao Phya Irrigation Improvement Project II, Volume II, SAR dated June 1977, p. 19
To minimize investment costs, and give more flexibility to the operation of a large system, the concept of modern operation of a single canal as described above has to be combined with other design concepts such as:

(a) closed-pipe distribution systems (pilot project in Sri Lanka, Massa Project in Morocco);

(b) upstream and downstream controls;

(c) balancing storage reservoirs near the downstream end of conveyance canals; and

(d) storage reservoirs commanding small areas.

In summary, the main advantages of these modern technologies are (i) adequate water supplies; (ii) high efficiency; (iii) reduced operating staff. If, in addition, the water level is adequately controlled, the costs of maintenance of both lined and unlined canals are reduced. With the simple sill-baffle devices mentioned in para 12, the operation of turnouts is reliable and not time consuming which results in a more equitable distribution of water.

Conclusions

Introduction of design standards to reduce infiltration losses and increase or rehabilitate control structures as frequently proposed to correct the deficiencies of existing infrastructure, do not solve all the problems related to water management in irrigation projects. The OED report recommends that a system's physical infrastructure and its operation procedures should be designed at the same time. This recommendation does not go far enough. In addition, all the options offered by hydraulic engineering must be explored at the design stage of the physical infrastructure: (i) to improve water distribution; and (ii) to minimize operation of maintenance costs in personnel and equipment. The technology for a better design of new large-scale projects and to some extent for modernization of existing projects, exists. It is a matter of transfer of relevant technology through the international engineering community inside and outside the Bank. This approach does not pretend to solve all the problems of irrigated agriculture but will, at least, allow a timely and reliable water supply at the farm gate. It will seriously encourage farmers to greater use of other inputs and to increase of cropping intensity.

It is frequently said that some modern projects are "gold-plated", but the additional benefits of a well-operated project justify the incremental investments costs in most cases.

Large-scale projects can be as successful as small or medium scale projects. The relative failure of large-scale projects should not be the critical element to justify a Government's or Donor agencies shifting the emphasis of their policy in the agricultural sector from the large new schemes favored until early 1970 to support small scale projects. Both large and small scale projects have potential which are far from being exhausted and deserve the same attention.
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INTERDEPENDENCE OF DESIGN AND WATER MANAGEMENT IN IRRIGATION PROJECTS

PART II: IMPACT OF MODERN DESIGN ON WATER MANAGEMENT
by H. Plusquellec

A. Introduction

Poor water management in irrigation projects has become a major concern for the Bank and other donor agencies as well as for the governments involved. Indeed, one is impressed by the prevalence of problems relating to the inequity of water distribution, particularly the problem of inadequate water distribution among tail-end farmers, as well as the low efficiency of water distribution and problems relating to operation and maintenance.

Most, if not all, papers on water management circulated in the Bank during the last year (e.g., the Bottrall report on management, publications on irrigation in China, the OED report on water management in Bank-supported irrigation project systems) impute the deficiencies in water management to financial constraints on operation and maintenance (O&M), and to institutional and organizational deficiencies, as well as to the scarcity of qualified and experienced local personnel for O&M. While better management techniques can indeed play an important role in improving the operations of existing irrigation facilities, this should only be used to complement the physical upgrading of structural facilities. Very little is said in the existing literature of the impact of design on water management and the spectrum of possible alternatives for upgrading water management through the use of proven modern technology. This, I believe, is a serious gap, which I will begin to attempt to rectify here.

On-farm Versus Conveyance Water Management. Improvement water management is sometimes discussed in terms of on-farm versus conveyance management. But this, it is now understood, is not the real issue. Between 1850 and 1950, many large irrigation projects were built in Asia using a diversion or storage dam, a main canal and a skeleton of distribution canals. These projects did not perform well for a variety of reasons. Subsequently, emphasis was placed on a more intensive network of tertiary canals with turnouts from place to place, and farmers were expected to construct on-farm distribution systems themselves. The performance of these projects has also been somewhat disappointing. In reaction to this, some countries have instead concentrated on farm-level problems, but this in itself is not the answer either. It has become clear that emphasis on any one aspect of irrigation, be it the main system, distribution or on-farm, without proper attention to the system as a whole, does not give rise to satisfactory water management. When considering methods to improve overall
irrigation performance, it is necessary to consider the three aspects of the problem simultaneously, as well as the interface between them.

B. Conventional Systems

Disadvantages of Conventional Irrigation Schemes. Management of most existing irrigation projects leaves a lot to be desired. Irrigation is frequently in the form of uncontrolled or semi-controlled flooding of large areas for cultivation of a single wet season crop. The conventional irrigation schemes operate without adequate control, and are subject to water losses, malfunctioning, and high manpower requirements. The consequences of inadequate water control include:

(a) low overall irrigation efficiency between the source of the water and the plants. Efficiency has been as low as 20% to 30% in some Asian projects;

(b) low irrigation intensity;

(c) water delivery that is neither reliable, timely nor equitable; and

(d) the unreliability of water is not conducive to effective farmer participation in the O&M of tertiary systems, and the lack of confidence in the water supply discourages the use of high-yielding varieties and cash inputs such as fertilizer.

The design criteria of existing conventional systems were thought to be simple and economic. The approach was to disperse the benefits of irrigation water over as large an area as possible by extending the canal system as far as possible. However, these systems, in a way, are reversed rivers with little water control and are difficult to operate efficiently and to maintain for the following reasons:

(a) a predetermined irrigation program is needed to match supply with demand, but devising such a program is difficult due to changing rainfall conditions and the transmission time required to transport water over tens or hundred of kilometers of main canals;

(b) lack of or insufficient water level control which has a variety of negative effects, including:

(i) partial command of irrigable lands except in period of full supply in the wet season or in areas close to major control structures because the systems are designed for full flow condition or at the best for 40% of full design capacity;

(ii) complexity of operating water control devices at branching points because the diverted flow is a function of both the hydraulic head and the opening of gates;
(iii) risk of overtopping of canals; and

(iv) damage to the canal lining due to rapid variations in water level, as well as to unlined canals by erosion of canal sides during storms.

(c) water consumers may not be willing or able to cover costs if irrigation services are not sufficiently reliable. Owing to the lack of simple and accurate devices to measure delivery flow, water charges are not levied on the basis of volume; instead, costs are recovered in other ways, such as through the rice premium in Thailand which, I understand, has some disadvantages.

(d) The simplicity of design has to be counterbalanced by overstaffing of the operation and maintenance departments to reach an acceptable level of irrigation service. The O&M of the Jordan Valley Authority in Jordan, for example, includes nearly 1,000 people for less than 20,000 ha. One ditch tender handles less than 50 ha. The simplicity of design also requires a long period of operator training and a sufficient level of education to use tables and operational manuals.

C. Modern Technology

Modern design of irrigation projects was developed after World War II in Mediterranean countries where water is very scarce. This design based on hydraulic engineering has proved to be quite efficient in terms of water management.

The control system of an open-air irrigation system presents a double problem: both water level and flow must be controlled. Water level control constitutes the first stage in improving water management, and is necessary: (a) to maintain the area under command independently of the discharge; (b) to prevent canal deterioration by keeping water level within certain limits to avoid overtopping or erosion; (c) to store water in the network; and (d) to prepare for flow control. The water level can be simply regulated by means of duck-bill-shaped weirs or, better, by means of automatic equipment which offers two basic alternatives. The water level can be maintained constant either upstream or downstream of automatic, hydraulically-controlled gates.

Automatic gates. With automatic upstream control gates, there is still a need to establish a program of supply to branches and canals in order to schedule releases at the headworks in advance. The advantage of this system is that only one operator is needed at the headworks. On the other hand, operational losses cannot be reduced below 10%. With automatic downstream control gates, discharges along a canal are controlled by consumers. Each individual branch canal demand is automatically transmitted back to the headwater, and causes overall water supply in the canal to be
adjusted to demand. This operation resembles a municipal drinking water system. The role of operating staff for this type of system is limited to supervision and patrolling. As an improvement on both forms of automatic control, composite gates have been developed which combine the advantages of upstream and downstream control, ensuring safety of operation and providing the controls used in cases where demand exceeds supply.

Calibrated Distributors or Modules. In several Mediterranean countries constant-level gates are used in conjunction with calibrated distributors or "modules." Since the water level in supply canals varies only within certain limits, the discharge can be controlled by varying the width of the module section. For example, a module with a total capacity of 60 liters per second consists of four sections, each of different width delivering 5, 10, 15, and 30 l/s. The sections can be combined in 12 different ways. The outstanding features of these modules are:

(a) they are very convenient, practical and safe. Control operations are simplified in the extreme since there is no need to vary the degree of opening of any gate, to measure water levels or to refer to tables. Only opening or closing a section is required;

(b) their accuracy is within 5% for upstream variations of the water level in supply canals of 43 cm, and 10% for variations of 52 cm for a double baffle module delivering 50 liters per second per section of 10 cm.

(c) the modules can also be used as water meters by noting the opening times of the gates. They are also easily understood by the farmers, who are quick to appreciate the equity of distribution. The farmers are therefore willing to accept the principle of collecting water charges on a volumetric basis.

In addition, the combination of automatic gates and modules simplifies operations and reduces the manpower requirement. The operation of a conventional system is much more complex and time consuming than the operation of a modern control system to obtain the same level of performance. The simplicity of operations of a modern control system means that less time is needed to obtain the same level of water management and only a minimum of training is needed for operation. The reduced manpower requirement is a particular advantage in developing countries without a sufficient number of skilled operators. In view of these factors, a control system of this type, with hydraulic automation and minimum maintenance requirements seems highly suitable for general use in irrigation projects in developing countries.

Moroccan Experience

The impact of modern design on water management and the flexibility offered by modern technology are well illustrated by the Doukkala irrigation scheme in Morocco, which combines sprinkler and surface
irrigation, upstream and downstream control, and upgrading of an existing main canal.

A briefing paper on this project was prepared by Bank staff who visited Morocco last August (see Attachment). When completed in 1983, the project will serve 60,000 ha, about half by surface irrigation and half by sprinkler. The Bank is involved in financing only the sprinkler system. The 130 km long main canal was constructed in 1952, and remodeling to equip it with automatic gates began in 1970. The first 57 km of the main canal are under upstream control and the next 70 km under downstream control. A compensation reservoir between the two sections plays a critical role in operations. Operation of the pumping station in the sprinkler areas is automatically controlled by the water level in surelevated tanks or by the pressure in the discharge pipes. The average size of farm to be served is about 2.2 ha and prior to project implementation, farmers had no tradition of irrigation.

The results of this development are already impressive:

(a) overall conveyance and distribution efficiency is now 76%, although the main canal is only 10% lined. Efficiency is ultimately expected to exceed 80%;

(b) delivery of water to farmers is timely, reliable and equitable;

(c) water charges are volumetric. Bills are based on direct meter readings in sprinkler areas and on time of delivered flow in the surface areas; and

(d) despite the large number of farmers to be served, staff in the O&M Department are far fewer than the number needed for conventional systems giving the same level of performance. The main canal can be operated by two persons, one at the compensation reservoir and one at the headworks. A water master can handle about 700 ha in the sprinkler area and 200 to 300 ha in the surface area, about four to six times the area covered by a more conventional system.

In the sprinkler area, there is direct hydraulic transmission of demand of water between the hydrants and the compensation reservoir through the pipes, tanks, and downstream-controlled section of the main canal.

The staff devote most of their time to routine patrolling and inspection of equipment, meter reading, and supervising the movement of mobile sprinkler equipment. In the surface areas, staff have only to operate the modules at the head and along the distribution system down to the "crop turnout", and organize water distribution along the tertiary canals.

Remote Control. The ultimate development thus far in automation of irrigation systems took place ten years ago with the introduction of
centralized and computerized systems. These systems can include remote
control of the operations of gates, pumps, etc. as well as data processing
systems for seasonal, weekly and daily programs incorporating all data on
crops and rainfall. The systems are particularly useful in optimizing the
use of water resources of large river basin systems and subregional or
intersectoral water allocation, as in the Chao Phya plain in Thailand. One
advantage of centralized remote control operations compared to automatic
hydraulic gates is that all the regulating facilities along a canal can be
operated simultaneously and respond more quickly to a sharp change in
demand. Since the new systems are very sophisticated, highly qualified
staff are needed for their maintenance.

On-Farm Water Management

Besides using the latest technical resources to improve water
management, other aspects of land development may give rise to efficient and
highly innovative irrigation schemes. A case in point is Morocco where land
consolidation has been integrated into the process of designing the layout
of a distribution system. This concept, which has now been used for
20 years over an area of 200,000 ha, evolved after years of experience with
different schemes. The application of the selected scheme has largely
contributed to the modernization of agriculture in Morocco and the
development of industrial crops such as sugar beet and cotton even in
districts with average holdings of about 2 to 3 ha. (The principle is
illustrated in Annex, Appendix 2.)

The Moroccan model is much more than a land regrouping or realign-
ment of boundaries, yet it is not a land reform since each farmer receives
the same area of land, minus a percentage for right of way. The plots are
consolidated within rectangles (or parallelograms) of about 30 ha (400 m
wide, 700 m long) on which four to five crops are grown simultaneously. Crop
rotation is practiced every year. The farm boundaries run across the crop
boundaries. Water is delivered from a tertiary at the "crop turnout"
serving about 5 ha. By applying this layout, the concept of individual farm
turnouts disappears. Application of this scheme is favorable to, but does
not necessitate, collective organization of farming through water
distribution, the introduction of mechanization, etc. Each farmer remains
responsible for irrigation, treatment, and harvesting on his own holding. A
particular advantage of the combined land consolidation and tertiary layout
is that the optima economic and technical criteria for designing surface or
sprinkler irrigation can be applied independently of the size or boundaries
of farms.

The advantage of the moroccan model is demonstrated by comparing
it with the relatively unsuccessful Lower Medjerda project in Tunisia. The
design of the main canals and distribution system for the latter project is
similar to the design of the Doukkala project (composite gates, modules;
pumps are all manually operated). However, nearly ten years after
completion, the irrigation intensity is only 50% of the target value and the
water delivered for irrigation is still only about 30% of the theoretical
demand. This lack of success is due to marketing constraints and inefficient water distribution due to too low delivery flows as well as to a conventional regrouping of lands and distribution of state farms in square plots of 5 ha. The farmers act individually and fail to cooperate; the project is in a state of stagnation.

The Massa project in Morocco, south of Agadir, is another example of how a scheme can fail, despite modern design. Although an automatically operated sprinkler distribution system and canal were provided, irrigation intensity in the project area has consistently been below 30%. The cause of this failure lies not in poor operation and maintenance (the system is still in good condition), but in the social background of the beneficiaries who are herders or foreign labor in Europe.

D. Conclusions

The question is now whether modern design is, in general, the appropriate way to improve water management in developing countries. There is a growing understanding in certain regional departments of the Bank and in the countries themselves that more profound changes than physical works such as canal lining or additional check structures are required. What is perhaps less clearly perceived is how to proceed. I have previously stated that hydraulic automation is in my view highly suitable for projects in developing countries. The two most frequent objections to this conclusion are on technical and economic grounds.

Sophistication of Systems. Automatic hydraulic equipment has been found by some to be too complex for projects in some countries, since the design and construction of works, as well as supervision of operations, require foreign technical assistance for some time. It is true that the design of irrigation systems using automatic equipment is more complex. But I would also point out that a project equipped with automatic gates and modules requires a minimum of qualified and experienced staff and simple maintenance. On balance, the automatic systems is to be preferred.

Economic Justification. Critics of the new systems also point out that an automatic gate costs about two to three times more than a typical rectangular or radial gate. Other additional investment costs include increased civil works and technical assistance for design and supervision. On the benefit side, an economic evaluation should take into account (a) the savings in water; (b) the savings in manpower requirements for operation and maintenance; (c) the savings in maintenance costs; and (d) importantly, the increase in agriculture production resulting from a more reliable, timely and equitable distribution of water. Studies for the modernization of quite a few projects have indicated that the adoption of automatic equipment, hydraulically or remotely-controlled, is generally justified. Although the cost increase averages about 10%, the savings in water is expected to be about 20%. Again, the more modern systems prove to be superior.
Improved irrigation systems are becoming critical requirements for many countries now that agriculture is moving into a period of growth based on accelerated technological change and not, as in the past, through a continuous expansion of the irrigated area. A spectrum of techniques is available for improving irrigation systems, both existing and planned. For technical and operational reasons, upgrading of water management under new projects is clearly easier than rehabilitation of existing projects, although viable technical solutions may exist for the latter case. Operation and maintenance problems of existing irrigation schemes could be certainly alleviated by upgrading design standards of rehabilitation works to the current state of the art of hydraulic engineering. I hope that the Bank will be active in this "water revolution" and selective transfer of technology which will be useful and appropriate to specific project and country needs.
IRRIGATION STUDY TOURS

Briefing Note on

The Doukkala Irrigation Project in Morocco

The Doukkala Irrigation Project in Morocco lies near the coast about 100 km south of Casablanca. The Project will serve some 60,000 ha at full development, out of which 43,000 ha are presently equipped, comprising about 30,000 ha of gravity irrigation and 13,000 ha of sprinkler irrigation. The project provides a good example of canal system design using automatic hydromechanical gates and level-top canals to provide efficient canal regulation and downstream control responsive to farmer water demand under developing country conditions. The project supplies water to individual farmers on a limited demand basis. Attached as Appendix I is an outline map of the project.

Summary

The Doukkala Project has achieved a conveyance efficiency between the headworks and the farmgate of 76% which is expected to rise to 85% as the system moves toward full capacity operation since seepage losses will remain nearly constant. However, its outstanding success is that water is delivered to farmers in the right quantity at the right time. A number of key factors appear to be responsible for this high level of efficiency and service:

(a) The main canal uses automatic upstream and downstream controlled radial gates for cross regulation with level-top canals in the downstream controlled sections to enable flexible operation and rapid response to changing conditions.

(b) Secondary and tertiary canals in gravity areas are lined down to the farm gate (primarily because of microtopography; the main canals are only 10% lined) which reduces seepage losses.

(c) A two-way radio network of 10 stations and 5 mobile units enables rapid feedback of information on changing conditions in the system.

(d) Field staff have frequent contact with farmers in gravity areas to determine farm demand for water every 7 to 15 days, and to deliver to each farmer the required volume of water.

This briefing note has been prepared by Mr. Reidinger from South Asia Projects Department following his visit to Morocco in August 1981.
(e) Management and supervisory engineering staff are trained in modern concepts of irrigated agriculture and use those concepts in scheduling irrigation deliveries.

Background

The main canal in the Doukkala Project was built in 1952 with a reduced section and remodelled in the 1960's, using simple duckbill weirs to control flows and water surface levels. In 1968-71, the canal was remodelled a second time to be converted in part to downstream control with horizontal (level-top) canal banks. As the project developed and water flows increased, it had become necessary to upgrade the system of water regulation in the canals. In addition as presently operated, downstream control allows service in the sprinkler areas during daylight hours only, except in periods of peak demand when more hours of operation are required.

Today the Doukkala Irrigation Project service area totals about 43,000 ha divided into 4 sub-divisions of roughly equal size. Two of the sub-divisions comprise gravity service areas which predate World Bank involvement, and two sub-divisions are sprinkler service areas financed under two World Bank projects (with USAID cofinancing), Doukkala I covering 15,500 ha and Doukkala II covering 16,600 ha, to be completed by 1982 and 1983.

The project area receives about 300 mm of rainfall each year, mostly in the winter months. Soils are variable, ranging from deep, heavy soils to light, sandy soils. General topography is slightly undulating. Average farm size is less than 5 ha, with the most common size in the range of 2-3 ha. Major crops are sugar beet, alfalfa, cotton, wheat and corn. The area was arid and dry farmed prior to the project, and farmers are therefore relatively inexperienced at irrigating. Nevertheless, yield levels reportedly rise rapidly upon introduction of irrigation, generally reaching expected full development levels within about two to four years. On-farm water delivery and management is assisted greatly by an on-going program of land consolidation and rectangularization which is underway in conjunction with the irrigation project.

The Doukkala Project is operated by the Office Regional de Mise en Valeur des Doukkala (ORMVAD) headquartered in El Jadida near the project area. In addition to the Project, ORMVAD has general responsibility for agricultural development in the Doukkala region covering some 389,000 ha, and it operates local development centers (one center for each 3,000 ha of irrigated land in the project area). The centers provide extension services, farm inputs, livestock services, support for milk cooperatives, research, and farmer training. ORMVAD also plans and organizes production and sale of specified contract crops (sugar beet, cotton, and hybrid maize), requiring for example, all farmers in the irrigated area to grow a specified area of sugar beet which is sold under contract to the local sugar factory.
Main Canal System

The main canal serving the project area has a maximum capacity of 36 m³/sec and a total length of 126 km, including a 19 km long tunnel just downstream of the headworks. Only about 10% of the main canal length is lined. The system is supplied by a 2.8 billion m³ storage reservoir created by a recently completed buttress dam about 30 km upstream of the headworks for the main canal. The headworks are located at an older, heavily silted reservoir.

The main canal is upstream controlled from the headworks down to km 57, and downstream controlled below km 57. Above km 57, the canal is regulated by automatic upstream controlled radial gates (Neyrtec Amil gates) at three locations. These gates (cross regulators in the canal) are float controlled by water surface levels, and release or hold water automatically to maintain a constant pool level upstream of each gate. Canal banks slope parallel to the canal bed down to km 57. Remodelling this section for downstream control with horizontal (level-top) canal banks would have been unnecessarily expensive.

Offtakes from the main canal above km 57 for secondary and tertiary distribution canals are located just upstream of the Amil gates, where pool levels are held constant by the gate. These offtakes serve one of the early gravity irrigation areas in the project. Flow into the distribution canals is controlled by adjustable (Neyrtec) distribution modules. The modules maintain a constant flow for any discharge to which they are set, within the limits of pool level variation allowed by the Amil gates on the main canal. The module is easily adjustable and can be locked at any setting.

The interface point between the upstream and downstream controlled sections of the main canal at km 57 is also the location of the first downstream controlled radial gate (Neyrtec Avis gate). Just above that gate are located a set of emergency escape siphons totaling 14 m³/sec, a small balancing reservoir, and the offtake for a pump-lift station about 1.5 km away. The balancing reservoir capacity is sufficient to absorb the full flow of the main canal for about 1.5 hours. The pump lift station supplies a 7 m³/sec downstream controlled intermediate level main canal irrigating a second gravity area of some 9,000 ha. That canal is controlled by a series of 7 avis gates which maintain constant water levels along each reach between gates along its 25 km length.

Below the interface point at km 57, the main canal continues with an initial capacity of 24 m³/sec. It is controlled by a series of 12 downstream controlled Avis gates and at present supplies additional gravity areas and four pumping stations with elevated equalizing tanks which serve the sprinkler irrigated areas. Each sprinkler station
serves some 3,000 to 6,000 ha of land. Automatic downstream control in the main canal enables "on demand" water supply to the sprinkler pumping stations. The main canal below km 57 and also the primary canal beyond the pump lift station, since they are downstream controlled by float regulated gates, have horizontal (level-top) canal banks throughout the length of each reach between gates.

**Operation of the Main Canal**

The upstream/downstream control interface point at km 57 is the key to operation of the main canal. All cross regulator gates downstream of km 57 automatically open (close) in response to increased (decreased) demand. Upstream of km 57, all cross regulator gates automatically open (close) in response to increased (decreased) supply from the headworks. An imbalance in supply and demand along the main canal shows up first and only at km 57.

If supply does not meet demand, water levels at km 57 start to fall; if supply exceeds demand, water levels rise. A serious imbalance of supply over demand would fill the balancing reservoir and eventually activate the automatic emergency escape syphons. The key then is to regularly monitor changes in the pool level at km 57.

This observation is reportedly done by technicians at the pump-lift station nearby who radio to the headworks if any serious changes in water levels are observed in their supply channel which takes off at km 57. Other than monitoring water levels at km 57 and adjustment at the headworks, operation of the main canal is thus completely automatic (without electricity) and responds rapidly to demand and supply changes as needed. Cross regulator gate setting changes, while usually small, are almost continuous, as the gates respond to changes in water levels. Such operations probably would not be possible if regulation depended on continuous manual adjustment by operational staff.

**Distribution System**

The secondary and tertiary distribution system canals for the gravity areas are "canaux portes" (raised concrete half-round sections of about 6.8 m length each, joined and carried on separate precast support structures at each end). There are few if any falls, and head is maintained (by varying the height of the precast supports) down to the farm turnout structure. In addition, the "canaux portes" require no fill in traversing low areas and require relatively little land. Distribution structures between secondary and tertiary canals are similarly raised and equipped with (Neyrtec) distribution modules for adjusting flow rates and duckbill weirs (or a variant thereof) to maintain a sufficiently constant head for proper operation of the modules.
In the sprinkler areas, water is delivered by underground pressure pipeline to individual farm turnout hydrants. Each turnout hydrant includes a water meter for measuring deliveries to each farmer. The sprinkler areas will total some 31,000 ha when the project is completed, but at present, only part of the planned area is served. Soils in the sprinkler areas are shallow and the terrain is quite undulating and probably not technically or economically suited to surface irrigation.

Communications

All sprinkler pumping stations, the pump-lift station and several ORMVAD operational centers in the area have two-way radios for direct communication with sub-division offices. In addition, local supervisors have mobile two-way radio units in their vehicles. The project radio communications network comprises a total of 10 stations and 5 mobile units. The base station for the network is located in the sub-divisional headquarters at Sidi Bennour near the center of the project area. The network enables rapid information feedback and response to changing water supply and demand conditions in the project area.

Costs

Capital costs for the Doukkala Project are about US$4,000-6,000/ha depending on the area. The "canaux portes" type of distribution system and the pumping station and high pressure pipe system for the sprinkler irrigation account in part for the high capital costs compared to India. In addition, the automatic Amil and Avis gates on the main canal are more expensive than simple radial gates; e.g., the larger Amil gates in the upstream portion of the main canal (36 m³/sec) cost about US$50,000; the smaller Avis gates further downstream (capacity 6 m³/sec) cost about US$25,000, and the smallest Avis gate used in the main canal cost about US$15,000.1/

An additional major civil works cost is in the level-top canals required for downstream control using hydromechanical gates. The economic length of a level top canal reach varies depending on the size of the canal; e.g., the economic length would be 4 to 6 km for a larger level-top canal of 40 m³/sec, but is only 1.5 to 2.5 km for smaller level top canal of 3 or 4 m³/sec. The maximum economic elevation of the canal banks for level-top canals at the end of a reach is about 2 meters under Doukkala conditions, according to project engineers. Clearly, for larger canals and in difficult terrain (with slopes of more than about 0.03 percent), the additional costs to construct level-top canals rise rapidly in comparison to sloping bank canals. In addition, it is important at the design stage for level-top canals to ensure that canal bed gradients are relatively small.

1/ For reference, costs for Avis (lowhead) automatic gates of the same design in the USA are approximately as follows: 0.5 m³/sec, US$5,300; 1.5 m³/sec, US$12,500; 6.0 m³/sec US$26,800; 60 m³/sec, US$134,000.
Efficiency of Delivery and Operations

System delivery efficiency as reported is very high, currently about 76% between the headworks and the farm gate despite the fact that the main canals are only about 10% lined. Delivery efficiency is expected to rise to about 85% as the system is completed, since seepage losses will remain nearly constant as flows increase.

Operational efficiency is also quite high. Since all main canal cross regulators are automatic, no staff are required to operate gates. As an indication of the project's operational efficiency, the emergency escape siphons in the main canal have only operated two or three times since the automatic gates were installed, and then only for a maximum of a half an hour. This level of operational efficiency has been achieved while providing a high level of service to individual farmers. Canal system managers believe that the use of the automatic gates and equipment are a major factor in their efficient operation, as it allows them to focus more attention on proper water delivery to the farmers.

Water Distribution to Farmers

The project supplies water to individual farmers volumetrically on a limited demand basis, providing each farmer with the number of hours he demands at a constant flow rate. Every 7 to 15 days a new program of irrigation delivery turns is developed. Each farmer indicates how many hours of water he wants on his next turn (turns occur normally every 7 to 15 days, or more often during peak demand). Normal delivery flow is 30 l/sec. Each farmer is limited to a specified number of hours of water during his turn. The number of hours in a turn depend on local soil conditions (about 5-6 hours for medium soil, or about 650 m² per turn); the period between turns is also matched to soil conditions (e.g. sandy soils need more frequent but lighter applications). Operating staff appear very familiar with the use of soil-water-plant relationship concepts in scheduling irrigation.

To make a new program of irrigation deliveries, a local ditch rider records the number of hours of water requested by each farmer during the coming turn on a form (Demand d'Eau d'Irrigation). The ditch rider draws up a schedule of water turns (Fiche du Tour d'Eau) for the farmers on each secondary or tertiary canal, and then adjusts module gates and delivers water to each farmer according to his demand (request). Each ditch rider is responsible for about 200-300 ha serving 60-100 farmers. He earns about US$220-270 (equivalent) per month and is equipped with a motor bike.

For each farmer, a table of irrigation deliveries is also made. That table records the timing and quantities of water delivered, and is used to determine the water charge for each farmer. At the end of the
season, a table of water charges is prepared for each farmer based on the number of hours of water delivered.

Water Charges

Water charges are volumetric at a basic rate currently of about US$0.005/m³ (equivalent). That rate is scheduled to roughly double gradually over the next 2 to 3 years. The basic rate is adjusted upward depending on the level of pumping required for a particular canal. Water charged at the above rate amounts to a 50% subsidy on the actual cost of the water. Payment of water charges to ORMVAD is nearly 100% and is "encouraged" by a combination of crop pattern controls and contract sales. Crop patterns under ORMVAD regulations always include some sugar beets which can only be sold on a contract through ORMVAD to the local sugar factory. Water charges, along with costs for seeds, fertilizer, plowing, and other services, are deducted by ORMVAD from proceeds of the contract sugar beet sales at harvest.

Water Control Equipment Used

Design for upstream and downstream control and the type of equipment used in the project -- mainly hydromechanical gates, distribution modules and emergency siphons -- are not used in canal projects in India. Attached as Appendix 2 are outline drawings to illustrate upstream and downstream control, and the type of water control equipment found in the Doukkala Irrigation Project.
India
Irrigation Study Tours
Doukkala Irrigation Project, Morocco
India
Irrigation Study Tours
Doukkala Irrigation Project, Morocco

Designs and Equipment Used

Upstream Controlled Canal

Downstream Controlled Canal

Note:

(a) Horizontal (level-top) canal banks are unnecessary for upstream control.

(b) With upstream control the canal water surface in each reach tends to pivot about the downstream gate as discharge goes from 0 to maximum; with downstream control the water surface tends to pivot about the upstream gate.

Operation of Upstream Controlled Hydromechanical Gate

Operation of Downstream Controlled Hydromechanical Gate

Symbols:

- F: float
- C: compensatory counterweight
- O: axis of rotation
- ▽: water level set

Diagram:

[Diagram showing the operation of the gates with labels for F, C, O, and ▽]
Diagram of Upstream Controlled Gate

A Gate leaf
A' Damping tank
B Counterweight
C Float
D Float chamber
E Metal walkway
F Controlled downstream level

Diagram of Downstream Controlled Gate

G Bearing
H Fixed part
K Variable upstream level
L Float-chamber communicating slot
Single Baffle Distribution Module

Double Baffle Distribution Module
Operation of Single Baffle Distribution Module

Operation of Double Baffle Distribution Module
Use of Upstream and Downstream Controlled Gates in Conjunction with Distribution Modules

A battery of distributors in conjunction with a constant downstream level gate at the head of a branch canal. (Oftake equipment for canals or reserves with level variation ranges for which distributor would be unsuitable if used alone).

A battery of distributors in conjunction with a constant upstream level gate in the main canal. (Upstream controlled canal oftake equipment).

A battery of distributors in conjunction with a constant downstream level gate in the main canal. (Downstream controlled canal oftake equipment).
Diagram of Emergency Escape Siphon

Operation of Emergency Escape Siphon

1) LOW DISCHARGE
   Siphon operating as a weir

2) MEDIUM DISCHARGE
   Partialized operation, with varying air entrainment

3) MAXIMUM DISCHARGE
   Siphon is fully primed
Rapporteur's Comments
by
Sadiq M. Niaz*

Following the presentation of Mr. Plusquellec, Mr. Hotes added that he had visited the Doukkala Project in May 1981 and for the first time had the opportunity to study a system which had been equipped with automatic upstream and downstream constant water level gates, and was impressed by the overall performance of this successful Project, which used sophisticated technology in design but had a very simple operation and was managed by a relatively small staff. He also pointed out that the 76% efficiency mentioned by the author was the delivery efficiency at the farm turnout. The Doukkala Project also kept excellent records including a good revenue collection system; perhaps two of the reasons for a successful collection of water charges was (i) the installation of distribution modules, which were easily visible to the farmers (as compared to a complex water meter) and was, therefore, quite acceptable to them, and (ii) withholding of some fees from payments to farmers for sugar beet sales.

This paper generated a useful discussion, which is summarized below.

System Design and Suitability

Two speakers (CPS and EMENA) questioned the suitability of this technology for upgrading existing irrigation systems particularly if a system had canals with large capacities (500 m³/sec or above) (EMENA), or if a system located in a deltaic plain operated with small working heads and was also navigable (CPS). The author replied that although this technology for water control and distribution was theoretically adaptable anywhere, it was more suited for canals of smaller sizes and therefore perfectly adaptable to smaller distributing units of larger systems. In reply to a speaker (South Asia), Mr. Plusquellec stated that the distribution system equipped with downstream constant water level gates responded quickly to changes in water demand. However, responsiveness to changes in water demands in a large canal system would have to be evaluated separately for each distribution canal. The responsiveness of the whole system to changes in demand would depend on such features as any intermediate storages on the system, length of the main canal etc. One speaker (South Asia) wanted to know (a) how such a control system could be adapted for use in the Indian situation, when available water supplies in the non-monsoon period were smaller than demands and had to be distributed proportionately; and (b) whether it was possible to attach an economic value to the efficiency of response. The author replied that it was very difficult to assign an economic value to efficiency of response but emphasized that advantages of a quick response were evident - the most

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visible being reduction in operational wastage of water. In a water shortage situation, water distribution would have to be controlled by the operating authority (e.g. rotation), and if the system was equipped with automatic control devices on its smaller components, a possibility always existed of operating the whole system in a more efficient manner by integrating its smaller components in different forms.

One speaker (East Asia) questioned the automatic control of large irrigation systems carrying silty water because such controls (a) might induce silting at each regulator location; (b) did not respond quickly to changes in demand, such as those caused by a heavy rain; and (c) additional cost on account of sophisticated equipment and silt removal. The speaker thought that in such situations (large canal systems carrying silt-laden waters), changing over to volumetric measurement of water could alone substantially increase efficiency of water management. The author did not agree with the speaker and stated that siltation induced by automatic gates would be no more than that caused by other gates.

One speaker (South Asia) pointed out that in countries like India there was a considerable scope of using automatic constant upstream or downstream water level gates, but since such gates were more or less a monopoly of a French manufacturer, they were costly and involved expenditure in foreign exchange. The author stated that these gates were now manufactured in several countries (e.g. USA, Algeria, Tunisia, Morocco, Japan, etc.) and could be manufactured in India under license. One speaker (East Africa) pointed out that inspite of the advantages of such a water management system, it did not work in a project in East Africa Region because of weaknesses in project organization, and wild fluctuations in water supply.

One speaker (FAO/CP) painted the Indian scene and commented that the Doukkala technology was not suited in its entirety to the upgrading of existing irrigation projects in India, and the Bank and FAO/CP were working together with the Indian engineers to explore several innovations that would lead to better water management. These measures included reducing area commanded by one outlet; lining of minor distribution systems as well as major conveyance canals; introduction of piped distribution systems for tubewells; organizing farmers into groups or water users associations; introducing water measuring devices and initiating large scale water measuring and monitoring programs; introducing small storages at head of a minor distribution systems etc. He added that this was just the beginning and a lot needed to be done to improve water management in the South Asian countries.

Cost and Economic Rate of Return

Several speakers enquired about the additional cost of installing automatic gates, or overall cost of a system equipped with automatic gates and distributor modules, and information about the ERR of this Project. The author promised to distribute a paper, presented at the last ICID Congress held in Grenoble, which gave relevant cost data. In general, he indicated that the capital cost of the distribution system only (excluding
the main canal or storage dam etc.) was around US$2,000 per hectare in 1981 prices; capital cost of the whole system approximated US$4,000 per hectare; and the Doukkala ERR was now calculated around 13% as compared to about 11% at appraisal. The author elaborated that the Doukkala system involved the use of precast canaletti components, and therefore the above cost figures could be on the higher side. The operation and maintenance cost of the system was around US$29 per hectare. One speaker (EMENA) enquired whether benefits resulting from saving of water alone were evaluated. The author added that these would range from 10% to 50% depending on how much the operational wastage was before the system was upgraded.

Land Consolidation

Doukkala Project’s land consolidation system (Appendix 2, Page 7) and the manner in which the small landholdings (up to 2 ha) were arranged for (a) ease of mechanized farming; and (b) adoption of a largely regulated cropping pattern (sugarbeet, cotton, wheat, alfalfa) came under discussion. One speaker (EMENA) commented that a recent study by a Yugoslav Institute had concluded that benefits from land consolidation under the Yugoslav situation were dubious and were difficult to quantify, and that a better alternative was adoption of monoculture in the area served by one turnout. Another speaker (EMENA) enquired who decided the cropping pattern in Doukkala Project, and how was the supply to each farmer measured volumetrically particularly for the project area served by gravity. Mr. Plusquellec replied that the cropping pattern was decided by the Project authorities, and was regulated because of the existence of a sugar factory and a cotton factory in the area. He also clarified that the farmers were free to cultivate whatever they liked in one part of their land. Each turnout (distribution module) supplied a known volume of water to a strip of land (owned by several farmers) growing one crop and therefore could be rightly called a “crop turnout” rather than a farm turnout; this volume was divided proportionately amongst these farmers for billing purposes.

One speaker (EMENA) added that the success of Doukkala Project was in part due to the lay out of consolidated fields, which evolved after some trials to suit the particular cropping pattern. In another project in Morocco (Lower Medjerda), where conventional consolidation had been carried out and individuality of farms had been retained, farmers had failed to cooperate and the rate of project’s development was much lower and below expectations. A third project (Massa), has more or less failed inspite of a well-designed infrastructure because of social reasons. Another speaker (South Asia) concluded that full benefits from land consolidation would accrue only if the water supply was timely and reliable.
SESSION VI

PROBLEMS and PROSPECTS for INCREASING LIVESTOCK PRODUCTION THROUGH IMPROVED PRODUCTION SYSTEMS
PROBLEMS AND PROSPECTS FOR INCREASING LIVESTOCK PRODUCTION THROUGH IMPROVED PRODUCTION SYSTEMS

by

Dr. Richard O. Wheeler*

Before outlining some of the problems and prospects of animal agriculture, I first feel compelled to address several myths that have sometimes clouded the relative merits of livestock's contributions within the world food production system. And, as I build my case regarding the potential of livestock, I may trample a bit on work that we as development agencies have done in the past. (I say "We," because I was very much a part of the group of so-called "livestock experts" who were commissioned by many agencies to provide advice and recommendations for such work.)

However, the development people I'm really indicting today are those who have reviewed traditional livestock production concepts, added bits of conventional wisdom, images and attitudes, and then concluded that animal agriculture merits only the lowest of priorities on the global development agenda—that livestock production is somehow unimportant to the food system itself. My examination this morning is designed to reveal the "half-facts" or myths that lie behind such negative viewpoints. As Don Paarlberg has noted, myths have enough truth in them to make them believable—but sufficient error to make them dangerous. In terms of my topic today, such error could be the single greatest constraint to increasing global livestock production. For I am convinced that the clearest finding signaled in recent agricultural development studies is that animal and crop agriculture must share complementary roles in any well-balanced food production strategy. I hope that I have spoken plainly—I'll attempt first to put some of the purely rhetorical notions to rest—then I'll suggest some "real world" priorities and strategies required to increase food production for the world's hungry.

EQUITY

Let's tackle the "equity argument" first. This particularly pesky myth springs from the notion that livestock products are simply a luxury item in the global food system—an erroneous view held by many individuals, which, unfortunately, has sometimes become an institutional mind-set. Often the myth-makers using this argument have involved the term "efficiency" relative to optimum resource allocation.

There are several analytical approaches, however, that clearly demonstrate the food wants of people worldwide—rich and poor, rural and urban. In most countries, if we were to plot the amount of livestock products consumed per capita, we would require little other information as an index of economic development and growth. The correlation between per capita economic growth and per capita growth in livestock products is nearly one-to-one, and a sure way of stabilizing or decreasing per capita consumption of livestock products is to decrease economic growth. We see daily evidence of the geopolitical destabilization effects when that phenomenon occurs.

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I would venture a further hypothesis that, if the per capita incomes were distributed equally among the populations in developing nations (an equity argument), that, in fact, the aggregate demand for livestock products would shift upward. Those who argue against the merit of increasing livestock production are—in effect—arguing against observed general human population expressed tastes and preferences—an elitist position I think development agencies can ill afford to accept.

There is general agreement that animal products are desired by and readily become principal diet components for rural poor (and even urban poor) when animal products are easily available. Prime examples would be milk and meat produced by ruminants maintained under traditional low input/low cost production systems.

NUTRITION—HUMAN NEEDS

In terms of needs, as opposed to wants, many "half-facts" are cited about the nutritional worth or value of livestock products and other commodities. It is quite correct that a human diet can be formulated that would include few, if any, livestock products. There may even be defendable arguments that too many animal products can contribute to an unhealthy human diet. I would suggest, however, that this is hardly an important factor for most people in the developing world. Further, I would argue that it is a sad commentary that any of us in the development business should suggest a dull, bland diet (no matter how scientifically adequate) as the "best" that should be expected by people of the developing world.

Now, a few more technical notes on protein needs of humans. For maintenance, an adult human requires a ratio of 20 gms of "perfect protein" for each Mcal of metabolizable energy. In evaluating other proteins, the protein of mother's milk or the protein in a hen's egg is used as a reference standard; that is, "perfect protein." If we assume a value of 100 for milk or egg protein, ruminant meat proteins have a value of about 30 (Winrock International 1978).

The critical importance of protein quality from animal products is documented by Pino and Martinez (1981) who note that 1977 supplies of meat, milk, and eggs on a worldwide basis, were sufficient to supply 80% of the protein and 96% of the essential amino acids of the world populations' requirements. This importance is also indicated by a comparison of the essential amino acid content of a protein with a reference pattern of amino acid requirements for humans. Hen eggs, beef, lamb, and fish contain all the essential amino acids in excess of the reference pattern, thus have amino acid scores of 100. A slight deficiency of sulfur containing amino acids in cow milk limits its score to 96, while poultry meat rates 99. Rarely do plant proteins score higher than 75, with most scoring between 50 and 65.
Of course, plant proteins do provide sources of amino acids, and vegetarians can be perfectly healthy. However, nutritional deficiencies or imbalances are much more common in diets lacking animal protein. Cereals, in general, tend to be deficient in lysine, tryptophan, and sometimes threonine, while pulses (soybeans, peanuts) are likely to be deficient in methionine. Pulses have traditionally been the primary sources of protein to supplement the deficiencies in cereals. But pulses do not yield as much as cereals and can be expensive. Tuber crops are high yielding energy sources, but generally low in protein (Winrock International 1978).

Leaf proteins (e.g., alfalfa) have an array of essential amino acids similar to those in milk; however, man, pigs, and chickens can obtain only a small portion of their protein needs from this source because intake is limited by the high fibrous content of leaves. Estimated protein from all vegetables and fruits amounts to only about five percent of the total protein intake in countries with low-calorie diets. Concentration of leaf proteins by physico-chemical methods may eventually produce protein concentrate of high biological value, but it is doubtful if such methods will result in a product that can economically replace milk and meat. Recent research with concentrated alfalfa proteins indicates a protein efficiency ratio of only about half that of milk (Winrock International 1978).

An excellent illustration of the impact that the introduction of milk cows can have on human protein supplies is given by McDowell (1974). A small maize farm of 2 hectares is assumed to yield about 61,000 megacalories (Mcal) of metabolizable energy (ME) consisting of 38,000 Mcal of grain and 23,500 Mcal of plant residue and stover. After preparing maize as food, man derives about 23,470 Mcal energy and 246 kg protein from the grain alone. If the grain from one hectare is consumed and grain and residue from the second hectare fed to cows, the total energy available as human food drops to 21,491 Mcal (13 percent less), but total protein available rises to 653 kg—an increase of 165 percent. A total of 530 kg of protein comes from milk, a better balanced protein than maize grain.

LIVESTOCK EFFICIENCY

Among the related myths about livestock production, probably none are more deeply ingrained than those associated with the efficiency of plant energy conversion to animal food energy. It is quite true that the amount of grain energy (excluding rice) that flows through the global livestock system today is about equivalent to the grain energy used for direct human and industrial use (see table 1). In fact, if we have a moderate world economic growth, the amount of grain energy used in the livestock system in the mid-80s is projected to exceed that of direct human and industrial use. Clearly, most of the grain and oilmeal that flows in this world market is following the pull of livestock production. Thus, to understand the world grain trade of today and tomorrow,
TABLE 1
World Grain Production and Use, by Region, 1977-78 and 1985 Projections (million metric tons)

<table>
<thead>
<tr>
<th>Region</th>
<th>Surplus (Deficit)</th>
<th>Grain Production</th>
<th>Use</th>
<th>Major Grain Use Categories</th>
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<td>130.7</td>
<td>254.8</td>
<td>298.7</td>
</tr>
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<td>(6.4)</td>
<td>23.1</td>
<td>27.7</td>
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<td>(5.6)</td>
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<td>(32.5)</td>
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<td>14.6</td>
<td>16.0</td>
<td>21.8</td>
</tr>
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<td>4.1</td>
<td>12.5</td>
<td>14.3</td>
</tr>
<tr>
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<td>(19.6)</td>
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<td>19.6</td>
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<td>(16.0)</td>
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<td>World Total</td>
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* Estimates may differ from actual trade flows due to changes in stocks.
it is an imperative that we understand the world livestock system. In assessing the consequences of world shortfalls in feed grain production in terms of political, as well as social and economic stability, development agencies should carefully consider their priorities allotted to the various livestock species.

Another common misinterpretation is derived from data indicating that grain conversion to poultry meat requires only about two to three pounds of grain per pound of meat, while beef requires about eight pounds. This conversion factor is correct—but only under very specific production conditions, and it holds for only part of the normal production cycle. Such a conversion rate is generally not valid for most of the world livestock system, and it is certainly not a good indicator for judging livestock development priorities.

Poultry production seems to merit an especially critical look in developing countries. In relative terms, the growth in poultry production exceeds that of other livestock products (table 2). On a global basis, poultry uses nearly 30 percent of the grain energy used by the livestock system—but provides less than 10 percent of the human food energy derived from the livestock system. On the other hand, ruminant animals (primarily cattle, sheep, and goats) use about 33 percent of grain energy used in the livestock system but provide about 67 percent of the human food energy derived from the livestock system. Part of the explanation for the difference in efficiency is quite simple and direct—although poultry generally consume bugs, wild seeds, and scraps, any marginal growth must come directly out of the grain system. In contrast, ruminants generally derive their feed energy from sources other than grain, such as forages that are not generally consumable directly by humans. True, some lands used for forages and silage could be used for grain; but, in many instances, soil conservation and other factors depend on a crop rotation system that would not be economically feasible if ruminant products were not a part of the production system.

Poultry production is expanding more rapidly than other livestock sectors today for several good reasons. The most obvious is that the technology package is well tested and readily available for delivery into the production process. The poultry product has favorable consumer acceptance and is produced in a form that is well suited to the marketing process. Also, the product flow from inception to delivery is relatively short—an advantage that is attractive to the developing countries who want to get livestock products into the food system quickly. From an investor's viewpoint, the return cash flow is attractive to cover front end investment costs.

However, some of these same reasons that make poultry attractive could also weigh against their use in a rigorous development strategy. Perhaps such reasoning should serve as a caution flag indicating that development agencies should take a more careful look at their priorities and goals as they pro-rate development assistance among the livestock sectors.
TABLE 2
Projected 1985 World Livestock Production and Total Feed Use
(million metric tons)

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<tr>
<th>Region</th>
<th>Beef Offtake</th>
<th>Grain</th>
<th>Pork Offtake</th>
<th>Grain</th>
<th>Sheep &amp; Goats Offtake</th>
<th>Grain</th>
<th>Eggs Offtake</th>
<th>Grain</th>
<th>Milk Offtake</th>
<th>Grain</th>
<th>Draft &amp; Other Offtake</th>
<th>Grain</th>
<th>Poultry Meat Offtake</th>
<th>Grain</th>
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<td>H. Inc. E. Asia</td>
<td>0.2</td>
<td>0.0</td>
<td>0.5</td>
<td>0.1</td>
<td>0.0</td>
<td>0.0</td>
<td>0.8</td>
<td>4.9</td>
<td>0.4</td>
<td>0.0</td>
<td>0.0</td>
<td>0.3</td>
<td>0.5</td>
<td></td>
</tr>
<tr>
<td>L. Inc. E. Asia</td>
<td>0.3</td>
<td>0.0</td>
<td>0.4</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.4</td>
<td>1.6</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.4</td>
<td>0.5</td>
<td></td>
</tr>
<tr>
<td>Rest of World</td>
<td>0.7</td>
<td>0.0</td>
<td>0.3</td>
<td>1.0</td>
<td>0.2</td>
<td>0.0</td>
<td>0.4</td>
<td>1.9</td>
<td>1.2</td>
<td>0.0</td>
<td>0.0</td>
<td>0.1</td>
<td>0.1</td>
<td></td>
</tr>
<tr>
<td>World Total</td>
<td>61.7</td>
<td>117.7</td>
<td>53.3</td>
<td>201.6</td>
<td>10.7</td>
<td>8.5</td>
<td>29.8</td>
<td>108.6</td>
<td>472.6</td>
<td>105.3</td>
<td>24.3</td>
<td>31.4</td>
<td>67.5</td>
<td></td>
</tr>
</tbody>
</table>
In my own experience in assessing integrated crop/livestock development schemes, poultry has not always shown the highest internal rate of return over a 15 to 20 year time frame. However, without exception, the initial recommendation to the investor has been in support of the poultry enterprise. The reasoning again was simple--the rapid rate of cash return for poultry, as compared to the risk associated with alternative longer-term livestock enterprises, made the poultry option attractive. From a national long-term resource allocation perspective, however, the poultry option is questionable. I would guess that if we examined the World Bank portfolio of loans, a major driving variable toward expansion of poultry relative to other livestock enterprises would be reflected in the loan process.

The nagging questions I have are related to the consequences of short-term development pressures that place grain deficit countries on a track of dependency on external grain supplies. This is exactly what is going on in many areas where poultry production is expanding most rapidly. Recent world events suggest that it is begging the question to simply say that livestock production can be reduced in times of short world grain supplies. We have seen that reduction in meat supplies leads to consumer responses that are not conducive to political and social stability.

MORE THAN MEAT AND MILK

A host of products flow from the animal agriculture system other than meat and milk. Some are edible and others are not; some are difficult to quantify and do not enter into national accounts.

For example, a 450 kg steer yields about 200 kg of market meat. The remaining 250 kg yield numerous products such as leather, carpeting, glue, buttons, plastic surgery materials. Most livestock by-products used in industry come from cattle; lesser amounts come from sheep, goats, and swine (J. R. Romans and P. T. Ziegler, 1974). In developing countries, most carcass parts and blood are used as human food. Nothing is wasted; generally, any excess fat will appear in the form of household fuel or candles.

Inedible fat is an item in world trade--about 2.5 million tons a year. Nearly half originates in the U.S. and about one-fourth is recycled as animal feed, with the remainder appearing in the form of such items as soaps, cosmetics, cleansers, lubricants, and gelatin (McDowell 1974).

There are certainly many other livestock by-products, some of which are listed in Table 3.
Table 3. Livestock Contributions to People

<table>
<thead>
<tr>
<th>Category</th>
<th>Contributions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Food</td>
<td>meat, milk, eggs</td>
</tr>
<tr>
<td>Fiber and Skins</td>
<td>wool, hair, hides, and pelts</td>
</tr>
<tr>
<td>Traction</td>
<td>power for crop production, irrigation pumping, threshing, and transport</td>
</tr>
<tr>
<td>Animal Wastes</td>
<td>fertilizer, heating fuel, methane gas production, feed, construction material</td>
</tr>
<tr>
<td>Storage</td>
<td>storage of food supply or capital and seasonal excess of feeds</td>
</tr>
<tr>
<td>Weed Control</td>
<td>biological control of brush, plants, and weeds along roadsides and waterways</td>
</tr>
<tr>
<td>Cultural</td>
<td>provide security and self-esteem; are revered symbols</td>
</tr>
<tr>
<td>Sports/Recreation</td>
<td>competition, exhibition, hunting, and companion animals</td>
</tr>
</tbody>
</table>

Animal Traction Power

Livestock as a source of power have received much less attention than merited, as they have a proven ability to supply much of the traction and related power in many developing areas. FAO has estimated that 75 percent or more of farm traction power in Africa, Far East, Near East, and Latin America is provided by draft animals (table 4). Draft animals include oxen, buffalo, horses, mules, camels, and even other animals. Ruminants are often preferred due to their capability to utilize low-quality crop residues, and their adaptability to varying and marginal planes of nutrition. Makhijani and Poole (1975) estimated the use of noncommercial energy sources (wood, dung, crop residues) in the developing countries as being equivalent to the total crude oil production entering international trade, or about 30 million barrels per day in 1975.
Table 4. Animal and Tractor Power Used in Agriculture in Selected Regions and Countries

<table>
<thead>
<tr>
<th>Region or country</th>
<th>Type of power</th>
<th>Animal</th>
<th>Mechanical</th>
<th>Total</th>
<th>Animal (% of total)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>(×10³ Mcal)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Africa</td>
<td></td>
<td>2,095</td>
<td>449</td>
<td>2,544</td>
<td>82</td>
</tr>
<tr>
<td>Far East</td>
<td></td>
<td>19,591</td>
<td>282</td>
<td>19,873</td>
<td>99</td>
</tr>
<tr>
<td>Near East</td>
<td></td>
<td>3,320</td>
<td>436</td>
<td>3,756</td>
<td>88</td>
</tr>
<tr>
<td>Latin America</td>
<td></td>
<td>6,731</td>
<td>2,289</td>
<td>9,020</td>
<td>75</td>
</tr>
<tr>
<td>Morocco</td>
<td></td>
<td>231</td>
<td>102</td>
<td>333</td>
<td>69</td>
</tr>
<tr>
<td>India</td>
<td></td>
<td>15,481</td>
<td>119</td>
<td>15,600</td>
<td>99</td>
</tr>
<tr>
<td>Japan</td>
<td></td>
<td>200</td>
<td>1,466</td>
<td>1,666</td>
<td>12</td>
</tr>
<tr>
<td>Turkey</td>
<td></td>
<td>1,480</td>
<td>192</td>
<td>1,672</td>
<td>88</td>
</tr>
<tr>
<td>Brazil</td>
<td></td>
<td>2,604</td>
<td>326</td>
<td>2,930</td>
<td>89</td>
</tr>
<tr>
<td>Spain</td>
<td></td>
<td>536</td>
<td>520</td>
<td>1,056</td>
<td>51</td>
</tr>
<tr>
<td>Greece</td>
<td></td>
<td>293</td>
<td>135</td>
<td>428</td>
<td>69</td>
</tr>
<tr>
<td>South Africa</td>
<td></td>
<td>24</td>
<td>535</td>
<td>559</td>
<td>4</td>
</tr>
<tr>
<td>Italy</td>
<td></td>
<td>800</td>
<td>1,557</td>
<td>2,357</td>
<td>34</td>
</tr>
<tr>
<td>Argentine</td>
<td></td>
<td>671</td>
<td>568</td>
<td>1,339</td>
<td>54</td>
</tr>
<tr>
<td>France</td>
<td></td>
<td>902</td>
<td>2,883</td>
<td>3,785</td>
<td>24</td>
</tr>
<tr>
<td>Germany (Fed. Rep.)</td>
<td></td>
<td>378</td>
<td>3,453</td>
<td>3,831</td>
<td>10</td>
</tr>
<tr>
<td>U.S.</td>
<td></td>
<td>28</td>
<td>21,238</td>
<td>21,266</td>
<td>1</td>
</tr>
</tbody>
</table>

All types of draft animals in the world may total about 280 to 300 million head, with a market value of $100 billion. They provide the equivalent of 150 million horsepower; the replacement of which, by mechanical sources, would cost on the order of $250 billion (Ramaswamy 1981). Extensive usage of animals for draft power is likely to continue at current levels, or perhaps with some increase, due to high costs and unavailability of fossil fuels, use of farm-produced crop residues as "fuel" for draft animals, synergistic effects of animals and crops in small farm systems, plus other factors.

There are, however, some very real problems that hinder the full realization of draft animals as power sources for developing countries. Many of these problems are common to animal production in general—but others are use-specific; including the high proportion of feed required for maintenance relative to actual power provided, timeliness of operations, and high labor inputs for animal maintenance.

Several years ago, when I tried to convince development agencies of the merit of investment in research and development toward improving animal traction, I ran into an interesting phenomenon. Before I was thrown out of the office, in many instances I would be informed of the "real world" situation. This situation seemed to be that, although the agency might
see the merit of such an investment, the developing countries would charge the agencies with being paternal in attempting to keep the countries out of the mainstream of mechanization. However, "reality" is beginning to sink in on such countries as the cost of external supplies of energy becomes more expensive, while pressures continue to increase for production of more food from a shrinking resource base.

Today, there are several institutions doing some research in improving animal traction. I would argue that this work is fragmented—but then innovations are not necessarily the product of large structured programs. However, given space age technology that can combine computer simulation and engineering, along with new lightweight but durable materials—animal traction seems worthy of better organized efforts. A gain of a few percentage points increase in livestock traction power could translate into some rather large values. Such values would include not only increase animal energy efficiency but also added crop production capability.

Another livestock role that is not fully exploited is that of using animal agriculture as a tool for soil and water conservation. For example, we have a great all-purpose animal in the goat, which has been much maligned as a destructive exploiter of the ecology in many regions of the world. The cause and effect argument that depicts the goat as a destroyer is backwards—the goat is effectively a survivor; if properly managed, it need not be destructive. However, if the resource base is not managed properly, the goat will survive and be identified as destructive. Viewed within the framework of a family farming system, the opportunity to capitalize the goat's value is quite positive.

Crop rotation systems that not only improve soil and water conservation but result in more efficient resource allocation when forages assume reasonable value, are needed in many regions of the developing world. The ruminant product flow can create the value added to make such a system work—often, the larger animals are not efficient producers within such systems, while small ruminants may fit quite well (Winrock International 1979).

Other Important Issues

We've looked briefly at some key constraints and problems—now let's explore some opportunities for improving global animal agriculture.

I fully realize that I have not touched on other critical issues, such as the credit system, marketing, infrastructure development needs. I hope these topics will be discussed in other discussions at the Symposium. In the credit system, for example, we have not sufficiently exploited the potential for providing the producer with management assistance to improve the production system through the selective use of credit. In part, this is because those in positions that deal directly with the farmer are not well-equipped to diagnose the producers' problems and to identify specific needs for credit. Although they may have
had some university-level education in agriculture, they are usually from urban backgrounds. With today's technology in microcomputers, it is realistic to think in terms of providing producer loan officers, even those without first-hand experience, with a programmed process that will allow them to systematically look at the capital needs and opportunities for the producer.

Each of us could probably advance a dozen other areas with prospects and opportunities for livestock production today. But let's move on to a more rigorous part of my assignment--Improved Production Systems for Increasing Livestock Production.

TARGETING DEVELOPMENT FOR ANIMAL AGRICULTURE

Generally, as I've indicated, I feel that we've been targeting development assistance on the basis of criteria that do not reflect the "real world" of the developing economies.

For example, as an analogy to such flawed assistance planning, we could borrow from our U.S. experience and imagine that U.S. livestock production "must" be targeted to the "livestock country" of Wyoming, Nevada, and Arizona--rather than states like Arkansas and Missouri. The Western States are usually perceived as "cattle country," and it's quite true that a major part of their agriculture is livestock. Certainly, many Western-State producers are completely dependent upon livestock as their source of income. However, the state of Arkansas has more beef cows than those three western states combined. Bordering Arkansas is the state of Missouri; its beef cow inventory is second only to Texas. And in Texas, the largest numbers of beef cows are in east Texas--produced by smaller mixed crop/livestock enterprises; not on the large commercial ranches of western Texas (USDA d1980).

Another way to make this point would be to construct an overlay of the density of livestock in the U.S. to compare the ratio of livestock to cropped and noncropped lands. The more heavily cropped areas would be shown to also have the largest livestock inventories. Since World War II, our southern region of the U.S. has provided most of the livestock growth in national supply, with the largest share on family-operated, mixed crop/livestock farms, usually on rather small economic units.

Although the data is scanty, and we must make some rather sweeping assumptions, we could stretch our analogy and say that the developing countries livestock systems bear a striking resemblance to that of the U.S. When we identify the locations of the largest numbers of animals and of the largest numbers of producers, and then examine the types of production systems, we see that the livestock production is concentrated in the mixed crop/livestock areas. Generally, less production is found on the animal-based farms of the more arid regions. In my discussion that follows, I'll present data that strongly support these observations--which have crucial implications for all of us in agricultural
development. Having reviewed various World Bank publications and discussed the matter with some of the Bank's personnel, I believe that the Bank in a sense has been "burned" in the past with loan portfolios involving livestock projects that were patterned much like the systems found on the classical western U.S. or Australian ranchs. Further, I believe that the World Bank may now be a step ahead of other development agencies in assessing the livestock development potential in the mixed crop/livestock systems. Because of this current interest, perhaps I'm talking to the wrong audience, since you are generally ahead of the rest of us. However, I'm still concerned that many Bank activities that focus on the crop/livestock sectors do not reflect the relative importance of the livestock component. Certainly, livestock get less attention in the mix of appraisal personnel and technical support activities.

Let me add quickly, before another nonissue arises--I am well aware of the implications of putting less development emphasis in the animal-based arid regions of the world. There are certainly social and environmental problems in these regions that deserve our concern; unfortunately, these problems seem likely to remain with us and are a serious social development problem.

IMPROVED PRODUCTION SYSTEMS

Let me turn now to a more detailed discussion of the livestock production systems that I mentioned in my analogy.

For this discussion, I will borrow heavily from a draft position paper recently prepared by Winrock for USAID. Drs. Ned Raun and Bob Hart led a team of our staff in preparation of a paper that not only analyzes crop/livestock and grazing systems, but also provides a list of priorities and a strategy for improving these systems in developing countries (Winrock International 1981)--and thus more precise targeting for development.

It seems to me that as we look for opportunities to advance animal agriculture, especially in the mixed crop/livestock areas, we must think in terms of total agricultural production systems. In general, if we start with the assumption that the system is in equilibrium, and if we jar the system through a single intervention, the new equilibrium may be less desirable than the original. Examples of ignoring the hazard of single intervention strategy can be found all over the world where new genetic stock has been considered a good single intervention. The plant people found out decades ago that the production improvement package required much more than simply injecting new strains or varieties into the production system.

The strategy developed by Drs. Raun and Hart deals specifically with the allocation of resources for implementing of action programs to protect and improve the natural resource base on which livestock depend, and to
increase the productivity of the livestock components of these agricultural systems. National, regional, and international organizations are integrated within a global systems approach. The draft position paper has served as an excellent means of focusing several state of the art studies made at Winrock since the Center began in 1975. I'll attempt to summarize the paper here, but I hope you'll read our Executive Summary.

As I've said, the importance of livestock in nutritionally balanced human diets is well documented, but much less is known about the many complementary roles that link livestock within the global food-supply system and in the growth and development of a national economy. There has been little hard data to systematically document their impact—or for that matter provide an adequate description of livestock production systems.

COUNTRY CLASSIFICATIONS

Thus, as an initial task, the Winrock team analyzed 60 developing countries and set up classifications of the countries. The dominance of crop, animal, or mixed systems was calculated (table 5) by using the ratio of ruminant animal units to economically active members of the country's agricultural population. Countries with a ratio of ruminant animal units to economically active population of greater than 5:1 were classified as (I) animal-based; countries less than 5:1 but greater than 1:1 were classified as (II) mixed-crop and animal; and countries less than 1:1 were classified as (III) crop-based. Table 5 provides strong evidence to support my contention that global livestock production is concentrated in the mixed-crop/livestock areas.

BASIC PRODUCTION SYSTEMS

Winrock's review of the country characterizations and the correlations among precipitation, animal and crop species, and the rankings of animal, crop, or mixed systems suggested seven basic types of livestock production systems. In turn, the relative importance of each of these seven systems was determined for Africa, the Near East, Latin America, and the Caribbean.

Three criteria were used to determine the relative importance of the system types: (1) agricultural population, (2) grazing land, and (3) total ruminant animal units associated with a particular system. These criteria were selected because some systems are used by many small farmers but do not require much land; other systems require extensive land but are used by only a few farmers; other systems are used by many farmers but do not include a high percentage of animals.

The relative importance of each system type was analyzed by assigning a production system type to each country (with the exception of India,
### TABLE 5

The relative importance of different animal production systems in countries with USAID missions in Africa, Near East, Asia, Latin America, and the Caribbean. Importance is measured in % of the agricultural population (% AP), % grazing land (% GL), and % ruminant animal units (% RAU) associated with the different states.

<table>
<thead>
<tr>
<th>SYSTEM TYPE</th>
<th>GEOGRAPHIC AREAS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>AFRICA</td>
</tr>
<tr>
<td></td>
<td>AP %</td>
</tr>
<tr>
<td>I. Animal-based farms</td>
<td></td>
</tr>
<tr>
<td>A. Low rainfall; pastoral migration of cattle, sheep, and goats</td>
<td>12</td>
</tr>
<tr>
<td>B. Medium rainfall; pastoral, cattle: Subtypes, 1 = extensive grazing for meat; 2 = intensive, milk and meat.</td>
<td>12</td>
</tr>
<tr>
<td>II. Mixed crop and animal farms</td>
<td>54</td>
</tr>
<tr>
<td>A. Low rainfall; cattle, sheep, and goats; millet and sorghum.</td>
<td>13</td>
</tr>
<tr>
<td>B. Low rainfall; camels, cattle, sheep, goats; wheat, clover.</td>
<td>--</td>
</tr>
<tr>
<td>C. Medium rainfall; cattle, sheep, goats; pigs and chickens; maize or wheat.</td>
<td>42</td>
</tr>
<tr>
<td>D. High rainfall; buffalo, and cattle; rice or roots and tubers.</td>
<td>3</td>
</tr>
<tr>
<td>III. Crop-based farms</td>
<td>29</td>
</tr>
</tbody>
</table>

* This system is important in the Near East; the analytical procedures used to characterize countries makes the system appear important.
which was assigned two types: 65 percent to one and 35 percent to another, based on the relative areas planted to rice and wheat. The agricultural population, grazing land, and ruminant animal units were calculated for each system type in each geographic region.

Let me run quickly through each of the seven systems and their relative importance.

(I) Animal Based

(I-A) Livestock-based: pastoral migration of cattle, sheep, and goats; in low rainfall areas—predominantly in Africa and the Near East (although no country is assigned this category in table 5). Although the system in Africa is relatively unimportant in terms of the percentage of the agricultural population using the system (12 percent), it is very important in terms of percent grazing land devoted to the system (35 percent) and percent of the total ruminant animal units associated with the system (35 percent). As would be expected, farmers using this system have very few nonruminants. In some areas of Africa, this system is linked with mixed farms (system II A).

(I-B) Livestock-based: pastoral sedentary cattle; in medium rainfall areas (100 – 200 mm)—predominantly in Latin America. While only 37 percent of the agricultural population is associated with the system, 70 percent of the grazing land and 74 percent of the ruminants in Latin America are associated with this production system. The system, which includes few nonruminants, has two basic subtypes:

Subtype 1: Extensive grazing, primarily to produce meat on large ranches.
Subtype 2: Intensive grazing to produce both milk and meat (dual purpose) on small and medium-size farms.

(II) Mixed Crop and Animal

(II-A) Mixed farms with cattle, sheep, and goats; millet and sorghum; in low rainfall areas (500 – 1000 mm)—predominantly in Africa, but also in a few areas of Central America. The system sometimes includes chickens, but seldom includes pigs. (This is true in non-Moslem areas in Africa, as well as in the Near East). This system is often linked with migratory grazing systems (system I A) in Africa.

(II-B) Mixed farms with camels, sheep, and goats; wheat and clover; in medium rainfall areas or in low rainfall irrigated areas—predominantly in the Near East. Camels are used for draft as well as for milk and meat in this system. Chickens are also included and pigs only in non-Moslem areas (such as Lebanon).
(II-C) Mixed farms with cattle, sheep, goats, pigs, and chickens. Maize and/or wheat are the dominant crops in this system which is found in areas with enough rainfall (medium to high) to support a highly diverse mixture of ruminants and nonruminants and different crops. It is very important in all areas except the Middle East. In Africa and Latin America, maize is the dominant crop, but in South Asia (for example, India and Pakistan) wheat is dominant.

(II-D) Mixed farms with buffalo and cattle; rice or roots and tubers. This system is very important in Asia (more than 50 percent of the agricultural population and ruminant animal units are associated with the system) and in high rainfall areas in both Africa and Latin America. Pigs and chickens are often included.

(III) Crop-based Farms

This system could be subdivided into many different subtypes. The animals tend to be used for draft power, manure production, and holding of assets. In Africa, Asia, and Latin America, the system includes very few ruminants (5, 8, and 1 percent, respectively). However, in the Near East (primarily Egypt) 24 percent of the ruminant animal units and 1 percent of the grazing land are found in this category, indicating the importance of crop-residue as a feed source.

Limitations of Systems Methodology

There are two obvious limitations inherent in the methods followed in the preceding analysis. One limitation is that assigning a country only one production-system type can lead to misleading results. A country that is 45 percent System Type I and 55 percent System Type II is arbitrarily classified as Type II. Farm-level analysis would be much preferable to country-level analysis. Information is available as to farm size, species, and numbers of animals, crops, etc.; however, information is not available as to the land resources, crops, grazing land, and number of type of animals found on farm units.

Another limitation is that of using the ratio of ruminant animal units to economically active population as the only criteria for classifying a country as livestock-based, mixed, or crop-based. If a ratio of grazing to arable land had been used instead, the results would have been slightly different. For example, a country such as Ethiopia (classified as mixed) has a higher grazing-to-arable ratio than Somalia (classified as livestock-based); Sudan (classified as livestock-based) has a lower grazing-to-arable ratio than Ghana (classified as crop-based). However, the general results that would be obtained using the grazing-to-arable ratio would not be substantially different, since this ratio is highly correlated with the ratio of animal units to economically active population.
PRINCIPAL PRODUCTION CONSTRAINTS

Characterization of livestock production systems involves clear definition of resource inputs, production processes, and product outputs--any of which can be a constraint to system productivity. The implicit goal of most research, training, and development projects is to push past these barriers.

Our Winrock team examined three general categories of constraints to livestock production:

1) **Ecological**: land, climate

2) **Biological**: livestock nutrition--water, feed; livestock health--disease, parasites, and predators; livestock genotype--production and adaptation traits

3) **Socioeconomic**: labor availability and management skills; consumer taste/preference and disposable income; credit availability and cost; marketing infrastructure; and policies--trade, prices, and land tenure

Feed supply is the most pervasive constraint to livestock production. It is directly dependent upon the production of plant biomass, both in grazing and crop/livestock systems. It is an absolute requisite that must be treated in the broadest context, including native and improved pastures, forage crops, feed crops, crop residues, and by-products. Feed supply has both quantity and quality dimensions. Quantity can be increased by the proper stocking of rangelands, the establishment of improved pastures to complement native pastures, the planting of forage crops, soil and water conservation practices, and the timely harvest and storage of crop residues. Quality relates to the overall nutrient adequacy of pastures, forages, and other feeds consumed, as well as the means to correct any deficiencies through improved pasture management, improved pastures, fresh cut and stored forages, and/or supplementation.

Seasonal fluctuations in feed supply can be a special problem, especially in the wet/dry tropics. Whereas feed may be abundant in the rainy season, inability to preserve this abundance leads to dry season deficiencies.

Nonruminant systems based on imported concentrates are vulnerable to changes in policy on imports and foreign exchange. Nonruminant systems based on household wastes are generally constrained by the lack of systematic management of feed supply and livestock.
SETTING PRIORITIES

Having described the systems and the basic constraints within these systems, the analytical process requires identification of:

- Types of producers that would benefit most from technical assistance programs
- Major categories of livestock production systems that are amenable to improvement
- Specie priorities within the farming system (considering both use of available feed resources and useful outputs)
- Major constraints most amenable to change
- Priority technical assistance activities in research, training, technology transfer, and production inputs to alleviate major constraints
- Training needs for research/development personnel and producers at field level

Within this basic process, general priorities can be developed for worldwide technical assistance, as well as specific priorities at the country or regional level. (While direct extrapolation from the general priorities was not made for specific country requirements—such general priorities can serve as a standard against which needs at the national level can be evaluated.)

HIGHEST RECOMMENDED PRIORITIES

Producers

The primary target population is the family farm unit—owned and/or operated by the farm family, with principal income and employment derived from this unit, and with food produced not only for subsistence but also for market.

Ecosystem

Tropical and subtropical regions are the primary target ecosystems. Of the 60 developing countries examined, only 12 are located outside of the tropical latitudes (and these have only 12.8 percent of the total animal units). Although some countries in the tropical latitudes have high elevation and temperate climate areas in which livestock are raised, most of the livestock are now found in tropical/subtropical regions, and these numbers promise to increase as agriculture continues to expand into these regions.
Production Systems

Priorities on livestock production systems were recommended based on: 1) quantity of food, fiber, and traction power derived from animals; 2) proportion of the total livestock population found in a system; 3) potential for major increases in productivity with interventions that can be successfully introduced and that fall within the resource limits of producers at an acceptable level of risk; and 4) need for technical assistance/technology that is not otherwise available.

Following these criteria, highest priority is placed on mixed crop/livestock systems and range/pasture (livestock) based systems.

Of these two, higher priority is placed on mixed farming systems in medium to high rainfall and irrigated regions where the greatest proportion of livestock and livestock products are found/produced. In the analysis that characterized the dominant type of agriculture at the country level, the data indicated that an estimated 75 percent of the ruminant livestock are found on mixed crop/livestock farms. This is consistent with the estimate made by McDowell and Hildebrand (1980) that 85 percent of the ruminants in developing countries are on small farms. While the percentages are based on assumptions that are open to question, there would seem to be little doubt that in most of these developing countries more of the agricultural population is dependent upon the income produced from livestock in mixed farming systems than in other types of systems.

Second priority is placed on pasture-based systems in semiarid, subhumid, and humid areas, particularly in Africa and Latin America, on lands that are not suitable for cropping, either in the short- or long-term. These include lands on which high numbers of animals are now found or there are major programs for the expansion of livestock production in these areas. Worldwide it is estimated that 18 percent of the ruminants are found in these systems.

A lower priority is placed on those systems where ecological constraints to production cannot be alleviated, where there is little or no potential for increased production, and where natural controls bring livestock populations into balance with the environment, e.g., Sahel. Also, a lower priority is placed on those systems where livestock are now of minor importance, e.g., plantations, vegetable farms, remote-uninhabited areas.
Species

Of the animal species, the domestic ruminant species (cattle, sheep, goats, and buffalo) were recommended for emphasis. Higher priorities for ruminants are merited because:

- Ruminants can transform low-quality crop residues and other lignocellulosic materials, which have no value for direct human consumption, into milk, meat, hides, fiber, and manure, and into "fuel" for animal traction power.
- Ruminants provide most of the agricultural traction power in developing countries, utilizing farm-produced biomass as the energy source which minimizes/obviates the need for expensive and scarce fossil fuel for internal combustion engines.
- Many LDCs depend upon ruminant products for a significant proportion of their foreign exchange earnings, which benefit a broad spectrum of producers and consumers.

The majority of swine and poultry are found in family farm, mixed crop-livestock units. They provide meat and eggs for home consumption and for sale. Additionally, swine are living "piggy banks," simultaneously serving as food and cash reserves. On family units, both species are scavengers of feeds that would otherwise be wasted, and sinks for feeds that are not readily marketed. Only in commercialized units are significant amounts of feedstuffs used that might be otherwise used for direct human consumption.

While recognizing the major importance of swine and poultry, the recommendation was that major effort should not be devoted to these species because: 1) swine production technology is now available and readily applied over a wide range of ecosystems and production systems; and 2) commercial poultry production technology is likewise available and readily applied worldwide, and poultry which enters commercial channels is increasingly dominated by commercial poultry operations. On the basis of these assumptions, it is suggested that 1) swine and poultry improvement programs should be incorporated principally within national programs with emphasis on the application and adaptation of technology within comprehensive farming-system-oriented research and development programs, and 2) the private sector can promote and develop the production of poultry, eggs, and swine in larger sized commercial operations and does not need technical assistance from the public sector.

Research Approaches for Alleviating Constraints

The principal constraints to livestock production that can be alleviated by research are: 1) feed supply and feeding systems, 2) livestock management, 3) control of disease and pests, 4) germ plasm improvement, and 5) production economics. Of these constraints, feed supply and
feeding systems are the most pervasive and by far the most limiting. The livestock management constraint is of human origin. While effective controls have been developed for most diseases and pests of ruminants, some difficult constraints remain, i.e., trypanosomiasis and theileriosis in Africa, and ticks worldwide. Germ plasm improvement becomes the limiting factor as the higher order constraints are removed. In production economics, availability and cost of production inputs are the most critical.

Two research approaches are proposed to remove production constraints.

(1) **Systems-based research**, generally applied and adaptive in nature and conducted principally in national and regional programs, is proposed for:

- Range and pasture management
- Year-round feeding systems
- Livestock management and breeding practices
- Disease and pest control
- Production economics

(2) **Problem-oriented basic research** is proposed to generate new technology; this research would be conducted in specialized research centers having the institutional base and expertise to conduct sustained problem-oriented research. Such research is needed in:

- Plant selection and breeding (including recombinant DNA techniques) to develop superior pasture and forage species and other crops to be used as animal feed
- Animal breeding (including recombinant DNA techniques) to incorporate desirable production and disease/pest resistance traits (gene/s) in animals lacking these traits (e.g., the high reproductive rate of the Australian Booroole Merinos which may be controlled by a single gene; the trypanotolerance trait of N'Damas)
- Genetic engineering for the production of vaccines for diseases not having effective vaccines, principally trypanosomiasis and theileriosis
- Biological control of major pests of livestock, principally ticks
- The development of improved ruminant traction power systems
- Marketing of livestock and livestock products

There are perhaps many other production constraints and research efforts that could be mentioned. However, most would be either subsidiary or tangential to the previously noted constraints/potentials. They would
probably be highly situation specific and could be addressed only at the local level (most commonly within farming-systems research in national institutions).

TRAINING

The first recommended priority of the Winrock report was to train high level persons who can assume leadership responsibilities in the planning and management of livestock research, training, and development programs. Such persons are often available in the more advanced, developing countries but not in the less advanced countries.

Priority must be placed on programs to train key persons at all levels, i.e., decision, operational, and producer. Key persons are those who can produce a multiplier effect; too often training programs have little impact because people trained do not multiply their knowledge/production skills. Training priority, therefore, must be in descending order, with highest priority on the decision makers in national institutions, next on key operational personnel within these institutions, and finally producers. Since producers are at the action point, it may be argued that training should simply focus on producers without concern for higher level training. This argument is refuted, however, by the absolute need for trained decision makers, leaders, and trainers qualified to lead and train others before producers can be trained on a sustained basis.

TECHNOLOGY DELIVERY SYSTEMS

A two-way, technology transfer process between researchers and producers is proposed. This method utilizes a Farming Systems Research (FSR) approach that seeks to learn first from the local people what they already know about their own systems. Then technology transfer moves on multiple paths into field testing and evaluation of improved technology at the local level. Farmers and researchers concurrently promote and obtain feedback for setting research priorities and guiding programs.

FSR proponents generally emphasize that when the farming system is perceived as a source of technology, transfer is more effective than with the traditional "top down" approach. In FSR, information is gathered, analyzed, or interchanged continuously within several stages of research: 1) from the producer (with his accumulated knowledge and experience in the test area) information flows to the more formal research system; and 2) from the multidisciplinary research team in the field testing of alternatives, information flows to the producer. Thus, the FSR process serves to channel information between producers and appropriate research system components (national, regional, and international). The joint research-farmer effort in the analysis and evaluation of the research becomes a "do-it-yourself" information-gathering and delivery tool. Moreover, many of the results can plug directly into
a worldwide system (through international centers) while serving simultane-ously as "eyeball" evidence for the producer, his family and friends, as well as local agricultural agency workers, policy makers, etc. The expression of the production alternatives within farming systems serves as a universally understood language. For the farmer, the testing of results and delivery are simultaneously and immediately observable. Similarly, the research team can make on-site analyses of the technologies and their goodness-of-fit within the local ecosystem. Firsthand knowledge is obtained of incentives and constraints bearing directly on the farmer. They can also identify external policy issues that affect decision making.

For resource-poor national programs, the FSR team can strengthen, or serve in lieu of, the traditional extension arm. Because of the specialized technical training of the team, data retrieved from the field can be analyzed and fed into (and from) the formal research system (international center, universities, etc.) much more precisely and quickly. However, further relay of the data requires development of "analysis stations" with information support staff helping in standardizing terminology, reporting procedures, etc. FSR research also provides a convenient and efficient vehicle for other development institutions to interface with the farming-system components (training, special projects, and other related social science analysis).

MARKETING AND PRODUCTION ECONOMICS

Four major considerations need to be taken into account in the formulation of appropriate marketing strategies to complement the technical elements outlined above.

- A common constraint in developing countries is the negative impact upon the farming sector of pricing policies, slaughter regulations, and controls on animal movement. It is understood that these regulations are expressions of very real concern to host country governments; however, it must be recognized that implementation of country livestock development programs will usually require changes in these control mechanisms to allow producers to respond to new opportunities for using improved inputs and new opportunities for marketing animals and animal products. An effective strategy for implementing these changes often requires research inputs that demonstrate losses from current policies as well as the potential benefits from implementing more rational, producer-oriented policies, e.g., increased production, income, employment, and foreign exchange savings.

- An effective marketing strategy should place major emphasis on the input marketing side since the recommended strategy is input oriented. In most developing countries, the livestock input marketing sector is very poorly developed, while the
output marketing sector represents an old, well-established set of institutions. Research is needed on specific problems in marketing inputs such as feed, forage seeds, fertilizers, innoculants, vaccines, insecticides, acaricides, fencing materials, and drenches.

The marketing of live animals and animal products such as meat, milk, hides, and skins requires a considerable research input since many public sector programs are based upon assumptions concerning performance of the marketing sector that may be faulty. Development strategy should concentrate on improving competition (if this is a problem) by encouraging entry into this field of activity and by providing infrastructure such as selling facilities, market information, feeder roads, and processing facilities.

Milk marketing should receive high priority since studies show substantial producer responses to the development of regular milk-purchasing facilities. There are also major secondary effects through increasing the supplies of hygienic milk products to susceptible groups of the population so that substantial expenditures on improving milk marketing, milk pricing, and repayment methods may give high returns to the host country. In addition, a good system of milk marketing provides a steady and reliable cash income to the farm family.

These marketing research and development strategies are all oriented towards improving the input/output price relationships facing the farmers. In addition, it must be recognized that livestock represent a major capital asset to the farmers. A variety of schemes have been tried to reduce this cost, including animal purchases for farmers, animal loan agreements with offspring being provided as repayment, specific loans being extended for the purchase of animals and for short-term and long-term input purchases, and gifts made of immature animals. The critical element for any scheme to alleviate the capital requirement for the animal and complementary inputs is that the scheme must proceed in step with the other elements of the strategy or the return on the additional investment will be determined by the traditional production system and will, in general, be quite low. In addition, the institutional arrangements governing resource use for animal production require careful study—and where this is deemed a major constraint, innovative strategies will be needed with strong local-level inputs.

STRATEGY RECOMMENDED FOR IMPLEMENTING PROGRAMS

An implementation strategy recommended here is consistent with the priorities identified above. National research programs should identify priority livestock production systems and the primary constraints associated with each system, and implement field research and technology-transfer activities to find and disseminate innovations that will im-
prove the farmers' present production systems. Provision must be made for the academic and field training of research and technology-transfer personnel. Regional centers should conduct research with livestock production systems of regional importance and provide methodological assistance to national programs. International Agricultural Research Centers (IARCs) should continue to conduct research on specific commodities and specific problem areas that are presently known to be major constraints in many production systems in many countries. As national programs identify priority production systems and their primary constraints, the international centers should focus their research on specific areas with regional and/or international impact. U.S. institutions should assist national programs through bilateral programs and through research efforts in areas where they have expertise and where the research would be directly relevant to the situation in less developed countries. Also U.S. institutions should collaborate with the IARCs in basic research to develop new technology to advance agriculture.

Host Country Programs

National program research and development. Implementation of any technical assistance program requires both a clear research and development strategy and the institutional capability to carry out the strategy. Development projects should assist host countries in both of these areas. The design of a livestock research strategy must be keyed to the role of national research and development programs in developing countries. These programs are often the weakest link in the present agricultural research and development network (National Academy of Sciences 1977; World Bank 1981). The creation of the International Services for National Agricultural Research (ISNAR) and the growing tendency of international centers to station staff in other countries as part of outreach programs are responses to this deficiency.

In the identification and analysis of important livestock production systems in this paper, we have pointed out the importance of mixed production systems. Also we have noted the difficulty in generalizing about livestock production systems and the influence of the livestock component on the ecosystem. Livestock research on mixed farms is almost impossible without taking an FSR approach.

An advantage of the FSR approach is that, following established development criteria, it allows national research programs to identify the important livestock production systems in specific areas. In this way, specific problems can be identified and studied and national research institutions can request help from international centers in designing research programs to resolve critical problems. The FSR approach presented here proposes that research be conducted on only those components of the farming system which are amenable to major improvements in productivity; it does not propose research on total farm systems per se.
Institutional problems are among the initial barriers when an FSR strategy is adopted by national research programs. Most national institutions are organized along commodity lines, and cannot simply be reorganized overnight. Since commodity programs have an important function within FSR methodologies, a logical way to implement an FSR project would be to require integration of commodity programs into area-specific, multidisciplinary teams. The make-up of these teams would depend on development objectives and the predominant type of farm system.

**Basic FSR Methodology.** Generally, FSR includes:

1. Identification of target area
2. Initial characterization of current production systems
3. Identification of physical, biological, and socioeconomic constraints
4. Identification of potential alternatives
5. Evaluation of potential alternatives on selected farms
6. Evaluation of best alternatives on many farms
7. Mass transfer of technology to entire target area

Figure 1 is a diagrammatic summary of a general FSR strategy that should be useful as a guide for national research programs. It combines the methodologies developed by various institutions and individuals with the foregoing livestock and farm-system analysis.

The general strategy begins with the selection of specific geographically defined target areas. Criteria for target-area selection include country development objectives, technical capabilities, institutional structure, and economic resources. The results of an initial characterization are used to identify the farm-system type(s) that will be emphasized. The farm-system type selected will depend on the development objectives. For example, if meat export is an objective, large livestock-based farms may be selected even though this farm type represents a small percentage of the farms; however, if farmer welfare is an objective, small mixed farms may be selected for emphasis.

Field station trials of potential technology suited for the specific environment as well as on-farm analysis of specific production systems can begin simultaneously. If crop-based farm systems are selected, the role of the livestock specialist will be that of advising crop specialists as to livestock-related evaluation criteria that can be applied in cropping-system experiments. If livestock-based farm systems are selected, the role of livestock specialist will be dominant and crop specialists will play an advisory role. The mixed-farm systems, where crop and animal specialists must work together, requires methodologies that are not yet available; but given the conclusions from the preceding sections of this paper, the development of a mixed-system methodology is a high priority.
### Phases in a Technology Selection, Evaluation, and Transfer Process

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#### Figure 1: A General Farming Systems Research Strategy to Design Alternative Livestock Technology That Fits Into Existing Farming Systems, and Can Be Transferred and Adapted to Produce the Development Objectives Identified for a Geographic Area.

Source: Winrock International
The strategy summarized in Figure 1 assumes that the first step in a mixed-system methodology is the identification of the specific crop/livestock system to be analyzed. Examples might be: maize residue--dual-purpose goats; sweet potato--swine; and maize and beans plowed with oxen. Most mixed systems would include other feed sources in addition to crop residue. For example, cattle on the same farm may be grazed, fed cut-and-carry forage crops, and tethered to feed on crop residue. An initial task should be the identification of the components that interact to form the mixed system.

Procedures used in the analysis of the crop and livestock components within a mixed system are similar to those followed in crop-based and livestock-based systems, except that the analyses must systematically include crop/livestock interaction criteria in the selection of potential modifications. For example, the agronomist analyzing the crop component must be continually aware of the nutrition requirement of the animal components, and the animal specialist must be aware of the feed-producing limits of the system. Many mixed systems also include a feed storage component. In areas where dry-season feed availability is a constraint, this component is obviously extremely important.

The advantages from emphasizing on-farm activities (as opposed to field station research) are: (1) the researcher is forced to work under the same constraints as the farmer and is, therefore, more likely to direct the research towards "real problems" as opposed to problems associated with the researcher technical biases; (2) the cumulative experience of generations of farmers that lived and survived in the area is available if the farmer participates in the design of alternatives; and (3) the evaluation of potential technology and technology transfer is a continuous process as neighbors begin to copy successful technology.

SYSTEMATIC LINKAGE WITH OTHER DEVELOPMENT INSTITUTIONS

Within the framework of the Winrock position paper, national programs received most emphasis; however, some of the crucial roles of other development institutions were outlined also. Regional environmental, socioeconomic, and farm management studies can be conducted concurrently with the on-farm-production-system studies. The results from these studies and the field-station screening of potential technology generated by international research centers or other research groups can be combined to identify potential alternatives. The evaluation of these alternatives within the environmental limits of the target area is an important step, not only to screen and reject less promising alternatives, but also to identify the environmental limits of the potential alternatives.

The IARCs serve primarily to generate new technology that will alleviate constraints and develop potentials for major increases in agricultural productivity. Such technology is not available now, and is not likely to be developed within current national, regional, and other research
programs. Thus, the Winrock team recommended that IARCs should focus on high-level constraints/potentials such as: pasture management and improved pastures; immunological mechanisms and methods of control of trypanosomiasis and other hemoproteozoan diseases; incorporation of disease and pest resistance traits in susceptible animals; incorporation of desirable production traits in local stocks; integrated pest management programs (e.g., to control ticks and tsetse flies); and animal traction power. IARC research would be sharply focused on priority production problems/potentials.

It was suggested that the United States institutions, both public and private, should continue to have a prime role in agricultural development with (1) academic institutions providing the technological and educational base and personnel to contribute to research and training programs in developing countries; (2) private foundations and public nonprofit organizations engaging in a wide range of research, training, and development programs; and (3) the private sector becoming increasingly involved in the implementation of joint ventures with developing countries.

CONCLUSION

With this necessarily brief description of a worldwide strategy and priorities, I will conclude—hoping that we can discuss any questions that you might have... either about the myths that I've mentioned—or the priorities and strategy that can replace the myths and produce more meat, milk, and grain for a quality world food system.
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Rapporteur's Comments
by Peter Hopcraft*

Mr. D.N. Sutherland, the Chairman, opened the discussion by saying that he was glad to see that a number of familiar myths regarding livestock in developing countries had been laid to rest. The first is that livestock production and the consumption of livestock products are unimportant for the relatively poor. For a great many low income producers and consumers livestock is, in fact, extremely important.

A further myth is that an inherent conflict exists between human and animal nutrition. The origin of this myth is the impression that livestock are predominantly in feedlots, consuming grain. While intensive feed components can play an important part in a more extensive livestock production system, there is very little grain fed to livestock in the developing world and the Bank finances virtually none of it. Most of the grain fed to livestock is in the OECD countries and the Communist Bloc. Apart from that it is almost entirely to poultry and swine rather than to cattle.

Mr. Sutherland also strongly agreed that priority should go to ruminant animals rather than single stomached livestock such as swine and poultry. There are vast forage resources from crop residues and from marginal or inaccessible land where food crops are infeasible. The special role of the ruminant is to transform these abundant and low cost resources into consumable and saleable products.

On the issue of animal traction Mr. Sutherland noted that while it has been regarded with disdain by some officials in developing countries, it is a major, low-cost energy source for agricultural production and transport. Development agencies and host governments are currently showing increasing interest in research and support in this area. Three avenues are particularly important for further research/or promotion. The first is innovation with respect to harnesses and animal-drawn equipment. The second is improved nutrition and management of the draft animal. The third is adjusting the pattern of tillage and other demand for the animal's time so that capacity can be used more evenly.

On the issue of concentration on livestock areas and livestock projects, Mr. Sutherland noted that the Bank has moved more toward mixed agricultural and livestock projects. The greater potential for increasing livestock numbers and livestock productivity is in the medium and higher rainfall areas and this is being recognized and supported by the Bank with livestock components in projects relating to agriculture, credit and rural development.

While the potential is greater in the higher rainfall areas the problems are also more complex. Problems of livestock management, breeding, disease control and forage production require more attention in a move toward integrated crop livestock activities. Mr. Wheeler noted that a

* Economist, Economics and Policy Division of AGR.
great deal of the development of the livestock industry in the US has taken place in the South. Higher temperatures and rainfall have raised disease and pest problems that are far more serious than those occurring in the North and the West. Much depends on the skill and management ability of the producer and the technological support he receives.

Mr. Parbery discussed the need to reconcile agriculture, livestock and human nutrition. The long-term problem is the ability of the soil to sustain the production system, and an ecologically balanced approach that considers soil, plants, animals and humans is required. Apart from land resources he also discussed those of the sea and inland waters. Mr. Wheeler responded that there is a unfortunate tendency to ignore the total system and look at it in pieces in isolation from each other.

Mr. Jones noted that while swine and poultry are major grain consumers in some countries they are raised far more efficiently in others. In China, for instance, swine hardly compete with humans for grain at all. Mr. Wheeler agreed that the Chinese have a very efficient system and that it is not necessary to use grain for swine or for them to compete with people. The aggregate world picture however is one of massive grain consumption by swine.

Mr. Nissen noted the increased appreciation of draft animal power and asked what constraints the speaker saw to its introduction. Mr. Wheeler emphasized the deficiencies in engineering and manufacturing support for draft power activities. He noted that in the 1920s a stream of ingenious innovations resulted from a concentration of skilled engineers on draft power problems. The problem is that the most interesting and promising career opportunities for engineers are now elsewhere.

Mr. ter Vrugt noted that in West Africa there were also physical constraints on the farmers' use of draft power. Where animals are used only once a year furthermore they become wild and need to be broken in again each season. In the drier areas soils often become too hard, and if plowing has to wait for the rains to soften the ground the benefits of early planting may be lost. Mr. Wheeler agreed that animals are often undernourished, weak and untrained at plowing time and that equipment is often heavy, dull and poorly designed. This can result in an inadequate depth of plowing, poor weed control and the raising of hardpans. He again emphasized the need for better lighter weight and cheaper equipment. He recognized that some good work is going on in this area but not enough. He felt that a centralized effort to design and test equipment and techniques is called for. Mr. Ellis described some work relating to improved yokes that had very substantially improved the energy transfer between animal and equipment. He felt that the first job was to gather the best techniques and materials that are already available relating to ploughing and other practices.
Relating to pigs and poultry Mr. Ellis pointed out that these very often had an important role on the periphery of agricultural production systems. In using residues, marginal feed and waste, such livestock operates at very low cost but makes a significant nutritional or income contribution.

Mr. Ashworth described the anachronistic grain dependence of much of the livestock industry of Eastern Europe and the Middle East, some of it supported by the Bank. He felt that traditional livestock systems in low income countries, often written off as unproductive and inefficient, are frequently far more efficient than the development projects set up to replace them. It is easy to point out that bigger and more productive animals exist but to ignore questions of cost and feasibility. He particularly warned against the naive importation of expensive breedstock from more developed countries. It is often not feasible to reproduce the level of management, nutrition and disease control to which these animals are accustomed. Beyond the question of their survival is the question whether they can perform economically in their new environment. He felt that one should look very carefully before saying something that exists in low income agriculture is inefficient. Given the circumstances it may be far more efficient than its alternatives. Mr. Wheeler agreed that it was very often possible to be diverted by issues of biological efficiency when the real issue is economic efficiency.

Mr. Wallis noted the antipathy for livestock in the agarian reform movement in Latin America. There is a belief that livestock is a large farm enterprise and has no place with the small farmer. In fact he noted that there was considerable coincidence of crop and livestock activities, though in some areas crops such as sugar appear to be displacing livestock. Mr. Wheeler reemphasized that the image of where cattle are is often not true, and that livestock play a crucial role where there are very poor people and high population densities. He again noted that in the US there has been virtually no livestock production increase in the Western states, traditionally regarded as livestock areas, and that the major increases have been in the more intensive farming areas.

Mr. Argyle noted that it was the farmers not the professionals who had shifted livestock production patterns in the US, and that the same applied in other countries. The impression that there was little Bank lending for livestock was also not true. For many of the crop-oriented projects a good deal of the money finds its way to increasing livestock production at the initiative of the farmers. Mr. Wheeler again noted the importance of livestock to the resource use and the food supply system of small farmers. It is not merely a luxury.

Mr. Olivares discussed the role of livestock for transport and raised the possibility of mule trains and camel trains as an alternative to feeder roads in the southern Sahel. Mr. Wheeler felt that these were economical means of transport but that projects in this area were unlikely to sell.
Mr. von Samson discussed the possibility of unconventional feed sources for livestock and mentioned the recycling of chicken manure as a feed source for cattle. Mr. Wheeler felt that such sources were not very significant in most areas and warned against seeking miracles in the area of feed supply.

The final question related to the institutional and administrative structure and the coordination between crop and livestock production services in developing countries. A drive for separation between the various branches of government often exists, in some cases resulting in the splitting of ministries between livestock and agriculture. Mr. Wheeler mentioned the political issues that frequently underlie such splits, but also noted that two ministries could have more political clout than one. Mr. Sutherland concluded by pointing out that it was very hard to look at a total farm system on an individual commodity basis and that the countries that had made the split were tending to experience greater difficulties with coordination.

Mr. Sutherland thanked the speaker for a lively and interesting presentation.
SESSION VII

ECONOMIC IMPACT of DISEASE on LIVESTOCK PRODUCTION in DEVELOPING COUNTRIES
THE ECONOMIC IMPACT OF DISEASE
ON LIVESTOCK DEVELOPMENT IN DEVELOPING COUNTRIES

by

Peter R. Ellis*

Through this contribution I hope to put animal disease into clearer perspective among the main constraints on livestock productivity. I hope too, to seed a few ideas which will help developers of livestock projects to anticipate and avoid many of the health problems that could jeopardise the success of their schemes. Thirdly, I want to draw attention to the urgent need to develop appropriate infra-structures which will promote herd health and productivity while also strengthening control over major diseases.

THE NATURE OF DISEASE PROBLEMS

The Challenge of Epidemics

To anyone who has worked with livestock in developing countries the words "Animal Disease" usually bring to mind dramatic events and frightening risks. A new dairy herd, carefully built up from imported animals over many years is decimated by foot and mouth disease. The best Holstein bull is in agony with oozing blisters around the top of each hoof. One hoof is so severely affected that it will be deformed permanently and he may never again be able to serve a cow properly. As the veterinarian begins his examination the entire surface layer of the bull's tongue slips off like a glove. Meanwhile, the cows' daily yields have dropped from 15 litres of milk to two and mastitis has flared up in some of the udders, to add to the damage. Many of the young calves have died and more will go. The future breeding animals we were counting on to help to start new herds and to upgrade the country's hardy but low-producing native stock are disappearing. A migrant herd had passed by two weeks or so earlier and there was contact across fences. This was a real situation that I encountered a few months ago. The owner wept! As we looked around we found native and cross-bred stock not so desperately sick but suffering in hundreds, calves dying by the dozen and the sheep involved too. Many had been vaccinated but a new sub-type of foot and mouth virus from a neighbouring country had broken their immunity.

Other scenes, other times, but the same story: in an Indian village in 1976 two thirds of a maize crop lost because almost all the buffaloe had been lame for a month and could not cultivate the land; at the Palermo show in 1960 so many fine animals affected that the Secretary of Agriculture of Argentina called it a national disgrace and declared war on foot and mouth disease; Botswana misses its meat export earnings target in 1980 by nearly 30% because foot and mouth disease in the North results in a ban on the valuable trade with the EEC. Indeed, so many examples of this problem could be cited from Asia, Africa and Latin America that it is hard to stop.

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One could go on, too, to even more dramatic disease events. We read of Malta's decision to destroy all the country's pigs two years ago, and start again. A single disease had already killed a high proportion of pigs and threatened all future development of the industry. African swine fever had slipped into the country. At about the same time in 1978, this same disease appeared in the Dominican Republic and Brazil, probably through feeding pigs on waste meals from transient aircraft, and caused the death of tens of thousands of pigs not to mention all the consequences that such a crisis brings to farmers, meat processors and veterinary services. In a typical outbreak in the Dominican Republic 20% of pigs were affected and half of these died. Equally important from the economic point of view was the fact that the price of pigmeat fell as much as 50% in the first few months of the epidemic, due to consumer's fears that they might contract the infection, although they had been given all possible assurances to the contrary (McCauley 1979).

Rinderpest is again threatening the cattle populations of East and West Africa. Vaccine coverage and quarantines have dwindled and political upsets have caused irregular movements of stock. Rinderpest persists in Asia too and wherever it occurs effects are very severe, as the countries of the Near East found to their cost when it spread into that Region in 1969.

Rinderpest became dominant among the many constraints on livestock development further back in time. An enormous epidemic began in the Horn of Africa in 1889 with the introduction of affected stock from Aden into Somalia. From there it spread relentlessly and disastrously towards South Africa, which became infected in 1896 despite extensive control measures including the construction of a 1,000 mile quarantine fence. Very high mortalities occurred in all the countries en route, not only among cattle but also among game species. Phrases such as "ruin and devastation over vast areas of the country" occur in descriptions of this epidemic. The long term effects of similar epidemics in West Africa were particularly interesting. Historical and statistical evidence suggests that the policy of retaining old and less productive cows in nomadic herds in West Africa arose as a defence against the sporadic and epidemic outbreaks of the disease which continued until the late 1950s (Felton and Ellis 1975). Until vaccination was introduced in the 1920s mortality was often as high as 90% among animals that had not experienced the disease before, whereas recovered animals remained permanently immune. The success of the internationally funded Joint Project 15, under the aegis of the Inter African Bureau of Animal Resources, in almost eliminating rinderpest from Nigeria and many other African countries must have restored producer confidence. They seemed willing to concentrate more on the productivity than on the survivability of their animals. From 1968 onwards they became willing to sell a more appropriate proportion of females for slaughter than had been recorded previously.

Such examples illustrate how the transfer of a disease agent into a different animal population can affect animal industries in various ways. In addition to immediate losses in meat and milk there are long term effects on herd structure due to depressed fertility and delayed growth. Risk and uncertainty may bring fundamental, and detrimental, changes in management policy. There can be effects upon the prices of products too: downward due to consumer reluctance to buy as well as upward due to scarcity. Loss due to removal of draught power may be as much as ten times greater than the loss of milk and meat where there is no alternative power source for cultivation (Ellis and James 1977), and even more if irrigation water cannot be pumped out of wells at critical times. It should be borne in mind, however, that the full extent of these losses can only be avoided if eradication programmes are carried through to a successful conclusion.
Disease Challenges from the Environment

Stories about epidemic diseases are always fascinating and capture public attention but their significance must not be over-emphasised. Thanks to modern disease control aids many epidemics can be brought under control before they can have such severe impact. In the natural evolutionary process, animals either learn to live with disease agents, as warthog have done with African swine fever virus, or disappear, as pig herds have done from many affected areas in Africa. Similarly, myxomatosis almost eliminated the rabbit populations of many countries but a few resistant animals have survived and the populations are regenerating in equilibrium with the disease.

Health measures contribute far more to economic development by minimising the effect of disease challenges from the environment. Trypanosomiasis is the most obvious example. If cattle, sheep and goats are to be maintained in some 4,000,000 square kilometres of Africa steps must first be taken to prevent the highly lethal effects of this blood parasite. The parasite is found in many wildlife species. The tsetse fly, its main vector, must either be eliminated and the protective habitats destroyed so that it cannot return, or the animals must be kept on a constant regime of high priced drug treatment. A few breeds with relatively small numbers in each, appear to be resistant to this problem but it remains to be seen whether resistance can be maintained when efforts are made to improve their productivity by selection and cross-breeding. Since man is also affected by trypanosomiasis the problem has many social as well as economic implications. In fact, our own studies have shown that effective control depends on population pressure on land (Putt et al 1980). Unless land use is going to be intensified, tsetse fly control is uneconomic. If more grazing or cultivable land must be brought into use, as is the case in many parts of Niger, tsetse control can speed this process so much that benefit/cost ratios of the order of 5:1 result from the expenditures involved. Other resources are needed to realise the productivity of the land and secure it against the return of the fly but even so, the economic returns to trypanosomiasis control are very high.

Tick-borne disease is another and much more widespread environmental hazard. There are many species with many wildlife hosts and many of these are also reservoirs of blood parasites. Very few tropical and sub-tropical areas of the world are free of ticks. Ticks need to feed on blood so they cause direct wastage, toxic effect, and skin damage which allow serious secondary infections to develop. In addition they carry a wide range of protozoal infections: theileria, anaplasma, babesia and heartwater which destroy red blood cells and, thus, disturb the metabolism of infected animals. Stress of climatic, movement or other diseases make matters worse so productivity of animals in all respects is chronically depressed. The theileriosis problem of East Africa is exceptionally serious. Theileria parva, the causal agent of East Coast Fever, kills a high proportion of young calves if they are exposed to even a very small number of infected ticks. Mortality rates among calves in their first year of life are frequently as high as 40% and East Coast Fever is responsible for more than half of these deaths. The symptoms are so striking that most cattlemen can make a diagnosis.

Efficient animal production in any tick infested environment, therefore, requires a regime of tick control and a policy toward any tick borne disease that may be involved. For the former, regimes may range from dipping selected
groups of animals four to six times a year to the dipping of all animals once
and sometimes twice a week throughout the year. Fairly effective vaccines are
emerging for some of the blood parasites and these may be used to complement
tick control regimes. Neither ticks nor the related blood parasites can be
eradicated so the animal population must achieve an equilibrium with them which
is acceptable in terms of costs and productivity.

Paralytic rabies, Derreingue, in cattle is a special constraint in Latin
America and the South Western U.S.A. Sometime, perhaps around the turn of the
century in Brazil, a blood-lapping bat fed on an animal which was in the viraemic
stage of rabies. The virus established a disease pattern in bat colonies and
as cattle production has extended and intensified, so have the bats and so has
the disease. Wherever suitable caves and hollow tree-trunks are available bat
colonies go through a cycle of infection, epidemics and wholesale deaths. As
they take their nightly feeds, moribund bats infect cattle and horses and man,
with virus in their saliva and this produces invariably fatal damage to the
animals' nervous systems. Average annual mortality rates of 5% to 10% used to
occur in the Pacific coastal region of Mexico and occasional, localised, epidemics
in cattle resulted in death of 30% of animals of all ages. Affected bat colonies
are decimated and in the delirium before they die some bats may slip into
fresh colonies to start a repetition of the cycle. In time too, the vacant
habitats will be restocked with new bat colonies - and so the cycle continues.
Unless a vaccination regime is maintained, and linked to bat control techniques
in the worst affected areas, cattle productivity is constantly at risk.

There are many bacterial hazards to be contended with too. Anthrax spores
can lie dormant in the soil for decades and only a very few are needed to
establish a lethal infection in animals as they graze or man as he works the soil.
A steady challenge persists in most tropical areas and where floods occur, epidemics
often follow as the land dries out. Spores are brought to the surface and contam-
ninate the succulent new grasses or vegetables. Cattle owners of the Bolivian Beni
area face this problem every year and Haiti has seen catastrophic animal losses
and hospitals over-flowing with human cases of anthrax following a hurricane and
associated floods. A strict regime of vaccination is essential if livestock
industries are to survive in such ones.

Similar preventive programmes are essential for many other bacterial
infections in different species and different areas of the world. Cattle
owners must beware of the clostridial infection which causes blackquarter
in their calves. Shepherds should develop vaccination cycles for ewes and
lambs to avoid severe losses from dystentry in lambs and a variety of conditions
in older age groups caused by the same family of bacteria. Anyone who has been
associated with cattle in Asia will recall, too, the dangers of haemorrhagic
septicaemia at the onset and during the rainy season; unfortunately, we are
still not sure of how this infection survives and develops, nor are vaccines
fully effective against it in the field. Mortality can range from 15% to 20%
in cattle and from 30% to 45%, and even to 64%, in unprotected buffalo herds.

The Challenge of Disease in Changing Production Systems

The mention of man brings us to the third type of animal health problem -
the one that he induces. Intensification of grazing systems for cattle and
sheep - more animals on the same piece of ground, facilitated by fencing and
fertilizer - creates potential for enormous challenges by worm parasites. Not
only are more parasite eggs deposited per hectare but also the more favourable
environment that man induces allows more of them to produce infective larvae.
An improvement of the grazing system must be paralleled by control strategies
which minimise this new risk.
Similarly, larger settled herds and flocks develop greater risks from "special" diseases such as tuberculosis and brucellosis. By reducing concentrations of people and improving living conditions public health authorities have removed tuberculosis from many human societies. Intensification of animal production forces cattle populations in the opposite direction: contact rates increase and so does the incidence of tuberculosis. The spread of brucellosis also depends on intimate contact between domestic animals. In neither instance is there a significant wildlife reservoir so managers and their advisers must do all they can to prevent the introduction of such diseases as herds enlarge, and maintain constant vigilance so as to be able to take prompt action if disease does appear. The solutions to such problems obviously lie in part through management and in part through veterinary intervention.

Emphasis on high productivity also induces more sophisticated problems. The higher the production required of the dairy cow, the higher is the incidence of mastitis. If input/output relationships are not correctly maintained, metabolic disease develops due to deficiencies of energy or amino acids required for general body maintenance or subnormal levels of the specific chemical ions which maintain particular body functions. Simple, but none-the-less damaging problems, arise from the difficulties in managing larger numbers of animals and consequent lessened contact with individual animals: fertility drops because animals ready for mating are not identified in time; subclinical infections of salmonella and coliform organisms build up in ewes and cows that can infect progeny at birth while the mothers remain healthy; progeny get lost or do not receive, opportunely, the colostrum from their mothers which contains the initial supply of antibodies that is so necessary for their survival; and lameness becomes a problem because animals' hooves are not subjected to enough normal wear and tear. Preventive measures can be taken against all these problems but new levels of management discipline are needed.

Yet another facet of man's involvement may be the induction of completely new disease problems. Vesicular exanthema and swine vesicular disease are good examples. The former seems to have been associated with the feeding of sea-lion meat, along with food waste, to pigs in California during the second world war. A virus, since related to one found in sea-lions off the California coast, caused a condition like foot and mouth disease and spread across most of the U.S.A. Fortunately, elimination of affected herds and more effective heat treatment of garbage-feed have brought about the eradication of vesicular exanthema. Swine vesicular disease has proved more intractible. It seems that a coxackie virus, which normally causes mild respiratory disease in man, became established in pigs somewhere in Asia. Infected pig caracses brought the virus to Europe where it was propagated by the extensive practice of using waste foods for pigs. Unfortunately, swine vesicular disease is less dramatic in character, and the virus is more resistant to cooking and to disinfection, so eradication is proving much more difficult. Other new diseases have arisen and are certain to arise from time to time, due to chance combinations of events.
Animal Disease and Human Health

Up to this point the focuses of attention have been the nature, dynamic character and impact of disease in animal populations. We must also take into account more than 100 diseases, generally termed zoonoses, which are shared by animals and man. Sleeping-sickness, caused by tsetse-transmitted trypanosomes, and rabies are well-known examples, as are the bovine form of tuberculosis, the brucellosis/undulant fever complex, anthrax and hydatidosis. As cooperation between public health and veterinary authorities has intensified a much deeper understanding of the interactions between man and animals in the propagation of disease has emerged. It has become clear for example, that influenza infections in horses and pigs can so change the causal virus that it produces major epidemics when it passes back into humans. The significance of animal salmonellosis as a source of food-borne epidemics has become obvious, too, and more insidious problems like diarrhoea in farm workers, associated with parvo-virus diarrhoea in pigs, are attracting attention. It is imperative, therefore, that cooperation with doctors and public health authorities be sought in developing animal health activities.
FIGURE 1.

Interaction between host and environment.

MODELS AND ECONOMIC ANALYSIS

At this point the casual listener or the reader might be forgiven for wondering how any animal production system ever manages to operate successfully amid all these challenges. In fact, all that is required is recognition of the fact that each ecosystem will present its own unique mixture of health problems. These will result from the interactions between the characteristics of the animals, the agents and of the environment in which they find themselves. Figure 1 gives some idea of the complexity of these inter-relationships. Susceptibility of an animal is affected by individual, breed and species characteristics per se as well as by its reactions to external effects induced by management, nutrition and climatic conditions. The viability of disease agents will be affected similarly by their own innate characteristics, and those of any vectors that may be involved, as well as by the response of each to environmental characteristics, whether they be natural or man made. Then there is the combination of factors in the host and agent systems which determines whether they make the effective contact which will give rise to a disease process.

It is not surprising, therefore, that there are major differences between the ranges of health problems encountered in different Continents of the world. With many constraints working against the survival and transmission of agents and high probabilities that the natural characteristics and responses of animals will prevent the establishment of infection the odds are stacked against the development of disease, quite heavily. Thus, paralytic rabies has remained unique to the Americas while East Coast Fever and tsetse-borne trypanosomiasis appear only to affect Africa and Haemorrhagic Septicaemia is a far more serious health problem in Asia than anywhere else in the world. The mix of problems must also vary from zone to zone, and even from district to district within a country, as a result of differing ecological, economic and human social circumstances. Ticks, worm parasites, bacteria and viruses and other agents as well as their hosts and vectors are all influenced very strongly by micro-climates, geography, marketing systems and other variables which determine whether different disease processes can become established and then prosper, disappear or reach a tolerable equilibrium level.

Conceptual and Economic Models: Obviously, all diseases can be viewed as dynamic biological systems. Individual diseases can be depicted in conceptual diagrams and, when the flow of events is understood, mathematical models can be devised. Figure 2 shows the flow of events in a relatively simple disease, swine fever (Hog cholera) infection circulates within each type of pig unit and may spread between units and between farms by movement of pigs which can be traced and measured. Typical disease outbreaks may result but a combination of definable factors may also allow inapparent infection to persist in breeding herds. Immune-tolerant piglets can then spread the disease to other units without ever showing signs of the disease themselves. Such a conceptual model helps field officers and research workers to determine the features of the production and marketing systems which facilitate these events and to quantify the risk that spread will occur. In figure 3.1, the more complex events involved in bovine brucellosis are shown. The initial status of groups of animals is depicted and the types of event which change the numbers of animals in each group over any selected time period are shown by arrows. The probability that each event could occur in each time period can be estimated for each animal according to age and management system from existing knowledge of the epidemiology of brucellosis. Thus a herd or population model composed of different categories of stock, as symbolised in figure 3.2, can be used manually or in a computer
to simulate the changing pattern of disease. Effects of disease and of control techniques can then be measured through changed parameters: births, growth rate, deaths and output - in this population. Realistic monetary values for these effects can be obtained by assessing their impact on inputs and outputs and we return to swine fever for a simple illustration in tables 1 and 2 of the physical and financial effects of an average outbreak of disease in a British pig herd. Response to control measures can be reflected through assumed
FIGURE 2.

Fig. 2. Simplified conceptual model of swine fever in an open herd.

- Disease transmission by direct contact between individuals.
- Disease carried by pigs transferring between classes.

[Disease transmission by direct contact between individuals.
Disease carried by pigs transferring between classes.]
FIGURE 3.1.  
A Model of Bovine Brucellosis.

FIGURE 3.2.  
The Structure of the Brucellosis Model.

[From Hugh-Jones, Ellis and Felton (1975) An Assessment of the Eradication of Bovine Brucellosis in England and Wales, University of Reading, Department of Agriculture and Horticulture, Study No.19]
TABLE 1

CHANGES RESULTING FROM SWINE FEVER IN A 100 SOW HERD BREEDING AND FATTENING TO CUTTER WEIGHT (BASED ON MLC PIG FACTS 1971)

<table>
<thead>
<tr>
<th></th>
<th>TOTAL</th>
<th>BOARS</th>
<th>SOWS</th>
<th>PIGLETS (0-8 wks)</th>
<th>STORES (9-14 wks)</th>
<th>FATTENERS (15-26 wks)</th>
<th>NO. SOLD PER MTH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal Herd</td>
<td>1080</td>
<td>5</td>
<td>100</td>
<td>300</td>
<td>225</td>
<td>450</td>
<td>150</td>
</tr>
<tr>
<td>*SF. Mortality</td>
<td></td>
<td>1</td>
<td>8</td>
<td>101</td>
<td>81</td>
<td>75</td>
<td>-</td>
</tr>
<tr>
<td>Premature Slaughter</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>375</td>
<td>-</td>
</tr>
</tbody>
</table>

Herd Structure at end of:

<table>
<thead>
<tr>
<th>Month</th>
<th>-</th>
<th>4</th>
<th>92</th>
<th>238</th>
<th>243</th>
<th>-</th>
<th>375</th>
</tr>
</thead>
<tbody>
<tr>
<td>Month 2</td>
<td>-</td>
<td>4</td>
<td>95</td>
<td>281</td>
<td>247</td>
<td>96</td>
<td>-</td>
</tr>
<tr>
<td>Month 3</td>
<td>-</td>
<td>4</td>
<td>98</td>
<td>290</td>
<td>236</td>
<td>245</td>
<td>-</td>
</tr>
<tr>
<td>Month 4</td>
<td>-</td>
<td>5</td>
<td>100</td>
<td>297</td>
<td>228</td>
<td>395</td>
<td>-</td>
</tr>
<tr>
<td>Month 5</td>
<td>-</td>
<td>5</td>
<td>100</td>
<td>300</td>
<td>225</td>
<td>449</td>
<td>96</td>
</tr>
<tr>
<td>Month 6</td>
<td>-</td>
<td>5</td>
<td>100</td>
<td>300</td>
<td>225</td>
<td>450</td>
<td>149</td>
</tr>
<tr>
<td>Month 7</td>
<td>-</td>
<td>5</td>
<td>100</td>
<td>300</td>
<td>225</td>
<td>450</td>
<td>150</td>
</tr>
</tbody>
</table>

*Reflecting mortality and depressed growth rate in recovered animals.

TABLE 2

CASH FLOW CHART FOR THE 100 SOW HERD IN TABLE 1.

<table>
<thead>
<tr>
<th>PERIOD FOLLOWING SF CONFIRMATION</th>
<th>A VALUE OF SALES £</th>
<th>B (3) COST OF FEED USED £</th>
<th>C (4) OTHER COSTS £</th>
<th>(B+C) TOTAL COST £</th>
<th>A-(B+C) GAIN OR (LOSS) £</th>
<th>D NORMAL MARGIN £</th>
<th>A-(B+C+D) NET GAIN OR (LOSS) £</th>
</tr>
</thead>
<tbody>
<tr>
<td>Month 1</td>
<td>3263(1)</td>
<td>932</td>
<td>768</td>
<td>1,700</td>
<td>1,563</td>
<td>124</td>
<td>1,439</td>
</tr>
<tr>
<td>Month 2</td>
<td>-</td>
<td>1,136</td>
<td>768</td>
<td>1,904</td>
<td>(1,904)</td>
<td>124</td>
<td>(2,028)</td>
</tr>
<tr>
<td>Month 3</td>
<td>-</td>
<td>1,401</td>
<td>768</td>
<td>2,169</td>
<td>(2,169)</td>
<td>124</td>
<td>(2,293)</td>
</tr>
<tr>
<td>Month 4</td>
<td>1</td>
<td>1,671</td>
<td>768</td>
<td>2,439</td>
<td>(2,439)</td>
<td>124</td>
<td>(2,563)</td>
</tr>
<tr>
<td>Month 5</td>
<td>*1697(2)</td>
<td>1,758</td>
<td>768</td>
<td>2,526</td>
<td>(831)</td>
<td>124</td>
<td>(955)</td>
</tr>
<tr>
<td>Month 6</td>
<td>*2634(2)</td>
<td>1,760</td>
<td>768</td>
<td>2,528</td>
<td>106</td>
<td>124</td>
<td>(18)</td>
</tr>
<tr>
<td>Month 7</td>
<td>*2652(2)</td>
<td>1,760</td>
<td>768</td>
<td>2,528</td>
<td>124</td>
<td>124</td>
<td>-</td>
</tr>
</tbody>
</table>

Loss = £64.2 per sow in the unit

Total = £(6,418)

(1) Emergency slaughter value
(2) *Sale price = £18.23 less 3% for normal mortality = £17.68/pig.
(3) Feed costs per month: Boars £3.5, Sows £4.55, Piglets £0.26 and fattening pigs £1.80 (adjusted for minor "rounding" error in months 5, 6 and 7).
(4) Normal fixed operating costs per month excluding feed.

(From Ellis (1972) An Economic Evaluation of the Swine Fever Eradication Programme in Great Britain. University of Reading Study 11)
effects on production parameters and in addition to the cost component of the financial model. As an example from a study in the Third World, Table 3 presents some of the losses estimated to occur from foot-and-mouth disease in different types of Indian cattle and buffalo unit.

Prediction of trends and responses: In each of these examples, observed losses could be linked to statistically determined probabilities that the events and losses would occur in a series of different populations over a reasonably predictable period of years. Changes in the populations could be taken into account and the likely impact of control strategies deduced. In fact, the author and associates felt confident enough from the U.K. study (Hugh-Jones, Ellis & Felton) to predict in 1975 that bovine brucellosis could be eradicated in 1981. The Minister of Agriculture announced this achievement in November 1981. Through such analyses it has also been possible to provide decision makers with evidence which resulted for example, in the acceleration of brucellosis, tuberculosis and swine fever eradication activities (ECC countries: Ellis et al) initiation of intensive foot-and-mouth disease control (India), changed animal health priorities (Tanzania) and the abandonment of a major disease control scheme (in a country that should remain nameless). At the herd level too, in a Sri Lankan village and in large high technology dairy farms in Colombia, for example, it has been possible to develop physical and financial projections on which appropriate health and production policy could be based.

Priorities: A final consideration emerges from this review of the impact of animal disease. Since disease is only one of many constraints on animal production systems, health control schemes cannot be viewed in isolation. They must be allocated an appropriate degree of priority among the whole range of feasible actions that can be taken to improve productivity. Figure 4 illustrates how the different constraints place ceilings on productivity but the order may vary, just as the complex of health problems varies, from ecosystem to ecosystem. Trypanosomiasis control must take precedence over pasture improvement in a tsetse infested zone, for example, and intensive tick control must be given very high priority wherever East Coast Fever exists. In other zones of Africa provision of water is still the limiting factor to livestock improvement. In Latin America nutrition and management often require thorough attention before disease becomes a serious limitation to productivity.
### TABLE 3

**ESTIMATED ANNUAL IMPACT OF FOOT-AND-MOUTH DISEASE IN CATTLE AND BUFFALO IN INDIA**

Thousands of Rupees (at 1976 values)

<table>
<thead>
<tr>
<th></th>
<th>MILK ANIMALS</th>
<th>DRAUGHT ANIMALS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Native Cattle</td>
<td>Buffalo</td>
</tr>
<tr>
<td>Direct loss of milk</td>
<td>205,901</td>
<td>516,506</td>
</tr>
<tr>
<td>Loss of milk due to infertility</td>
<td>153,229</td>
<td>481,894</td>
</tr>
<tr>
<td>Loss of milk due to Abortion</td>
<td>33,519</td>
<td>111,821</td>
</tr>
<tr>
<td>Disposal/mortality of animal</td>
<td>43,096</td>
<td>55,910</td>
</tr>
<tr>
<td>Values of calf lost through abortion/mortality</td>
<td>38,307</td>
<td>39,936</td>
</tr>
<tr>
<td>Cost of hiring draught animal</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Permanent disability</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Longer rearing time for young stock</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><strong>TOTAL ('000 Rs)</strong></td>
<td>474,052</td>
<td>1,206,067</td>
</tr>
<tr>
<td><strong>% of Total</strong></td>
<td>11.3%</td>
<td>28.7%</td>
</tr>
</tbody>
</table>

**GRAND TOTAL = Rs 4,198,500,000**
FIG. 4. Relationships between various inputs and livestock production.

[Ellis and Hugh-Jones, 1976]
EFFECTIVENESS OF VETERINARY SERVICES

Disease Control: Having reviewed the types and extent of disease constraints, it is now appropriate to consider how successful developing countries have been in dealing with them. As suggested earlier, spread of disease overseas is less common now than in the past because import controls and prohibitions are being more effectively exercised. However, pursuit of publications from international reporting services such as those of OIE, FAO, IBAR, PAHO and APHCA, (see list of abbreviations) reveals that localised spread of major diseases across borders is still a common occurrence in the developing world. This is understandable because movement over a vast majority of inter-country borders is uncontrollable due to terrain, climate and lack of staff. Often such movement is technically, economically or socially desirable because of family or tribal links across the border or the need for transhumance or access to markets. Progress against new epidemics of disease, the first of our challenges depends, therefore, on the formulation of inter-country and regional projects which address individual problems on the basis of thorough understanding of the ecological and socio-economic factors involved. The success of JP15, which brought rinderpest near to eradication from Africa was very encouraging and it is to be hoped that the present initiatives will recoup lost ground and lead on to complete eradication from the whole of Africa. However, this success may have caused undue optimism toward the possibility of eradicating other diseases. Rinderpest is almost unique among animal diseases in its epidemiological simplicity: a single type and strain of virus, no significant wildlife reservoir, death or permanent immunity following recovery, and a reliable vaccine which confers a strong resistance with a single dose. Few other diseases offer this combination of features. Contagious bovine pleuropneumonia, often mentioned as the second candidate for eradication in Africa, is much more insidious, complex and, consequently, difficult to control. Foot and mouth disease is even more complex, with so many types and new subtypes of virus, as well as easy transmissibility between cattle, sheep, goats, pigs and several wildlife species, to be overcome. Vaccines have to be correspondingly complex and varied to suit local needs and at best they still confer immunity for less than a year. Limited schemes are clearly justified. Botswana, could export beef to Europe as a result. Kenya, with a well developed dairy industry and high quality beef, showed a benefit cost ratio of 4.55:1 from its vaccination programme over ten years (Ellis and Putt 1981). Costs are very high, however, and the discipline of intensive surveillance, quarantines and movement controls is hard to maintain.

On balance, the near term prospects for major infectious disease control schemes on a nationwide and international basis in Africa are not very encouraging. In Asia, however, the human resources are available and more could be done through systematic campaigns. In Latin America prospects are varied. A start has been made on foot and mouth disease in some zones but in others livestock populations and support services are too sparse to mount the necessary operational and supervisory teams.

In dealing with some of the environmental disease hazards veterinary services have made substantial progress. Nigeria’s tsetse eradication schemes have, in most instances, paved the way to much higher productivity from land and livestock with benefit cost results as high as 5:1. A further result is a set of criteria on which the choice of control strategies should be based (Putt et al 1980). Tick control is quite well established too, worldwide, but deficiencies in management and supervision of dips diminish their effectiveness in some areas. Preventive routines for the main bacterial diseases, such as anthrax, blackquarter and haemorrhagic septicaemia, are fairly well defined and producers and private services, as well as Government, are fostering increasing coverage.
over other, more complex problems like paralytic rabies in Latin America is also being increased by well ordered routines. It is obvious, however, that almost all the health control effort is being directed toward specific diseases through the application of a vaccine or a control technique which can be given by a member of the veterinary team.

Herd Health and Productivity: What is lacking, in almost all developing countries, is veterinary advisory and extension activity which deals with health problems associated with management deficiencies and change. With real calving rates in the 40% to 60% range, fertility control, pregnancy diagnosis and planned breeding need to be added to the increasing use of artificial insemination. Calf and youngstock health should also be a focus for urgently needed attention with mortality rates in the 20% to 40% range. Dipping is carried out to an increasing extent but there is little or no infrastructure to supervise and advise on the most effective use of dips. Worm parasite control is a neglected topic. As cross-breeding programmes accelerate, production systems undergo fundamental change. Livestock move from the periphery of cropping agriculture, where they survive on by-products, aftermath and small areas of uncultivated land, into full participation in the agricultural system. Fundamental changes must be made in the provision of fodder and supplements if the potential of improved animals is to be realised. Similar improvements in extensive livestock production require the improvement of grazing and fodder conservation measures. Higher productivity also means a change in patterns of disease and generally higher susceptibility.

Outputs from our models tell us that livestock development cannot be limited to the addition of high technology herds. Improvement schemes have to reach the mass of traditional and extensive livestock systems if desired gains are to be made in animal protein production and the provision of draught power. To achieve this, new means must be found through which appropriate technology and support can be made available to the village and to the herd owner in the traditional sector, on a steadily increasing scale. Among a number of groups examining this problem, my associates and I have become convinced that it is possible to add a new cadre of support staff by drawing trusted people from villages and herding societies into low level training schemes. The new cadre should operate within their normal environments and field assistants must be re-oriented from the traditional veterinary assistant/vaccinator role toward that of adviser on health and productivity. In this way it should be possible to overcome the problem that a very high proportion of trained extension and field assistants are from urban backgrounds. The veterinarians, too, must broaden his outlook and help to evolve an inter-disciplinary team approach which feeds ideas and support into the new grass-roots initiatives.

I am happy to be able to say that this is not just wishful thinking. Various starts have been made – in India, Nigeria, Pakistan, Tanzania and Zambia, to mention just a few countries – to the great leap forward to new approaches to funding. Costs are so high, even at an early stage, that it would be unrealistic to expect Governments to take on more than a few "pump priming" expenditures. The producer will have to pay most, if not all, the on-going cost and to secure his support he must be able to appreciate the benefits. Indirect payment through producer controlled cooperatives is one obvious approach but other self-help systems seem possible too. Our recent work in Tanzania suggests that a series of localised schemes could be economically viable and self-propagating and we hope to be given the chance of putting our self-help ideas into practice. The key to success is hope and consequent motivation.
Information Systems: As work in this direction - on health and productivity services - has been added to our assessments of specific disease control needs, an underlying need has emerged and become an over-riding pre-occupation. Effective planning and implementation cannot be achieved without reliable information, at every stage in the production system but particularly on herd and flock performance. In almost all instances where we have checked commonly used facts on disease and figures on productivity we have found errors and deficiencies which could invalidate any plans that might be based on them. A pre-requisite, therefore, to further efforts in livestock development must be the introduction of appropriate information systems. This requirement applies throughout the whole spectrum of production systems from the village small-holder to the manager of the most sophisticated herd in Asia, Africa or the Americas. Indeed, this need even extends to the advanced production systems of Europe and North America.

A start has already been made and the systems being developed should be self propagating because they are based on the approach of stimulating producers to record data which is then made useful to them. Recording has to be integrated with action programmes and action programmes must have targets for the individual to attain. These call for step-by-step but simple monitoring activities and, thus, motivate continuity of accurate recording. Once the grass-roots data emerges from a few representative situations, production units representing other strata of the livestock industry can be encouraged to participate and so a full sample frame can be built up. Modern data-processing technology can be brought into use at strategic locations. Many simple, as well as sophisticated, aids are now available. Micro-computers are now robust enough to be taken to quite remote locations. Thus easily usable data banks are being formed where centralised computer systems could not be brought into play. My Unit has joined several other groups in endeavouring to meet these needs through pilot schemes in several countries. For this, as for every other activity I have discussed, appropriate technology must and can be developed.

The remaining major corollary to the development of "Health and Productivity Services" and appropriate "Information Systems" is the need to evolve practical training and supplementary educational programmes for field advisory and supervisory teams on a much larger scale than have yet been undertaken. Present educational systems emphasise academic and scientific preparation to diploma, undergraduate degree and, for a very few, postgraduate degree level after courses lasting two or many more years. What appear to be needed are complementary courses of much shorter duration, perhaps staged over several years, to prepare local liaison and junior field officers and to update and reorient professional leaders in mid-career. Field research projects can also be used as a medium for acquiring appropriate training materials. Fortunately, several international agencies, among them FAO, GTZ and ILCA have recognised these needs and potentials. My associates and I have started a postgraduate programme at Reading, linked to field research projects now in progress in eleven developing countries. We have also helped to conduct a series of short seminars and workshops for groups of professionals in developing countries to introduce these ideas on new veterinary activities, information systems and complementary education. Judging by the demand for further activity of this kind it appears that the needs are now widely recognised. Fortunately, the costs in each case are quite small while the cost-effectiveness ratios are very high.
To sum up, we must recognise that:

- specific disease and sub-optimal productivity will require greater attention if livestock production in developing countries is to gain new impetus.

- fair progress is being made on specific disease control programmes but more inter-country collaboration is needed.

- new initiatives and additional infrastructure are needed to take up the promotion of herd health and productivity, particularly in the traditional livestock sectors.

- much more powerful "information systems" are needed throughout the whole spectrum of animal production systems and related industries.

- training and educational activities must be widened if the benefits of new and existing schemes are to be realised.

It would be appropriate to close this presentation with a re-statement of my conviction that development is more dependent upon the rate at which human capabilities and, especially confidence, can be built up than on the availability of material resources. Despite the world recession, human resources are still more scarce than money for effective development work.
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ABBREVIATIONS

EEC European Economic Community.

OIE Office International des Epizooties

FAO Food and Agriculture Organization

IBAR Inter-African Bureau for Animal Resources.


GTZ Duetsch Gesellschaft fur Technische Zusammenarbeit (The German Agency for Technical Cooperation)

ILCA International Livestock Centre for Africa.

PAHO Pan American Health Organization.
Chairman's Comments by N. Nissen *

I very much agree with what Professor Ellis said. In particular, I share his view that after water and nutrition, disease control is the most limiting factor to improvements in livestock productivity. However, since animal health is closely inter-related with husbandry and nutrition, it is difficult to assign different weights to the various limiting factors. As a general rule for developing countries, it is estimated that inadequate animal health accounts for at least one-third of the foregone productivity increase.

In this field of animal health two major developments have occurred over the last 30 years. Firstly, enormous progress was made in the development of new drugs and vaccines. While disease control measures remained relatively modest in price, drugs became more effective and much safer in their application. Secondly, livestock owners have become aware of the economic benefits of disease control measures and have gained confidence in the use of drugs and vaccines.

Given these two developments, I consider it necessary to now focus attention on the system of veterinary services. From a historical perspective, the present system of veterinary services was designed to facilitate the application of relatively expensive drugs, which often involved considerable side effects. Hence the need for well-trained veterinarians, sophisticated diagnostic facilities and close supervision of drug application. Most developing countries have organized their veterinary services on the basis of these assumptions, with the result that only employees of the veterinary department are authorized to handle and distribute drugs, and to administer animal health services. Given the growing demand, these countries have been obliged to continue to expand their relatively large veterinary services which now generally use 95% of the allocated budget for staff salaries and related expenditures, leaving only 5% for drugs, vaccines or other veterinary materials. It is therefore not surprising that the existing veterinary services generally have a very limited impact on the actual animal health situation.

I would now like to return to what Professor Ellis said, in particular, when he mentioned the use of a new type of animal health assistants, i.e. people who are no longer Government employees but are instead self or community employed. In addition to the countries he mentioned, I know that Ethiopia and Sudan are also experimenting with this new approach to improve veterinary services. In the future one can envisage reduction of the tasks of the present veterinary services to essential functions, such as protection of the national livestock population against major disease outbreaks, quarantine activities,

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meat inspection and the authorization of drug imports. In this framework, the staff of most veterinary services can be reduced to a relatively small number of supervisory positions, thereby achieving savings of between 30 and 50% of the present budgetary allocations. At the same time however, countries should permit people with basic veterinary training to become self or community employed and the handling and distribution of veterinary drugs should be liberalized. The veterinary services would then be supervised by a small group of officers, while actual treatments and disease prevention activities would be carried out by a large number of self-supporting veterinary technicians. As I have already noted before, livestock owners are increasingly aware of the economic benefits of proper disease prevention, and willing to pay for these services and therefore to assume the major share of this financial burden. I am convinced that this is the only feasible way to further improve livestock productivity in the future.
A speaker with East African experience solicited Mr. P. Ellis' views on the effectiveness and the economics of dip establishment to control ticks. He said it was not uncommon for the sight of ticks and the presence of tick borne-disease to lead to the assumption that dipping is the sine qua non of livestock development. In establishing a relationship between dipping and improved livestock productivity, he said that two questions should be raised, one of them technical, the second economic.

The technical question was whether dip construction had a significant and sustained effect on tick populations or tick-borne disease in the area. He reported that the experience with communal grazing areas in Africa had been that neither the coverage of the livestock population nor the regularity of dipping had permitted effective tick and tick-borne disease control. Problems of sustainability and coverage (the percentage of animal regularly dipped) were particularly difficult where there was no enclosure and where livestock herds were mobile. A herder quickly realized that the dipping of his own animals was ineffective if those animals shared pastures with undipped herds. Where local livestock were resistant to enzootic tick-borne diseases, furthermore, herders were not strongly motivated to bring their animals in for regular dipping, especially if a dipping fee was levied.

He added that the coverage and sustainability problems were frequently compounded by problems of dip management, particularly the maintenance of a dip wash with adequate acaricide strength. If dips were not killing the ticks it was particularly hard to convince herders that it was worth dipping their cattle. The result of inadequate or sporadic coverage was that a pool of ticks and tick-borne disease was maintained. The economic benefits assumed for the control program then did not materialize and the existing dips were underutilized or abandoned. This had been the general pattern with dip construction programs in such areas, and many thousands of dips in Africa now lay idle.

He went on explaining that an even more serious risk came from the fact that the maintenance of natural disease resistance in cattle, particularly to ECF, appeared to require a regular disease challenge, and dissipated if the challenge was withdrawn. The implication was that a resistant herd could lose its resistance if the disease challenge was withheld over an adequate period by an effective control program. This was true even if no genetic changes were introduced. Such a herd was at far greater risk in that a renewed disease challenge, resulting from the breakdown of the control program, might cause many mature animal deaths, whereas it would not have caused any if the herd had maintained its resistance.

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The economic question was an empirical one, he said. Did the benefits of the dipping program outweigh its cost? Analytically, this required information regarding the income foregone as a consequence of the disease and the costs of preventing these losses.

With regard to losses, it was important to realize that in an enzootic ECF area local animals were resistant to the disease. (They would otherwise be dead.) This resistance was a combination of genetic predisposition, and natural immunity acquired in response to the disease challenge in the first year of life. The characteristic pattern in enzootic ECF areas was an elevated rate of calf mortality, perhaps as high as 35%, but no mature cattle deaths from the disease.

From the above pattern it was clear that the economic benefits of effective ECF control in existing herds derived almost entirely from a decline in calf mortality. The value of these additional calves could be estimated from a normal herd model that yields off-take and sales over time.

A further, and in some areas more significant, cost imposed by ECF was the extremely high, in some cases 100%, incidence of death among non-resistant cattle exposed to the disease. Typically this death rate was 100%, implying that such animals simply did not survive. These susceptible animals might be migrating into the area from non-enzootic, e.g. drier, areas. More dramatically, this death rate was among genetically improved stock imported into the area to raise productivity, either by "upgrading" local stock or by creating herds of high potential animals.

While it was technologically obvious that a genetic improvement should not be considered without effective control of ECF in these areas, there was economic evidence to suggest that the converse might also be the case. The benefits of ECF control in a resistant herd might be quite minor, involving, as they did, merely a reduction in calf mortality. These benefits might not justify a dipping program that, to be effective, incurred considerable cost.

In his response, Mr. P. Ellis agreed that tick control programs had generally failed. He said that until farmers wanted to dip, the program was unlikely to be effective. He felt that a dipping system could not be effective if it is run directly by the Government or if the running is shared because there is no interest in maintaining the efficiency of the system. He suggested that the herders should pay a dipping fee so they become keenly involved in the efficiency of the system. He said he favored self-funding, self-sustaining dipping programs with government acting as a catalyst.
In replying to Mr. Ellis, the first speaker commented on the attractiveness of dipping programs for individual herders, and on the merits of a dipping fee. He said that in this respect, a further problem should be mentioned. Where resistant stock and susceptible stock coexisted in the same area an externality problem tended to arise which could create problems for the coverage and effectiveness of the dip program. The herders of the resistant stock were not highly motivated to dip since their animals would not otherwise die of the disease. If they did not dip, however, a pool of ticks and disease was maintained which made it difficult or impossible to keep the disease-susceptible, genetically improved stock alive. The herders of the local animals were therefore being asked to dip, not in the interests of their animals but in the interests of the improved animals that they may not possess. For this reason the charging of dipping fees, which made excellent cost-recovery sense for the improved animals, tended to aggravate the disincentive for dipping local animals. Despite the problems of a coercive approach, there was a clear case for mandatory dipping where genetically improved, disease-susceptible animals were being introduced.

The same speaker then asked Mr. P. Ellis his views about quarantine regulations. He felt that these regulations were very often excessive and illegitimate. While they were conscious of the costs of disease spread, veterinarians were not sensitized to the costs of inhibiting marketing, nor were they made responsible for these. Therefore they tended to be overly cautious, and to prescribe quarantine regulations that were so strict as to be non-enforceable. As a result, the trade would find a way around them and for example use different trekking routes. Where this happened, quarantine regulations created more problems than they solved since when there was an outbreak, trekking routes were not known and there was no efficient way to stop the disease.

Mr. Ellis agreed with the speaker that where quarantine regulations were not enforceable, they should be eliminated because they discredited the system. Instead, he recommended that surveillance systems be established to give early warning of disease outbreak, and he stressed the importance (as well as the difficulties) of exchanging information on diseases between countries.

Another seminar participant reported on IDB’s animal health program in Latin America. The emphasis he said was on building the infrastructure for delivering services in preventive veterinary medicine. First, advice to farmers extended to hygienic and sanitary conditions because farmers tended to think that vaccines took care of all problems. Second, advice was delivered on both animal health and production. For example, extension advice was associated with the tick control program which allowed animal health officers to get in touch with farmers every 15 days.
The planning phase of projects was regarded as critical and was done starting at the farm level. A static diagnostic of the health and productivity status of livestock was carried out before deciding upon a national approach to animal health.

Mr. Ellis complimented the speaker on this approach, which came close to what he was himself advocating, especially concerning animal health program planning, and infrastructure building to bring animal health officers in contact with the producers.

During the follow-up to plenary sessions 6 and 7 which took place in the afternoon a large part of the discussion focussed on the issue of collection of information on animal health and productivity. In answering a number of questions, Peter Ellis made the following points:

(a) Existing information on animal health is generally grossly inaccurate and, as a result, development plans regarding animal health interventions are often made on the basis of erroneous facts;

(b) Because of this, the collection of reliable information is an essential prerequisite to the planning and implementation of animal health and production projects;

(c) This information can be collected by a survey of livestock herds in the project area; for this purpose, livestock production units should be classified into a number of strata (typically 12 to 20) and information on health and productivity should be collected by visits to a sample of units in each stratum;

(d) The information on each unit is collected in the following manner:

- First, the livestock owners' impressions and recollections are recorded on the status of the herd over the past 12 months in regard to health, breeding and productivity of the herd;

- Second, a physical examination of the herd is made to record information on herd composition by age and sex, reproductive status (pregnant, in milk etc.), health condition and productivity;

- Third, samples of blood, saliva etc. are collected for testing for a range of diseases; these tests may be carried out in the spot with equipment carried in the vehicle or in a regional diagnostic laboratory;
(e) the information collected in this manner gives a reasonable view of the status of health and productivity of the herd in the region;

(f) a survey of this type in the Rukwa region of Tanzania took six months to organize and carry out; this included three months of field work with one expatriate full time, another expatriate part time and four Tanzanians who were trained for the purpose by Peter Ellis' unit (PAN livestock consultants);

(g) the survey indicated that the incidence and effects of various disease were very different from the previous perception by the local veterinary officials; in particular, the mortalities from East Coast Fever were well below previous estimates; a major cause of loss of productivity was infertility which prevented coordination of calving to make optimum use seasonal available of feed supply.
SESSION VIII

PROBLEMS in AGRICULTURE CREDIT INSTITUTIONS
INTER-REGIONAL COMPARISONS
Introduction

In Tunisia, Algeria and Morocco the basis for institutionalized credit was laid before independence. At that time banking systems were mostly urban based and focused on serving the agro-businesses and large farms owned by European colonists. Small farmers (Fellahs) had little access to institutional credit and either did without credit or tapped private sources: suppliers, merchants, moneylenders, relatives or friends. Since independence these countries have developed their agricultural credit systems in different directions. Of the three, Morocco probably has the most efficient agricultural credit system today, while Tunisia presents an interesting example of parallel official credit systems. The Moroccan and Tunisian systems are described in detail in this paper. The World Bank has no agricultural credit projects in Algeria, so only an overview is provided of this socialist rural credit system.

General Overview - Tunisia

In ancient times agriculture flourished in Tunisia. Crops grown were essentially the same as today. Substantial amounts of food were exported to other parts of the Roman Empire. About the Third Century B.C. the famous Carthaginian Mago published his 28 volume work on agriculture which is considered as the starting point of agricultural science. It was mainly Tunisia's agricultural prosperity which made it so attractive for conquest by Phoenicians, Carthaginians, Romans, Arabs, Spaniards and Turks.

In medieval times financing of agriculture through moneylenders and merchants at often usurious lending rates developed and contributed to the gradual impoverishment of the rural population that was reinforced by oppression by colonial powers through the ages. Under the French, institutionalized credit was introduced in 1905 by establishing Caisse Locales de Credit Mutuel, local mutual credit agencies administered by the Caisse Mutuelle de Credit Agricole to which mainly the colonists cultivating the best land had access. The fellahs, farming small, fragmented pieces of land with archaic methods, stayed in subsistence agriculture. A bank was established in 1952 to serve the fellahs, but credit was issued only against land mortgages. Since most of the Fellahs lacked proper titles, this bank's activities were very limited.

After independence in 1956, the credit system was reorganized to provide greater access to farmers and to support the Government's objective

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of achieving self-sufficiency in food production. In 1959 the Banque Nationale Agricole (BNA) was founded by the Government to promote agricultural development by providing short, medium and long-term loans to the farming population. In 1969 its name was modified to "Banque Nationale de Tunisie" (BNT), and its charter and by-laws were changed to allow involvement in banking activities outside the agricultural sector. Lending has gradually shifted away from agriculture into more profitable sectors. Although also today more than half of BNT's portfolio is related to agriculture, most of its income and all of its profits stem from lending to commerce and industry. BNT is a cost conscious and financially sound organization which raises most of its funds from the private sector. It makes loans to farmers only after careful appraisal or with a government guarantee. Because of bad experiences with high overdues, BNT's management is not inclined to risk its capital in new lending schemes for small farmers or fishermen which are costly in terms of administration and provisions for bad debts. Guarantees regarding default risk and assistance from the Ministry of Agriculture's field personnel in on-farm appraisal have been used to offset these costs and compensate BNT for small scale loans, however. Today, BNT makes about 30,000 loans annually. BNT's records show that more than 100,000 farmers have obtained at least one loan since 1969, out of a farming population of about 350,000.

General Overview - Morocco

Morocco became independent in 1956 with a complex and comprehensive agricultural credit system mainly geared toward large farms and agricultural companies. Small farmers obtained credit from government initiated Provident Agricultural Credit Societies (SOCAP) and from moneylenders and merchants. After independence suppliers of farm machinery and inputs, who had been important credit suppliers to the modern sector, reduced their lending abruptly and commercial banks withdrew gradually from agricultural lending. By the early 1960's government institutions also reduced their lending due to lack of resources and high arrears. These conditions prompted the Government in 1962 to establish a new credit system under which "Caisse Nationale de Credit Agricole" (CNCA) became the principal institution for agriculture lending. CNCA is Government-owned. CNCA conducted lending activities at first from its headquarters and through regional branch offices, the CRCAs.

A new banking law in 1967 laid the basis for establishing local branch offices, CLCAs, to replace gradually the SOCAPs as lenders to small farmers. The CLCAs were controlled and supervised by CNCA, and by 1975 had taken over all SOCAP assets and liabilities. SOCAPs had made up to 700,000 short term seasonal loans annually. They were administered by the Ministry of Agriculture with CNCA only managing their accounts, and financial viability was not an important concern. Many of the 700,000 SOCAP clients were in default. The whole attitude toward meeting financial obligations changed when the CLCAs entered into the picture and lending to small farmers was subjected to the same rigorous financial discipline that CNCA applied to its other clients. The consequence was that the number of small farmers reached
decreased initially along with the improvement in portfolio quality resulting from denying defaulters further credit. In 1975, the CLCAs approved about 30,000 short term and 45,000 medium/long-term loans, representing 71% of CNCA's total number of loans. In 1981 the total number of small farmer borrowers reached 220,000 farmers, who received 394,000 loans or 79% of the total CNCA loan files. This means that about 15% of the 1.9 million farms in the country have used agricultural credit from the CNCA system. CNCA has remained in the agricultural sector only. Its resources stem mainly from equity (37%), external borrowings (36%) and deposits. Through prudent management and diversification of lending it has avoided the risks inherent in this concentration, such as from crop failures because of droughts. CNCA has skillfully cultivated the main advantage of specialised development banks; which is to be able to concentrate all efforts and staff expertise to agricultural development.

General Overview - Algeria

Algeria became independent in 1962, six years later than Tunisia and Morocco, and has chosen a profile of development completely different from that of the two other countries. While in Tunisia and Morocco the administrative structures available at independence were largely retained, Algeria pressed for structural reforms through a central economic planning system. In the agricultural sector the goal became to produce for domestic food consumption targets instead of the export orientation that prevailed during the colonial period. Before independence about 20,000 European farmers cultivated about 2.4 million ha, while 630,000 Algerian farmers cultivated 4.4 million ha. The European's land was nationalized in 1963. Farm workers obtained the right to use the land in the form of 2,000 "self managed" farms consolidated into units of about 1,050 ha each. Investment and operating plans are given to these units by government. During the "Agrarian Revolution" absentee landowners and the largest private landowners' tenure was also expropriated. Their land, together with state land was distributed to landless peasants organized into production cooperatives. By 1980 about 6,700 cooperatives had been created which, together with the "self managed" farms, form the socialist sector, cultivating about 3.1 million ha. About 4.4 million ha of cultivable land (excluding pastures) is owned by private farmers. Unsatisfactory performance in the agricultural sector is mainly due to lack of government commitment. Public investment in agriculture has declined steadily from 25% of all investment funds in the 1967-1969 period to 6% in the 1980-1984 plan period.

The agricultural credit sector has also been marked by structural changes. The local assets of the European-dominated banking system have been consolidated in government-owned and controlled banks. The "Banque Nationale d' Algerie" (BNA) is responsible for agricultural credit and channels government-allocated funds to the agricultural sector. BNA also loans to industry and commerce. Small private farmers receive almost no credit: loans go mainly to the socialist farm sector without evaluation of the expected
profitability of the investments financed or consideration of repayment capacities, and defaults are high. They are offset by Treasury transfers to BNA. Interest rates in 1980 were 3.5% for medium-term and 3% for long-term credit, compared with an annual inflation rate of about 10%. While no revisions of this interest rate structure are planned, a specialized agricultural credit institution is to be set up that would introduce evaluation criteria for credit demands from the socialist and private farm sectors. The World Bank is not planning any agricultural credit operations in Algeria until reforms in the sector have been implemented.

Selected Topics - Tunisia

BNT seems to be slowly drifting away from identifying itself with the government-initiated and often politically-motivated programs to channel subsidized investment credit to small farmers. Subsidized investment credit is financed from the Government's Special Fund for Agricultural Development (FOSDA) which in turn receives annual budget allocations. The proceeds of this fund are channelled exclusively through BNT, which keeps all payments from Government and from loan beneficiaries in a revolving fund. BNT handles administration and recovery, but has no decisive vote in loan approval. Therefore BNT bears no default risk and receives a handling commission of 2% on the portfolio outstanding at the end of the year. Consequently BNT does not show much enthusiasm for strong loan supervision and collection efforts, but tends to consider itself more as accounting agent for this type of lending.

The government is mainly interested in increasing production and not primarily in the financial soundness of a lending program or of BNT; it does not encourage putting great pressure on farmers or fishermen to repay FOSDA loans. On the contrary, the Government would like to see BNT relax its financial viability and technical appraisal criteria for loans which are not financed by FOSDA and for which BNT is the approving entity. BNT is reluctant to do that, and is not ready to lend to farmers who are not creditworthy or in default on previous loans. This may be one of the reasons why the Government is considering creating an agricultural development bank. Simultaneously, more participation by other commercial banks in agricultural lending is envisaged.

Institutional agricultural credit in Tunisia is characterised by a multitude of credit programs financed by different sources. Lending procedures and terms vary according to the source of finance which causes confusion and administration problems in dealing with farmers' preference for loans granted without appraisal of financial and technical viability and without appraisal of creditworthiness. While there is technical and creditworthiness appraisal for BNT-financed loans there is practically no appraisal for FOSDA loans, which are disbursed and repaid through BNT. Over-centralised BNT procedures—now being decentralized—have accentuated the differences, and the number of loan applications from small farmers has declined drastically.
Problems arising from conspicuous differences in lending terms, are illustrated by financing for commercial farmers, defined as those whose total annual agricultural revenue exceeds Dinar 3000 ($6000). The lending rate on loans to these farmers refinanced by the World Bank is supposed to be 7%, and no investment grants are permissible. While the FOSDA legislation differentiates between types of investment, it does not consider the farm income of beneficiaries as an eligibility criterion. This has led commercial farmers to prefer investment loans under FOSDA terms with an average 15% investment subsidy and a 6% interest rate. Although the Government and BNT have full knowledge of the problem, the reservation of FOSDA funds to small farmers for all investment categories has not yet been undertaken. Difficulties from competition between funds have not normally emerged in the past when FOSDA funds were scarce and farmers were ready to accept less favorable terms rather than not getting a loan at all.

What has been the World Bank's role in agricultural credit in Tunisia? Bank group lending to agriculture began in 1967 with a US$18 million commitment for the development of agricultural production cooperatives on the former colon land. Project funds were on-lent to the cooperatives by BNA. This project was the first undertaken by the Bank involving cooperatives based on collective concepts, and it was one of the first whose ultimate beneficiaries were small subsistence farmers and landless workers. During project implementation the cooperatives developed a whole series of technical and management problems. In 1968 only 78 of 330 cooperatives were profitable and total debt in arrears increased significantly. Several reforms were announced, but before any sustained improvement could be achieved the Government decided in January 1969 to abolish the private sector in agriculture altogether and transfer all arable land into production cooperatives.

Opposition to this policy grew rapidly not only among the larger, politically influential farmers but also among the remaining small private farmers. The immediate result was that all farmers began slaughtering their livestock and selling their equipment before they could be taken over by cooperatives. Due to this opposition and to hostility from cooperative members already in the program, the decision was reversed in September 1969. Membership in cooperatives was again made voluntary and confiscated lands were restored to their previous owners. Within a few months after the decision almost all formerly private lands were withdrawn from the cooperatives. Only former employees of colon or state farms, or former landless seasonal workers, remained in the cooperatives. Upon request of the Government the Bank then decided not to withdraw its support but to participate in a revised cooperative project of a smaller scope, emphasizing improvement of cooperative management. The reduced project was successfully completed. Most of its objectives were reached, including improvement of productivity and institutional viability, and increased agricultural production and workers' incomes.
The Bank limited its next operation, the First Agricultural Credit Project, to financing commercial farmers for all kinds of on-farm development and the establishment of date palm plantations. Under this project a technical division—now a full fledged department—was created in BNT with responsibility for loan appraisal. The question of uniformity of lending terms and conditions was addressed for the first time, and FOSDA legislation was revised to make lending terms (but not procedures) for small farmers essentially identical.

The Second Agricultural Credit Project included a small farmer component which had to compete with FOSDA lending. The thorniest issue during implementation was lending procedures for loans to small farmers. In the first three Project years BNT started to channel loans to small farmers based on full on-farm appraisal and headquarters approval for every loan. Because of these complicated procedures, backlogs of applications started to build up; but the system worked, though at a very slow pace. In 1980 Government decided to decentralize FOSDA loan decision making to the regional level. BNT was unable to decentralize procedures for its own lending program, resulting in a drastic decrease in applications for small farmer investment credit.

Without knowing of these events, which took place in the second part of 1980 and in 1981, the World Bank appraisal report of Agricultural Credit III was written in May 1980. It addresses the need for BNT to improve and decentralize appraisal and supervision procedures for its agricultural lending. In Tunisia the World Bank faces the dilemma of having to deal with two parallel credit systems. The decision making process for one system is in the hands of BNT and based on technical and financial considerations although BNT does not have the staff to deal with thousands of small farmer applicants. The decision-making process for the second system, the FOSDA system, is in the hands of regional credit committees consisting of several GOT representatives and one BNT branch manager.

One of the speakers in last year's agricultural sector symposium presented five theses giving his views on the essential components of a lending program directed toward individual small farmers. They are worth repeating:

(i) A credit system for small farmers has to be brought to the village by mobile credit officers.

(ii) The mobile credit officers have to be capable of working as extension agents transferring agricultural technology.

(iii) The system must rely on adequate project appraisal rather than collateral.
(iv) Continuous contact between borrower and mobile credit officer is essential; and

(v) Timeliness of credit must have high priority.

Let us compare these theses with Tunisian reality. The ideal situation would be that all procedures as well as terms and conditions for loans to small farmers would be uniform or, to take it a step further, that the BNT system and the FOSDA system would be amalgamated. However, at the time of appraisal the Third Agricultural Credit Project the Government was not ready to give up the FOSDA program in favor of what they perceived as a cumbersome and possibly fruitless screening procedure that was not the right tool to help implement agricultural policy. On the other hand, BNT insisted on certain appraisal standards to preserve the quality of its portfolio, but was not ready to recruit the number of mobile credit officers that would be needed to run both programs.

The compromise negotiated was that (i) Government extension agents would continue to assist BNT in on-farm appraisal at standards set by BNT and satisfactory to the World Bank (and identical to the standards for FOSDA appraisals); (ii) BNT would increase its agricultural field staff to cover 20 branches by 1981 and all other branches by 1982; (iii) BNT would train its own agricultural and the Government extension staff and (iv) BNT would decentralize its decision-making process.

Selected Topics - Morocco

CNCA has a branch network of more than 30 regional and 100 local offices and new branches are added every year to facilitate farmers' access to agricultural credit. Lending to individual farmers, cooperatives and agro-business institutions is CNCA's only activity; its staff of about 1,600 (about 500 of whom work in headquarters in Rabat) can devote full time to this task. An additional 500 staff work in CLCA's which deal with small farmers only and make about 120,000 loans annually. Thus, 31% of the staff disburse 65% of all loans; an average of 230 loans is disbursed per CLCA staff.

This remarkable efficiency in making loans to small farmers is based on a unique appraisal system. On-farm appraisal and supervision are made only for farmers exceeding certain income levels. Loans to farmers below these levels are merely based on desk reviews of the loan application. The so-called "fiscal income" calculated by the tax authorities for the purpose of assessing tax liabilities is used to determine the farm income of an applicant. Lists of all farmers and their fiscal incomes are made available to CLCA staff, who serve farmers with a fiscal income below Dirham 3,000 (US$730). Each applicant for a loan can receive one or several short-term or medium-term loans as a function of his fiscal income and the type of investment for which the loan will be utilized. Loan criteria and
norms are regionalized and lending criteria and procedures are streamlined to provide maximum access to credit.

Using fiscal incomes as yardsticks for creditworthiness has several advantages. First of all, it is simple and low cost. Secondly, CNCA has a complete list of all potential clients and has therefore relatively exact information about the percent of the farming population reached by agricultural credit. A further advantage is the fact that lending to small farmers can be increased or decreased, in accordance with availability of funds, by increasing or decreasing lending norms in relation to fiscal incomes. Disadvantages are that (i) loans received by farmers are usually too small to finance certain investments or the purchase of all the agricultural inputs needed for a season. The amount of loan disbursed is not a function of the actual investment or input cost but a function of the applicant's fiscal income which is usually only a fraction of actual farm income. (ii) Another disadvantage is its passivism: loans are made only to farmers who come to the CLCA branch offices.

CNCA is testing a different system geared to the actual needs of farmers within the framework of the Fes-Karia-Tissa rural development project. This test is based on a mixture of farm appraisal and experience on yield, income and cost data for certain areas supplied by extension workers of the provincial directorate of the Ministry of Agriculture. Results are not yet available, but it is clear that the cost of lending will rise with the use of more personnel and more equipment, including mobile credit units. CNCA maintains a separate accounting system for the local branches and in this way is in a position to determine which lending activities are generating deficits and which are profitable. As may be expected, lending to small farmers generates losses despite the simplified appraisal procedures. Government compensates CNCA for its losses resulting from small farmer operations each year with the proviso that interest rates would have to be increased if the operating income of CNCA's local branches falls below a certain percentage of the expenses.

The excellent recovery rates obtained by CNCA deserve special mention. These are outstanding in comparison with agricultural loan recovery rates in many other countries. The basis for this excellent recovery performance is twofold: First, CNCA credit claims are treated like government tax claims and are directly executable without recourse to time-consuming and costly court proceedings. This procedure was introduced in 1935 but efficiently implemented only from 1970 when a Royal Decree determined the formalities of legal proceedings. Legal proceedings are started against individual borrowers very soon after loan maturities go into default. These first consist of mere reminders, then a "no-charge summons" in which the defaulter is requested to pay within 30 days and in which the next legal steps are listed: writ of execution, foreclosure of mortgage, distress and sale of property and imprisonment for debt. While writs of execution are served, with the assistance of local authorities, rather frequently, the
distress and sale of property are not frequent. Sale of property is by auction, and the public auction announcement in the village of the defaulter, with his name made public, does serious damage to his reputation and usually leads to the desired result, which is the payment of outstanding debts.

Second, for farmers having fiscal incomes exceeding Dirham 3,000 CNCA has introduced an elaborate system of supervision and appraisal based on a careful selection of lending criteria. Decentralization allows the regional branches to have personal contact with clients, who are categorized in two classes: class A clients are regular clients in good standing of the regional branches without any payment arrears. For class A clients, field appraisal is not compulsory and decision-making is fully decentralized. Class B clients are new clients or clients with payment arrears, and for them loan approval is referred to CNCA headquarters.

The result of government commitment to recovery and efficiency in appraisal and supervision is the high recovery rate. CNCA in a normal year collects about 80 to 85% of loans falling due during that year and about 65% to 75% of overdues. The corresponding figures for the local branches dealing with small farmers are 82-89% of amounts falling due and 72-83% of amounts overdue. The appraisal of the Fourth Agricultural Credit Project for CNCA revealed that of loans disbursed during a ten year’s period, those for small farmers had recovery rates of 99% and those for medium and large farmers of 97-99%.

The Bank’s involvement in the agricultural credit sector in Morocco started in February 1966 when a US$10 million loan became effective to finance investments on large farms and in a state company managing confiscated land. According to the World Bank’s Operations Evaluation Department the Project’s main achievement was improvement in CNCA’s operation and management. This loan was suspended for a short while in 1968 because the state company managing the confiscated land was dissolved without prior notification of the Bank and because government had intervened to direct CNCA resources to the local branches for onlending to small farmers, which was not envisaged in the loan documents. Disbursements were resumed after the Bank was assured that all small farmer operations would be separated from CNCA’s other operations, both in terms of staffing and accounting, and after the Bank had cancelled US$230,000 committed to the government company.

The second project provided US$34 million to finance CNCA’s 1973-1976 lending program to medium and large farmers. The Bank excluded lending to small farmers from the project, arguing that investments financed by such loans would not be financially viable and that institutional arrangements for CLCA lending were not adequate. Under this project 17,000 farmers were reached, and again the main achievement was improvement in the institutional performance of CNCA. For this second operation the Bank insisted on four covenants: (i) a separation of accounts of the CLCAs and the
government operations (ii) the strengthening of CLCA capital (iii) the audit of CNCA by independent auditors and (iv) adequate profitability of CNCA.

After Mr. McNamara's speech in Nairobi in 1973, Bank policy shifted toward helping smallholders. Thus, the Third Agricultural Credit Project that became effective in August 1977 for the first time included lending operations to small farmers. Smallholder beneficiaries were expected to receive 47% of all project funds while the strict separation of CLCA accounts from other CNCA accounts was introduced to prevent utilization of Bank funds for the financing of smallholders, these covenants were successfully used in the third and fourth projects to demonstrate that investments in smallholdings was economically and financially viable, but needed government subsidy to cover the high administrative costs.

The Fourth Agricultural Credit Project became effective in 1979 and covers CNCA's lending program until 1982. Its objectives are identical to those of the third project, with the addition of an agro-industry component. This project, with a total cost of US$737 million, is financed by US$70 million from the World Bank and co-financed by KFW (US$50 million) and IFAD (US$25 million). The percentage of funds going to smallholders has remained the same as under the third project.

CNCA's financial performance remained very satisfactory until 1980. A liquidity squeeze resulted from less than average repayment by farmers following a severe drought in 1980/81. CNCA had to reschedule 40–50% of all loans falling due in 1981 and has worked out emergency plans to cover temporary liquidity requirements. The World Bank helped in overcoming this difficulty by increasing its average refinancing percentage to CNCA from 28.5% to 42.3%.
Conclusions from the Comparison of Tunisia and Morocco

In the introductory section of this paper I have said that Morocco has the more efficient agricultural credit system. What is the reason for this statement? Tunisia's BNT has about 70 branch offices for about 350,000 farmers, a ratio of 5,000 farmers per branch. Morocco's CNCA has about 125 branch offices for 1.9 million farmers, a ratio of 15,000 farmers per branch. As a multisectoral bank, BNT emphasizes business with commerce and small scale industry. In rural areas this is supplemented by business with commercial farmers. Only about half of all BNT branches have one or two agricultural staff and in early 1981 none of the branch managers had agricultural backgrounds. All of them were specialized in commercial banking and had received only a short training course in headquarters on how to deal with the multitude of agricultural credit programs financed from foreign and domestic resources. On the other hand CNCA's personnel are trained only for agricultural credit and no other business distracts them from their task. Thus, the first reason for CNCA having a more efficient agricultural credit system is the fact that BNT is heavily involved in non-agricultural credit activities.

The second reason is that Tunisia does not yet have a properly functioning system to channel large numbers of loans to small farmers. Quite a few experiments have been done and are being done to develop such a system. The 1969 experiment to incorporate all private farmers into production cooperatives failed and was abandoned. Still, about 230 production cooperatives exist which have former landless farm workers as members. Some of these cooperatives perform excellently, the large majority do reasonably well, and about 25% make permanent losses due mainly to incompetent management. The creditworthy cooperatives have access to all types of credit from BNT. Service cooperatives are practically non-existent and play a negligible role in credit distribution. The FOSDA system does not operate on sound investment criteria, neglects financial aspects and is, therefore, largely ineffective. It is also not limited to small farmers, as it should be. The Bank-initiated approach to small farmer investment lending has not developed rapidly enough to achieve an impact on large numbers of small farmers. For short-term lending, village-based credit societies (SCM) are being set up which now channel about 11,000 loans annually to small farmers. Like the FOSDA program, BNT acts only as administrator for SCM lending and does not bear any credit risk if its representative in the credit committee votes against a loan to a SCM for creditworthiness reasons.

A system for channelling credit to small farmers exists in Morocco and functions well. The system has some deficiencies such as low levels of financing and not actively going out to the village level to promote credit. Neither the Tunisian nor the Moroccan system conforms to the five theses enumerated earlier. This does not imply however, that the theses
are wrong, but only that it would be very costly to translate them fully into reality.

The third and probably most important reason for the efficiency difference between the two credit systems is the different level of government commitment to financial discipline. Both governments put utmost importance on achieving high growth rates in agricultural production and spend large amounts of money, in the form of subsidies for agricultural investments, to achieve this target. While CNCA with government support has developed a sense of financial discipline among its clientele, BNT has not been as successful because of two reasons. First, Government lends only lukewarm support to endeavors aimed at enforcing loan repayment. An opinion often heard from government officials is that losses from loan defaults are the price for development. This is a dangerous attitude which can be very costly in the long run. As recently as 1980 legislation was passed in Tunisia that made foreclosure and selling of defaulters' properties subject to two court judgements instead of only one as before. This requires proceedings which are very costly and always take more than one year. Second, BNT is not keen to collect loans for which it bears no risks and acts only as administrative agency. The 2% fee that BNT collects on the outstanding FOSDA portfolio may even be counterproductive to the collection efforts.

What can the World Bank do to help improve the two lending institutions? In both countries the Bank's advice is highly appreciated—which does not mean that is is always followed in such sensitive and delicate matters as credit policy. The Bank should use that position to make its point patiently but firmly. We all know that changing farmers' attitudes takes a long time and may be an impossible task if government does not fully and systematically support change. For Tunisia, this means that the creation of a specialized agricultural credit institution can be successful only if based on financial discipline.

For CNCA, the time has come to take a more active role in carrying lending programs to the village, to go out and find new clients, to reach a larger percentage of the farming population. The experiment with the Fes-Karia-Tissa Project is a step in the right direction if its main thrust goes into developing credit cooperatives and farmers' groups. Creating a system which would be too costly to operate, or depend on too much cooperation from extension agents should be carefully avoided. In other words, it will be most important to find the right mix between farm and desk appraisal and make the system respond better to larger numbers of farmers while maintaining its cost effectiveness.
THE IMPACT OF INFLATION AND GOVERNMENT POLICIES ON AGRICULTURAL CREDIT AND CREDIT INSTITUTIONS

F.M. Crowe*

Introduction

The results of any credit project - as compared with, say highway or education projects - depends to a large extent on the general financial and economic environment of a country. To illustrate the impact of inflation and distortions, a review of agricultural credit in Brazil as part of a wider financial markets study carried out in 1979 is discussed in some detail at the outset. The balance of the paper is devoted to the performance of an agroindustry credit project in Brazil and an agricultural credit project in Jamaica, and agricultural credit issues in Thailand.

A. General Rural Credit Review of Brazil as at late 1979

Background

The most striking features of the Brazilian credit system, particularly during the late '70s, were the volumes of money involved, the degree of implicit subsidy in the lending rates, and the degrees of administrative direction over terms and allocation.

The agricultural credit system in Brazil was - and to a large extent still is - part of an extensive apparatus of Government regulation and control through which the authorities sought to direct and manage the economy. The instruments included price control on agricultural products, incentives to export, or quantitative restrictions on exports. Changes in the regulations were frequent, unpredictable and made at short notice. The flow of agricultural credit was, so far as practicable, administratively determined, for narrowly specified purposes. Thus, the percentage of cost eligible for financing varied from crop to crop; again, certain inputs like fertilizer or certain regions of the country attract unusually favorable rates of interest.

The subsidization of agricultural credit was of course a conscious policy decision, although the explosive growth of the subsidies, along with increased inflation after 1974, was probably unintended and due to the political difficulty of making rapid increases in interest rates. The subsidies were defended, or rather rationalized, as being a form of compensation to agriculture for the negative effects of other policies such as price controls and an overvalued exchange rate. More recently, subsidies of such magnitude have been recognized as being undesirable and attempts are being made to reduce and gradually eliminate them - although this is being done rather by restricting the volume of subsidized credit, than by raising interest rates.

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Rural Credit Programs

Rural credit in Brazil could be broadly categorized in two ways: first by operating, investment and marketing credit; and second, between normal credit and special lines financed by special funds and directed to particular regions, groups or activities.

Operating credit was given for terms of up to two years. The rates of interest of 13% to 15% for operating credit were highly negative. Inflation in 1978 was over 40%, for example. Credit for certain inputs, such as fertilizer, insecticides and other chemicals, was given at more heavily subsidized rates of interest which varied between zero and 7%; in 1974-76, this credit accounted for about 45% of all operating credit.

Investment credit was given for varying terms of up to five years for semi-fixed assets; 12 years for fixed assets; eight years, with two years of grace, for heavy equipment; and up to five years for land clearing, intensified fertilization, terracing and pasture renewal. Nominal interest rates ranged between 13% and 21%.

Marketing credit at 15% to 18% was given to farmers and livestock producers to cover storage, handling and processing of crops, and to hold their crops in government approved warehouses until marketing conditions improved. Rural promissory notes discountable at 22% were used by traders to obtain credit to finance their purchases from producers.

Special programs began to proliferate during the late 1960s and early 1970s. Most were regional development programs including government funds for transportation, irrigation, warehousing, technical research and assistance, electrification, and other purposes, in addition to rural credit on more favorable terms than normal credit programs. Some non-regional special programs were directed to specific techniques and activities such as the use of agricultural inputs, storage, cattle raising, or coffee growing. All lines of credit involved investment plans and technical assistance. Nominal interest rates ranged from 7% to 21% and the term of the loans was up to 12 years, with up to 6 years of grace. In some programs operating credit was given for 1 to 3 years.

Sources of funds

The various lines of rural credit were classified as Normal Programs or Special Programs, depending on the source of funds. The main sources for normal lines of credit were: (a) 15% of sight deposits with commercial banks (excluding certain official deposits and transitory items) as required by law; and (b) the Bank of Brazil's current account with the Central Bank.

Special Programs, which accounted for perhaps 20% of all rural credit, were financed through funds administered by the Central Bank. The main sources of funds in 1977 for the special programs were: (a) fiscal transfers amounting to some Cr$52 billion (about 66% of the total, of which Cr$41 billion came from agricultural export taxes; (b) Central Bank
advances of Cr$19 billion (23%); (c) Cr$9 billion from external and other sources (11%).

The Expansion of Rural Credit

The most striking feature of the Brazilian rural credit system was the amount of money involved; the volume of credit in 1978 was estimated at US$15 to US$16 billion equivalent. Almost equally striking, however, was the paucity of empirical evidence as to what had been achieved. It was known how many loans were made but not how many farmers received them; there was no comparative information on the output, productivity or profitability of farmers using more or less credit, or no credit at all. The value of the available information was, moreover, seriously vitiated by the fact that a substantial part of rural credit was diverted for other uses. The extent of these diversions is not known, but they probably accounted for somewhere between 20% and 30% of total rural credit. An example is that in 1976 the areas of some major crops financed with operating credit exceeded the areas harvested by margins ranging from 30% to over 100%.

Over the period 1969-76, the annual value of credit increased by about 4-1/2 times in real terms, while the net value of agricultural production roughly doubled. Other points were:

(a) the increase in the value of credit (going to perhaps 20% to 25% of farmers) was over 138% of the increase in the net value of production of all farmers; from 1973 to 1976, the figure was 170%;
(b) in 1975 and 1976, the value of agricultural credit was more or less equal to the net value of agricultural production;
(c) the share of agriculture in GDP remained relatively steady; and
(d) with the rise in inflation, the implicit subsidies by 1979 were equal to about 30% of the total net value of agricultural production.

Use of Credit

Of all rural credit, that for investment increased more rapidly than that for other purposes. Negative interest rates can be expected to stimulate demand for longer term investment loans especially strongly.

The use of operating credit for export crops and wheat was strikingly higher than that for staple foods. For example, beans, manioc, and corn accounted for 31% of the gross value of production, but only 13% of the operating credit; operating credit for these crops accounted for only 13% of the gross value of their production, while for soybeans and wheat together (which are often grown in rotation) the figure was 58%.

The relatively low usage of operating credit for food crops seems to be due to a variety of factors. First, basic food crops are more widely
spread, and not concentrated in the more developed parts of the country where credit is more generally used, as are soybeans and wheat. Second, although in the regions where they are grown, wheat and soybeans are produced on all sizes of farms, they take a larger proportion of the cropped area as farm size increases. Third, many Government policies, such as the unpredictable imposition of price controls on food crops, placed food crops at a disadvantage. Also, operating credit limits made more funds available for soybeans and wheat (70% to 80% of normal operating costs) than for food crops (around 50%).

Credit was more intensively used in the developed regions of the South and Southeast, than in the North and Northeast. The more intensive use of credit in the more developed parts of the country appears to have been affected in only a very small degree by patterns of land distribution and tenure. The distribution of credit between the Southeast and the Northeast seems to have been basically a reflection of different stages of economic development and associated features such as the use of modern inputs. The use of credit as the means of subsidizing agriculture inevitably led to a concentration of subsidies toward more developed areas.

Statistics suggest that the amount of credit going to large farmers increased much more rapidly than that going to small farmers. The figures should be treated cautiously, however, since the size classification was not based on farm size but on contract values; there was no size analysis by region, crop, type or purpose of credit. The more than tenfold increase in value of large contracts was quite disproportionate to that for small contracts, which increased about 1-1/2 times; the increase in value of medium contracts was about 3-1/2 times. This may reflect the better security and lower costs associated with large contracts, as well as the greater sophistication of these borrowers. Even in such a highly developed area as Sao Paolo, only one farmer in three takes rural credit from the formal system.

Administrative Costs of the System

Preliminary estimates for new "advance posts" designed to provide banking services in remote rural areas indicated annual operating costs of about US$120,000 to maintain on average at least two hundred accounts, or about US$600 for each account. In 1978, administrative costs of the Bank of Brazil were of the order of US$1,500 million, of which half can perhaps be attributed to its rural credit operations, which numbered about 1.3 million in 1978. As about 75% of rural credit contracts were normally short term, averaging about eight months, and taking an average term of four years for investment loans, it seems reasonable to assume about 2 million accounts. This would give an average annual cost of about US$375 for each account. On this basis, even at positive real rates of interest, loans with an average outstanding balance of less than US$10,000 would be unremunerative for the bank. At 1979 subsidized rates of interest administrative costs would take 20 to 25% of the total debt service on a US$10,000 four-year loan. All this suggests an annual administrative cost per customer in the range of US$800 to US$1,000.
The Subsidy Element in Loans

Brazil's rural credit policies have long been characterized by concessional interest rates. The Usury Law of 1933 fixed a maximum rate of interest for rural credit at 6%, as compared with 12% for other types of credit. In the 1950s and 1960s the rates continued to be low or negative in real terms. Between 1974 and 1979, however, a sharp rise in the implicit subsidy (with interest rates of negative 30% in 1978 and over negative 40% in 1979) coincided with a dramatic expansion in the volume of rural credit. In 1978 the implicit subsidy was about US$6 billion equivalent, equal to about one-third of total Treasury revenues.

Main Effects of Subsidized Credit

Credit subsidies are widely regarded as a means of compensating agriculture for protectionist policies favoring other sectors, although it seems to be generally agreed that the very high levels of subsidy came about not so much as part of a conscious policy, but rather by inertia following the increase in inflation from 1974. Nonetheless, subsidies were defended as maintaining a sort of rough justice between agriculture and other sectors. The conclusions of this review, however, run contrary to this view.

The effects of subsidized rural credit can only be assessed in broad impressionistic terms, although the nature and direction of these effects are fairly clear. To recapitulate, there were four main reasons why the effects were difficult to quantify. First, much important information was not available. Second, the value of the information that was available was undermined because the system provided borrowers with strong incentives to falsify information and because much rural credit had been diverted to other uses. Third, the influence of the interest rate subsidies was inextricably mixed, not only with that of the protectionist policies they were supposed to offset, but also with that of the instability resulting from controls on prices, imports and exports. Finally, and more generally, money is fungible so that much subsidized credit was used to replace, rather than supplement, other funds.

Even if subsidies to agriculture were at an "appropriate" level overall (assuming that this level could be determined) considerable misallocation of resources would be expected within agriculture, because subsidies were received by only about 20% to 25% of farmers producing, perhaps, 30% to 50% of output and because their impact on choice of productive factors was not neutral. Such evidence as was available points towards such misallocation. For example, idle capacity of farm machinery on smaller farms \(^1/\) must be encouraged by credit subsidies. Diversion of credit for fertilizer suggested that many farms actually accepting and using subsidized fertilizer did so with low marginal returns. It may well have paid to overstate requirements, even if this meant that the farmer had to overuse fertilizer or simply waste some of it, because the value of the

\(^1/\) From a 1975 study in Rio Grande do Sul which showed excess machinery and equipment of 68.8% on farms up to 10 ha and 28.8% on farms from 10 to 100 ha.
subsidies on the other inputs exceeded the cost to the farmer of the wasted fertilizer. The linking of credit eligibility to the use of certain techniques led on some livestock operations to the adoption of techniques which were uneconomic. Wasteful use of resources was encouraged, along with the survival, or even the creation, of inefficient farms.

Since credit to a minority of farmers was about equal to the net value of the production of all farmers, there can be little doubt that farmers' equity and other potential risk capital had been diverted, as had much of the credit intended for agriculture. Farmers taking credit had their total, not just their marginal, production subsidized. In addition, the structure of interest rates has induced substantial increases in land prices, leading to speculative investments and probably to falls in aggregate savings and a decline in growth.

The nature of the system led inevitably to very high administrative costs. The size of the benefits obtainable and the strength of the incentives to divert them evoked elaborate regulations designed to control the distribution and use of funds. These were burdensome and apparently ineffectual. An additional indirect cost was the absorption of entrepreneurial and professional time and talent by the complexities of the credit system. To this was added the uncertainties of marketing and pricing policies and the speculative opportunities created by these policies and by the financial system generally.

Reserve requirements and the obligation on the commercial banks to lend a percentage of their sight deposits at negative rates of interest greatly affected the average cost of money available for "free" lending and the rates they in turn charged on such funds.

Many activities of high social return, both within and outside agriculture, must have been discouraged by the high free-market interest rates largely caused by subsidized lending. Even if a portion of farmers' own funds or official credits diverted from agriculture happened to finance such activities, account must be taken of the efficiency losses of revenue-raising by the distortionary taxes that were needed to finance income transfers to the recipients of subsidized credit.

Subsidized credit has not only been a costly means of inducing economic distortions and inefficient resource use but tended by its nature to be undesirably discriminatory. Larger farmers in more developed regions tended to use more credit because of the technology and scale of their operations and because of their greater access and creditworthiness. Farmers not receiving subsidized credit shared not only in the general disadvantages of agriculture but also in the cost of the measures that were supposed to offset them. They received no compensating subsidies, while the price of land increased out of proportion to what could be earned from it; and while the protection of local industry affected the price and quality of domestic inputs. Farmers without subsidized credit were either obliged to do without inputs they would otherwise buy, or to borrow from other sources where interest rates had been forced up by attempts to apply restrictive monetary practices.
B. Brazil First Agro-Industries Credit Project

The difficulties of carrying out credit projects under the Brazilian environment are well illustrated by the first Agro-Industries Project.

The long-term capital market in Brazil was poorly developed in 1973 when the First Agro-Industries was appraised, and was so still when disbursements from the loan finally ceased, more than 7 years later. The factors which impeded its development were those which frustrated the achievement of the purposes of the project.

The project was expected to be the first Bank-financed project in Brazil with on-lending subject to full monetary correction. Largely because of Government control of the correction index used (ORTN), however, interest rates were increasingly negative in real terms from 1975 onwards. They were -25% in 1979 and -60% in 1980. In the last three years of the project (1978-80) limitations on monetary corrections caused the Central Bank total losses in real terms of about US$10 million equivalent on project operations. Another project objective was to increase beef exports by 140,000 tons a year by 1978, but by that year exports were 63,000 tons, less than half the level at the time of appraisal.

Investments by sub-borrowers had projected economic rates of return between 23% and 53%, and 14% and 24% in financial terms. Although it is virtually impossible to provide a meaningful updated rate of return for the project, data available on the financial results of sub-borrowers showed that at the end of 1980 fewer than one-third operating at satisfactory levels of profit and over half losing money.

The projected disbursement period for the Bank Loan of US$54 million was four and a half years. It took three years more than that to disburse US$21.5 million. At times the project suffered from competition from alternative sources of financing, while at other times general uncertainties in the economy limited the demand for funds.

The shortfall in achievement of project targets largely reflects Government policies and economic conditions in Brazil. Efforts to isolate the project from the general credit environment and to apply sounder policies were unsuccessful. The project illustrates the difficulties of trying to operate in isolation in a general environment which was also in a state of considerable turmoil over a prolonged period and not conducive to project success.

C. Jamaica Agricultural Credit II

The basic objective of the Second Project was to provide credit for the development of medium and large scale commercial farmers. The project entity was the Jamaica Development Bank (JDB), which finances industry, commerce and agriculture. The original concept of the project was sound and well adapted to the needs of the sector at the time the Project was formulated. However the appraisal process bridged the 1973
oil crisis, and it was difficult to judge: (a) the prospects for the economy and for investment in agriculture; and (b) the effect of general economic conditions on JDB's ability to execute the project.

In the event, the Second Project failed because the economic and political climate became so unfavorable during implementation that returns to investments in agriculture became very low or negative. This meant a declining demand for long- and medium-term credit, and at the same time increasing difficulty in collecting the payments due on the loans that were made. These problems were compounded by the general weakness of JDB as a banking enterprise.

The appraisal report was thorough and informative. The farm models were solidly based and the yields and standards of management were cautious. The fact that the expected production was not nearly achieved was due to other factors, such as shortages of inputs and the deterioration of the investment climate along with the decline of the economy generally.

The interest rate issue and its financial implications for JDB were matters of great concern to the appraisal mission. The mission's objective of a positive real interest rate of 6% was probably unrealistic at a time when interest rates worldwide were generally low or negative. The objective was undoubtedly based on the mission's assessment of the spread JDB needed. This in turn implies that JDB was not competitively viable.

The solution finally adopted, denominating sub-loans in US dollars, proved to be an unfortunate compromise. Jamaica's exchange rate was fixed, so that eventual devaluation would inevitably be abrupt. In April 1977 the Jamaica dollar was devalued by over 35% and by May 1979 its value vis-à-vis the US dollar had roughly halved. The project suffered the disadvantages of substantially negative rates plus disruptive changes in the financial liabilities of sub-borrowers.

Early signs of trouble were clear during implementation, and clearly reported. In December 1975 over 90% of the First Project's sub-loans were in arrears and farmers were becoming increasingly nervous about making long-term investments because of fears about devaluation and the possibilities of compulsory land acquisition by the Government. In October 1977, a supervision mission indicated that the question was not whether the Second Project could achieve anything approaching its original objectives, which were the casualties of the worsening economic conditions which prevailed during its implementation, but whether JDB could be salvaged as a functioning institution.

Although the immediate and obvious cause of the failure of the Second Project was the decline and virtual collapse of the Jamaican economy, this should not be allowed to obscure the more general lessons to be learned. Perhaps the hesitancy of the private sector was too briskly dismissed as being due to conventionality and a lack of development orientation. It is not clear whether it was expected that Government banks would succeed because they would undertake profitable, but hitherto neg-
lected, operations or because they would operate with higher efficiency and at lower cost. What is clear is that in several instances government banks do not always help the agricultural sector, and have very often been costly failure. Greater involvement of the farmers and private sector appears warranted.

D. Thailand Agricultural Credit Review

In 1981 the Bank surveyed Thailand's rural credit system, including the agricultural bank (BAAC) and three commercial banks. A review of the agricultural sector suggests the following general points are relevant to the financial sector:

(a) there is heavy underemployment and seasonal unemployment;
(b) land distribution is characterized by a very large number of small holdings;
(c) the overwhelming majority of farmers own the holdings they farm;
(d) farm machinery and equipment are owned by relatively few farmers, but are much more widely used;
(e) intensity of agricultural production is relatively low, and outstanding loans represent typically only about 5-10% of total assets;
(f) interest payments on loans are a negligible part of household expenditures and a relatively minor item in farm expenses;
(g) institutional loans typically account for 70% of total outstanding debt;
(h) a substantial part of the average family's income (around 35%) is earned off-farm.

Salient points regarding agricultural credit in general are as follows: Government attempts to expand the volume of agricultural credit—have taken the form of: (i) establishing a special bank, BAAC, and (ii) obliging the commercial banks to apply an increasing percentage of their sight deposits to lending to agriculture, either directly or by way of deposits with BAAC. These policies resulted in a rapid expansion of agricultural credit until about 1979, after which farm credit portfolios have, in real terms, stagnated or declined and a significant part of the commercial banks' deposits with BAAC are redeposited with them. Agricultural credit (particularly that supplied by BAAC) has achieved a remarkably wide coverage, reaching 45-60% of farmers in old settled areas; the loans made are as small as they are numerous, averaging only $350 in the case of BAAC and $1,200 for the commercial banks. Interest rates for agriculture (currently around 13%) have been administratively kept much lower than those for industry and commerce (about 19%).

A comparison of overall financial results of BAAC and three commercial banks indicates that:

(a) the commercial banks earn more on, and pay more for, the funds they employ;
(b) BAAC receives a large implicit subsidy through Government equity and cheap loans from the Bank of Thailand, which is several times greater than its profit;

(c) the commercial banks have maintained or improved their net equity in real terms over the last three years, while BAAC's has eroded, even with the implicit subsidy;

(d) BAAC's administrative costs are remarkably low in terms of the cost per account, but inevitably much higher than those of the commercial banks because of the geographical dispersion of its clientele and the very small average loan size.

The agricultural credit operations of BAAC and the three commercial banks have three main features: First, BAAC has an arrears problem. Collections of amounts due range from 75% from individual farmers to no more than about 30% in the case of farmers' cooperatives and associations. BAAC write-offs, however, are minimal. Second, because of arrears and limitation on interest rates it is allowed to charge, BAAC cannot become a viable, self-sustaining financial institution without radical changes. Finally, the commercial banks would all be prepared to expand medium- and long-term lending to agriculture, if supported by a rediscounting mechanism.

Appropriate Policy Framework for the Sector in Thailand

Policy should concern rural financial markets in a broad sense, rather than with agricultural credit in isolation. Non-agricultural operations account for a large part of rural production, occupy most of the labor force and make a substantial contribution to the income of farm families. It seems clear that there is mobility of both labor and capital between agriculture and other activities. A further reason for broadening the focus of policy is that, over the last three years agriculture has probably approached the limit of its capacity to absorb short-term credit, as indicated by the stagnation or decline, in real terms, of the banks' agricultural portfolios. This suggests that there should be the greatest possible use of a variety of financial intermediaries, along with a substantial number of bank branches and field offices. Costs dictate that services should be kept simple. Transaction costs should be covered and these will almost inevitably be higher than in densely populated urban areas.

Two main issues will need to be resolved if a policy on the lines proposed above is to be formulated and implemented. These concern interest rates, which need to be considered in conjunction with production incentives, and the general improvement of financial discipline. At the present time, BAAC has no incentive to mobilize rural financial savings because it cannot earn a positive interest spread on such savings. Apart from being an immediate obstacle to the development financial markets, subsidized interest rates also undermine the future long-term development of such markets since, once established, they are politically difficult to eliminate.
Accumulation of arrears in BAAC's portfolio is of some concern, particularly arrears in its lending to cooperatives and farmers associations. It is not entirely clear whether BAAC's arrears are due to imprudent lending, inadequate debt collection procedures or enforcement, or political pressures.

Lessons to be Learnt from these Reviews

The results of a range of projects and financial systems, including those discussed above, provide a number of conclusions. The liberalization of interest rates is the most important single issue affecting the development of rural financial markets. The perverse effects of artificially low or subsidized interest rates are now well enough known from experience in many countries. Such rates are a powerful mechanism for concentrating the distributing income—the larger the borrower, the larger the loan and implicit subsidy; those who get no credit in the end pay for those who do, either through taxes or inflation. Subsidized interest rates lead to weak financial institutions, which are often incapable of carrying the costs of servicing many small borrowers and try to improve their financial position by lending to larger borrowers. Such interest rates distort investment decisions, usually at the expense of labor; tend to increase administrative costs because of the need to regulate the allocation and use of credit; and discourage both savings and equity investment, while encouraging corruption.

Government agricultural credit banks have frequently failed to help the development of viable, self-sustaining agricultural credit systems. Many in fact, have undermined the long-term development of credit systems. Typical elements which appear in this type of bank include: rapid erosion of capital, because of low recoveries, negative real interest rates, or both; very high administrative costs; dependence on constant Government funding in one form or another, without which they would very quickly become unable to continue operations; susceptibility to political pressure and intervention; and insulation from the normal market tests of performance.

Most Government agricultural credit banks, like JDB, seem to have been set up because, apart from obvious political motives, the volume of credit available to agriculture was judged to be inadequate. Apparently it was not forthcoming in adequate amounts from commercial banks and finance houses because their financial structure did not give them access to funds for medium and long term lending, or because of their estimate of the risks of such lending.

A fresh look is needed at the risks and costs of agricultural credit operations and the conditions under which they might be viable. The first requirement is that there should be a reasonable climate or agricultural investment—as exemplified by the Jamaica Project, where problems caused by Government policies dwarfed the natural hazards of drought and flood. A closely related need is that the financial system should be able to serve farmers in difficult as well as favorable conditions.
The objective should be to improve and expand financial services available in rural areas in ways that are financially viable and self-sustaining. Some diversity of institutional arrangements is likely to be needed to help spread risk and reduce costs. Whatever the elements of any credit system, it is essential that it should:

(a) mobilize local funds;
(b) have broad freedom to fix the interest rates charged or paid;
(c) have full local discretion, based on local knowledge, over the creditworthiness of borrowers and the eligibility of the purpose of the loan; and
(d) make money or go out of business

Decentralization of decision making to local levels cannot be over-emphasized. Apart from reducing risks and costs to the intermediaries, this would greatly encourage local customers who are prepared to pay very high premiums for flexible local credit, as compared with regulated and formalized official credit. Distortions in prices to farmers should be used as an argument for changing pricing policies, not as an argument to reduce interest rates by using one distortion to correct another. Where credit subsidies regretfully do exist, they should be administered on a “trust fund” basis, where the lending institution is only the financial agent and Government carries the risks and losses.
PROBLEMS OF AGRICULTURAL CREDIT INSTITUTIONS

COMPARISONS WITHIN ASIA

Ramesh Deshpande*

Introduction

Agricultural credit programs in low-income countries, designed in the context of national political economy, often contain conceptual distortions and operational inadequacies which are potentially dangerous to institutional and program viability. These programs, as recent research /1 has pointed out, provide supply-leading finance at interest rates which are lower than the rate of inflation and insufficient to cover lenders' costs. Other characteristics of credit programs include an absence of appropriate incentives for credit institutions to lend to small farmers, and a potential for substitution and diversion of loan funds at farmer level on account of fungibility of resources, and lack of arrangements to promote savings.

However, elimination of sectoral or intersectoral distortions in an economy is ordinarily a gradual process. Credit institutions cannot insulate themselves from socio-economic and political environments although they should develop a resilience, through appropriate structural, financial and management innovations, to carry out effectively the tasks expected of them. From this perspective, this paper reviews agricultural credit institutions and programs in South Korea, which has achieved significant economic growth in recent years, and in two low income countries, the Philippines and India. World Bank support to agricultural credit programs in these countries has been substantial, the Bank's cumulative commitments being about $80 million for South Korea, $220 million for the Philippines and $2,000 million for India.

Subproject and Borrower Viability Critical to Success

National development plans in low income countries accord high priority to credit programs as a mechanism to achieve growth with social justice through capital transfers to rural areas which are characterized by poverty and indebtedness as well as a low savings ratio. In such situations, credit institutions are called upon to serve two distinct groups of clientele: (a) creditworthy farmers and rural entrepreneurs who satisfy conventional loan eligibility criteria and collateral requirements; and (b) small and marginal farmers, rural artisans and landless laborers who, in view of their low productivity, prior indebtedness and meager family budgets, present a credit risk.


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The question often asked is whether credit institutions should finance the second category of borrowers. In India, for instance, financing the rural poor involves an approach in which the clientele is categorized into three distinct groups on the basis of assets and actual and potential skills, as follows: (a) rural entrepreneurs, including small farmers who can become viable with loan assistance; (b) those who may require capital subsidy, in addition to loan assistance, to become viable; and (c) those who are nonviable and require special assistance in the nature of social security. It is intended that credit institutions serve only the first two categories of target groups, i.e. those who are viable, or potentially viable entrepreneurs, with capital subsidy from the government in marginal cases.

Subprojects financed by credit institutions are also expected to conform to standards of financial viability, including satisfactory rates of return. Formal credit institutions take into account with-project repayment capacity as the key point in credit decision-making, allowing a subborrower to retain a sizeable portion (say, 50%) of the incremental income for consumption purposes.\footnote{This arrangement is, however, not adequate in situations when annual gross income of farm families from both on-farm and off-farm activities is below the level necessary to meet minimum nutritional needs and other basic requirements, including repayment of past dues from non-institutional sources of credit to which farmers attach high priority.}

The Philippines' agricultural credit policy also emphasizes that credit institutions should not be expected to perform a social welfare function. The strategy is to strengthen demand for credit by increasing farmers' absorptive capacity, ensure efficient allocation by building up financial markets, and bridge the gap between high risk but potentially viable agricultural borrowers on the one hand, and credit institutions in search of bankable projects on the other.

### A. Agriculture Credit Institutional and Financial Innovations

#### Credit Institutions in South Korea

The success of agricultural credit programs depends, among other things, upon how efficiently the credit delivery system is organized in terms of structure, corporate objectives, organization and financial management. The success of South Korean cooperatives is impressive in this context. Korea's National Agricultural Cooperative Federation (NACF), created in early 1960s, is an apex body of a three-tier cooperative structure with Kun (county-level) cooperatives in the middle, and primary (village-level)
cooperatives at the base. Recently, Kun cooperatives at the middle tier became branches of NACF. The structure also provides for special cooperatives organized on a commodity basis, mostly for horticulture and livestock. Korea's cooperative system covers almost all villages and is easily accessible to most farmers. It accounts for over 90% of institutional credit for agriculture, about 15% of total deposits and 13% of the outstanding loans of the entire banking system. Cooperatives also handle about 21% of total marketed agricultural commodities, 70% of chemicals, machinery and equipment, and 100% of fertilizers.

NACF and its affiliated cooperatives provide integrated services to its member farmers, which include credit, extension, mobilization of savings, supply of agricultural inputs and farm machinery, provision of processing and marketing facilities and services, and insurance. Though some of the cost of its activities which are not income earning are covered by internally generated revenues, with some subsidies under government-sponsored programs.

**Deposit Mobilization**

The most remarkable feature of the Korean cooperative system is its deposit mobilization effort, particularly through the mutual credit scheme which is organized on the lines of American credit unions and traditional Korean cooperatives. Interest rates on mutual credit deposits are always positive in real terms and, therefore, provide a strong incentive to farmers to save. Loans from the mutual credit fund also carry relatively high rates of interest which tend to be close to informal financial market rates. Undisbursed loanable funds are deployed in NACF's general banking activities and the government makes good any deficit in the Fund's operations. Further, to emphasize institutional resource mobilization, government supported credit operations finance only a part of production credit, especially the cost of input supplies which carries interest at rates about 8-9% lower than the interest rates on loans from deposit resources. It has been a Korean government policy to provide a part of working capital and term resources at a low cost (15-18%), as a farm productivity incentive and to promote diversification. As a result of the integrated approach to farm financing, with emphasis on deposit mobilization (which is feasible in an economy with a high growth rate), the collection performance of Korean cooperatives is usually good. Arrears are less than 4% of outstanding loans, mostly for short periods under production loans. A high rate of collection is made possible by: (a) farmer's dependence on cooperatives for all production related services, especially input supplies at government controlled rates; (b) deposit mobilization arrangements with incentives to save including positive real interest rates and assured credit availability; (c) high cost of production credit and penalties for default; (d) marketing tie-up with profit-sharing arrangements; and (e) a pricing policy for rice which provides for a built-in government subsidy, which, however, is expected to be phased out over next few years. The Korean model of agricultural
lending through cooperatives largely eliminates the weaknesses in institutional credit arrangements normally found in low income countries. The socio-economic and political climate in Korea has also a lot to do with the success of its cooperatives.

B. Credit System in the Philippines

In the Philippines, the formal agricultural credit delivery system presents a mixed picture. In spite of a significant expansion in institutional structure since early 1970s and in the volume of credit, which increased by 25% in nominal terms and 12% in real terms, the share of formal credit in the total credit provided to farmers has declined from 65% in the mid-1970s to about 30%. This decline is mainly due to institutional problems including arrearages under past loans. Small farmers, who generally tend to be low priority clients, seem to have had growing difficulty obtaining institutional credit. Interest rates in informal rural financial markets range between 35% and 70%, depending upon the type of credit operation, compared with interest rates of 12-21% on institutional loans.

Problems of Credit Institutions in the Philippines

The Philippine credit system consists of a network of bank and nonbank institutions which by and large, are, highly specialized by type of clientele served and subprojects financed. Private sector banks provide as much as 72% of the total agricultural credit; government-owned commercial and development banks issue the balance. Cooperatives credit operations did not succeed, and cooperatives now confine themselves mainly to marketing and noncredit activities. The government has set up 24 cooperative rural banks; however, the system is yet very small and also faces problems of high arrearages and low profitability. The Agricultural Credit and Cooperative Financing Administration, established by the government in the early 1950s to extend liberal credit programs to small farmers, went bankrupt amidst poor management, low repayment of loans and political interference. This institution was later reorganized as the Agricultural Credit Administration to provide credit to small farmers, agrarian reform beneficiaries and agricultural cooperatives. ACA's present operations are small, accounting for about 0.1% of total agricultural credit.

Private Rural Banks

The expansion in institutional structure for agricultural credit came about mainly through the rural banks, doubling their number to over 1,000, since 1970. They operate as unit banks. Their coverage and accessibility enables them to play an important role in mobilizing rural deposits and providing credit to small farmers and rural entrepreneurs. The rural banks are owned and managed by close family groups, and rely heavily on intimate knowledge of local conditions and borrowers, and sound collateral, in their lending operations. Rural banks were called upon in early 1970s to provide production credit to farmers under the government-sponsored
Masagana-99 program which envisaged transfer of HYV technology through extension and credit to achieve self-sufficiency in rice production. The viability of the rural banks was adversely affected by this program because of gaps in its design and management which resulted in heavy arrears.

Central Bank and Government Support to Rural Banks for Production Credit

The Philippine Government and the Central Bank have provided financial incentives to rural banks to step up the flow of agricultural credit. These measures include: (a) rediscounting at an interest rate of 1% p.a. (since increased to 3%), which provided a spread of about 10-11% to rural banks on supervised loans outstanding at 12%; (b) guarantees up to 85% of production loan defaults; (c) field-level support for processing of loan applications and collections through agricultural technicians employed by the government for extension purposes; (d) group lending through a system of joint and several guarantees of participating farmers (4 to 5 in each group); (e) financial support through share capital contributions and rescheduling of Central Bank refinance. However, many rural banks have been unable to avail themselves of Central Bank refinance in spite of the soft terms because:

(a) The rural banks are private sector institutions concerned with profitability. They seem to hesitate to take credit risks inherent in small farmer financing, in spite of a sizeable margin on funds provided by the Central Bank. The transaction costs including the cost of carrying arrearages apparently exceed the spread available to the rural banks;

(b) Several rural banks, on account of heavy arrearages under past agricultural loans, are ineligible for Central Bank's rediscounting;

(c) The resource structure of most rural banks has not improved in real terms, particularly with regard to deposit mobilization and capital build-up. Their agricultural lending depends largely on availability of low cost funds from the Central Bank; and

(d) Most rural banks have not developed appropriate staffing arrangements to handle agricultural lending without the support of government extension workers.

Since 1964 the rural banks have been the channels of lending for farm mechanization and small farmer subprojects under World Bank-assisted

\[1\] In nonsupervised loans, the rural banks' margin was 9% on a rediscount rate of 3%. 
rural credit projects. In recent years many rural banks have not met eligibility criteria for participation in project lending on account of arrearages, mainly under tractor subloans. Moreover, term lending is less attractive to rural banks than short-term lending. The interest spread on resources provided by the Central Bank for term loans is lower (5%) than for short-term lending (10-11%); and the rural banks receive 85% refinancing on term lending as against 100% on short-term lending, requiring them to invest their own resources in term lending. The rural banks, therefore, prefer short-term production loans. This preference constrains the availability of long-term capital funds for agricultural projects, particularly for the small borrowers who constitute the main clientele of the rural banks.

**Commercial Banks**

Except for the government-owned Philippine National Bank, commercial banks have a limited network of rural branches and are not involved in providing direct loans to farmers. Since 1974, commercial banks set aside 25% of their loanable funds for agricultural finance, of which 10% is expected to reach small farmers and agrarian reform beneficiaries. While commercial banks have lent substantial amounts to agro-processing and marketing enterprises, they are not organizationally equipped to serve a large number of small farmers. The government-owned Philippine National Bank (PNB) is an important source of agricultural credit, but the bulk of its loans are for sugar production and commercial activities.

**Government-owned Banks**

The government-owned Development Bank of the Philippines (DBP) has been a major channel for Bank-assisted projects for livestock and fisheries development. DBP and the private development banks provide mostly medium- and long-term credit but their clientele is generally medium- and large-scale borrowers. These institutions do not have the organizational structure adequate to serve small farmers and enterprises.

**Land Bank for Agrarian Reform Beneficiaries**

The Land Bank of the Philippines, set up as a financial arm of land reform operations, is engaged primarily in providing credit to agrarian reform beneficiaries. LBP's operations are expected to expand substantially but this bank, too, faces the problem of arrearages. LBP has introduced credit programs with a package of services including extension, supply of inputs, post-harvest processing and marketing facilities and infrastructure development, which is a new approach to agricultural lending in the Philippines.

As the agricultural credit system could not adequately serve the needs of small farmer clientele and support a broad-based agricultural credit program, the government has developed special commodity or clientele
oriented credit programs to serve the plan priorities and channel resources to credit institutions on softer terms; some of these programs often overlap with normal credit operations and lead to a 'dole out' approach and related collection problems.

**Monetary and Banking Reforms in the Philippines**

The Philippine Government is concerned with the credit situation and has introduced or proposes to introduce financial and banking reforms. These are intended to bring about greater efficiency through a competitive system and increased availability and access to longer term funds based on the recommendations of a joint IMF/World Bank study of the financial sector. Major reforms would include revision of the banking structure through expanded commercial banking, elimination of functional distinctions among different banks and improved administrative regulations. The rural banking system will be given wider banking powers. Their lending coverage, hitherto restricted to small farmers or families cultivating less than 50 ha, small merchants and cooperatives, will be expanded. These limitations constrained the rural banks' growth and profitability. Further, rural banks which could function only as unit banks can now undertake chain banking or group banking and open branches.

In 1980, the Central Bank also enhanced the discount rates to encourage banks to lessen their dependence on Central Bank credit. However, the rediscounting window still provides low cost funds for priority sectors such as supervised agricultural credit programs, exports and small-scale industries.

The Central Bank has initiated studies leading towards introduction of market-determined interest rates. Meanwhile, the Central Bank has floated interest rates on loans with maturities more than four years. Floating should facilitate upward revision in lending rates on medium- and long-term loans to about 3% above the weighted average cost of time deposits for 2 years and more.

The proposed reforms should gradually lead the banking system, particularly the rural banks, towards self-reliance in the sphere of agricultural lending provided the reforms are backed up by institutional development. Arrears under subloans continue to be a major deterrent to financing agricultural production and infrastructure. Future policies should address this issue, particularly in the context of interest rate and commodity pricing and marketing policies. Improvements could result from institutional coordination, program planning, rationalization of rediscounting and lending terms, improved arrangements for restructuring of subloans in the event of natural calamities, expanded coverage of production subloans under recently introduced crop insurance scheme, rationalization of government-sponsored programs providing low cost funds and creation of a climate for satisfactory collection performance.
C. Problems and Status of Credit Institutions in India

Until the late 1960s, the cooperative credit system was the only formal sector source of agricultural credit. However, cooperatives could not develop uniformly throughout the country, leading to credit gaps, and systematic efforts were made to induct commercial banks into the field of agricultural credit. In the past, commercial banks in India performed conventional banking activities mostly in urban areas, with emphasis on financing of trade, commerce and industry. With the introduction of social control over private commercial banks in 1967 and, subsequent nationalization of 14 major banks in 1969, the process of orienting the commercial banks to financing rural activities was intensified. In 1975, the leading commercial banks became involved in the promotion of subsidiary banks, called Regional rural banks, with the objective of expanding credit to small and marginal farmers, agricultural laborers and rural artisans, at lower transaction costs.

During the past two decades the rural banking system in India achieved significant growth in geographical and farmer coverage, resource mobilization and credit disbursements, essentially through a multi-agency and integrated approach to agriculture and rural development. The strategies included structural expansion, institution development, orientation of credit agencies to growth objectives, operational coordination between credit agencies and development administration in matters of program planning and development. The nonformal rural financial market, however, continues to be predominant, though its share in total farmer borrowings has declined from 85% in 1961-62 to about 75% in 1971-72 and about 65% at present.

The Institutional Credit System In India

Agricultural credit is provided by two broad groups of institutions: cooperatives organized on a state basis and commercial banks which operate on a regional/national basis. Field level credit outlets include: (a) primary agricultural cooperative credit societies; (b) primary cooperative land development banks or branches of State Cooperative Land Development Banks; (c) branches of commercial banks; and (d) branches of Regional rural banks.

Cooperative Credit Institutions

Cooperatives consist of two independent groups of institutions: (a) Land Development Banks (LDB) which provide medium- and long-term credit but no production credit; and (b) cooperative banks which provide short (production) and medium-term credit but not long-term credit. The short-term credit structure - a three-tier cooperative system - comprises 26 State cooperative banks, 344 affiliated district central cooperative banks and about 107,000 primary agricultural credit societies. The LDB system comprises 19 state-level institutions with about 1,900 offices. In addition
to village-level cooperatives, commercial banks and cooperative banks have established about 1,575 Farmers Service Societies (FSS) at block level to provide all types of credit and a package of services to farmers, particularly small farmers. Some 1,400 large-size societies have also been established to serve tribal communities. Primary cooperatives are expected to provide complementary services, such as supply of inputs and marketing, to members, but only a small percentage of such societies have developed the required capabilities. Several functional cooperatives which provide commodity-specific or activity-specific services (such as dairy, livestock and fisheries development or supply of inputs and marketing), operate side by side with the primary cooperative credit societies.

**Commercial Banks**

The commercial banking system comprises public and private sector banks. Public sector banks account for about 90% of all Commercial Banks' direct lending for agriculture. Commercial banks operate through over 32,000 branches, of which about 25,000 are located in rural and semi-urban areas. Commercial banks have set up about 64 Regional Rural Banks, with a network of 2,400 branch offices located mostly in rural centers.

**National-level Institutions**

At the national level, the Reserve Bank (RBI) is the central bank and supervises the credit system. RBI supplements the short-term resources of the commercial and cooperative banking system, and long-term resources are provided mainly by its subsidiary, the Agricultural Refinance and Development Cooperation (ARDC)./1 The latest development in the institutional credit structure is the proposed establishment of a National Bank for Agriculture and Rural Development, which will absorb ARDC and take over RBI operational functions in production credit. It will address especially the problems of coordination of agricultural short-term and long-term cooperative credit and promote integrated rural development.

**Relative Importance of Cooperative Banks and Commercial Banks in Agricultural Credit**

During 1980, cooperatives disbursed about 62% and the commercial banks about 24% of the total production credit ($2.4 billion). The commercial banks' share of term loans ($1.4 billion) was about 48% and that of cooperatives 52%. Commercial banks' share in total outstanding agricultural loans increased from about 21% in 1974 to 38% in 1980.

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/1 ARDC functions as an apex agricultural development bank. ARDC does not lend directly to individual farmers but provides resources to member banks by reimbursement against subloans, under area specific subprojects approved in advance by ARDC on the basis of techno-economic feasibility studies and assessment of institutional aspects.
Short-Term Cooperative Credit System: Major Problems

The major problems of short-term cooperative credit are nonviable and managerially weak primary agricultural cooperative credit societies and the high level of arrears. Rehabilitation programs based on financial viability norms - minimum operational area and volume of business - and appointment of at least one full-time staff, are being implemented but progress is slow. Poor resource bases and ineligibility for central bank resources on account of high arrears have been the major causes of poor performance of village cooperatives. The primary credit cooperatives have by and large served as mere conduits for disbursing loans. They could not develop to provide integrated banking services to member farmers or attract deposits.

Recent evaluation/1 of the rehabilitation programs and status of primary credit cooperatives concluded that efforts should be directed to transform the cooperatives into a single contact point in the village for all types of credit, not merely for agriculture, and that the cooperatives should diversify their functions, augment resources and business, and offer a package of services to farmers. The principal reasons for arrears at primary credit cooperatives include defective lending policies, untimely loan disbursements, underfinancing/overfinancing and unrealistic schedule of repayments, neglect or absence of marketing arrangements and linkage of credit recovery with sale of produce, apathy and indifference of management to measures for recovery, and want of a sense of discipline and responsibility among the loanees for prompt payment of debts. While natural calamities such as droughts and floods have contributed to nonrepayment steps taken by state governments in the name of those calamities have adversely affected the climate for recovery and accelerated accumulation of overdues./2 It has been suggested to the state governments, that as a rule, they should not interfere with recovery endeavors of cooperatives since this vitiates recovery, encourages wilful defaults and generates a psychology of nonrepayment, endangering the survival of the institutional credit system itself./3 It is, however, recognized that short-term cooperative credit can potentially reach millions of farmers: in 1978, 107,000 primary cooperative societies covered 528,000 or 90% of the total number of villages in the country; and 88.6% of the total rural population. The cooperatives had a membership of 52 million, with a borrowing membership of about 34%. The strengthening of the cooperatives, therefore, receives high priority in development plans.

/1 Report of the Committee to Review Arrangements for Institutional Credit for Agriculture and Rural Development.

/2 Ibid.

/3 Ibid.
District and state-level cooperative banks undertake a wide range of banking activities including mobilization of deposits through a branch network. They command a sizeable resource base and generally stable financial position. Arrears at the level of district central cooperative banks generally range between 20 to 60% of the demand fallen due. District central cooperative banks with arrears exceeding 60% of demand generally become ineligible for central bank support. Financially weak banks whose bad debts, accumulated losses and overdues over three years exceed 50% of capital and reserves are placed under a rehabilitation program.

Deposit Mobilization by Cooperatives

Though primary cooperatives lag in deposit mobilization, deposits at district and state cooperative banks nation-wide now constitute as much as 50-60% of their working capital resources. Growth in deposits (about 20% per year) came about primarily from linking RBI refinance for agricultural credit to cooperative banks’ own effort at deposit mobilization, from extension of deposit insurance to some major cooperative banks and from slightly higher interest rates (1/2%) offered on deposits with these banks. State cooperative banks are encouraged to invest their own resources in the non-agricultural sector, which provides a higher interest spread to offset losses incurred in agricultural lending.

Cooperative Long-term Credit Structure

Land Development Banks provide medium- and long-term investment credit for irrigation, farm mechanization, land improvement and allied activities. Efforts are being made to diversify their lending. As for short-term cooperative credits, arrears are also the principal problem of the Land Development Banks. However, collection performance is generally satisfactory in states in Northern India where agricultural productivity is high on account of irrigation, HVY technology and consistent good cropping seasons.

The causes of overdues in land development banks include: "laxity in post-credit follow-up and monitoring of end-use, lack of technical guidance to the loanees; natural calamities and above all, wilful default ... the observations made earlier regarding deterioration of recovery climate in short-term credit structure and the unhelpful attitude of some of the state governments also apply generally to the long-term credit structure".\footnote{Ibid.}

Additionally, the split cooperative structure makes it impossible for farmers to obtain all their credit—short-, medium- and long-term from a single cooperative source. A limited integration is proposed under which primary agricultural credit societies would perform agency functions for long-term lenders.

\footnote{Ibid.}
Lending Eligibility of Cooperatives Related to Collection Performance

Recognizing the problem of arrears in land development banks and its adverse impact on financial viability, the Reserve Bank and ARDC began in 1975 to regulate new lending by LDBs through a lending eligibility criteria for LDBs and their branches on the basis of collection performance. New lending declines with increases in arrears. The arrangement provides that the concerned state governments may contribute to LDB's share capital to notionally reduce the level of overdues to the extent of 10% of amounts in arrears. Additional government contributions to create new lending capacity, was not permitted, however, since this could lead to laxity in collection efforts. These criteria have worked well in some areas, improving collection performance. Some institutions, however, require comprehensive rehabilitation with considerable financial support from government. Thus, the development role of credit institutions is recognized, but governments are expected to ensure their financial viability.

Commercial Bank Lending for Agriculture

Commercial banks are expected to ensure that at least 40% of total loans are made to priority sectors and that at least 40% of that is lent to agriculture. During the past decade CBs adopted innovative arrangements to promote agricultural lending: (a) under a scheme introduced in 1969, CBs adopted an 'area approach' for development of credit and banking and in districts assigned to them assumed a 'lead role' to survey and assess areas requiring branch expansion, credit gaps, development potential and preparation of credit plans with the cooperation of other banks and financial institutions operating in the district. The scheme has been streamlined from time to time and is the main instrument for ensuring better spatial and sectoral distribution of credit by the commercial banking system;\(^1\) (b) CBs adopted village-level cooperatives as channels for lending to clusters of farmers; (c) CBs participated in lending programs prepared by Small Farmer Development Agencies. These government agencies extend capital subsidies and technical assistance to small and marginal farmers; (d) CBs adopted several thousand villages for integrated development and financed over 1.5 million farmers through this scheme; (e) the branch expansion policy for CBs required them to open more branches in rural areas; during 1969-80 24,000 offices were opened, of which over 13,000 were in rural areas; (f) CBs were asked to ensure that 60% of deposits mobilized in rural/semi-urban areas are deployed in those areas on the principle that rural resources should be used for rural development; (g) CBs carried out institutional development (including staff recruitment) and training and improved arrangements for loan processing and documentation; (h) CBs have established Regional Rural Banks, which have the advantage of low cost

\(^1\) Ibid.
administration, to promote deposit mobilization and agricultural credit especially for small and marginal farmers. All these measures have enhanced commercial banks' capabilities to expand lending for agriculture under improved supervision and follow-up arrangements.

Commercial Bank's Collection Performance under Agricultural Loans

Commercial Banks, as in the case of cooperatives, face problems of low collections which range around 50% of amounts fallen due. A recent study revealed that factors like wilful default, misutilization of loans and insufficient incremental income accounted for as much as 84% of arrears, while defective appraisal and lack of effective supervision and follow-up accounted for about 16%. All banks emphasize satisfactory collection performance, and steps proposed include additional staff, improved sub-loan appraisal, further orientation of lending under area-specific programs with forward and backward linkages and government involvement in improving the climate for recovery. /1

Role of ARDC

Establishment of ARDC in 1963 was a significant innovation in Indian banking. It was set up primarily to augment medium- and long-term lending for agricultural development, and to reorient and improve operational and lending policies of member banks, particularly land development banks. Later, ARDC became an apex agricultural development bank and widened its objectives, which include: orientation of commercial banks to greater participation in agricultural development programs, translation of plan objectives into bankable propositions, providing assistance to government agencies in project formulation, promoting projects for small and marginal farmers and underdeveloped regions, mobilizing resources by issuing long-term bonds to commercial banks and institutional investors and by borrowing from other sources (including foreign lenders through government); and undertaking project evaluation, research and studies.

From 1969 to 1980 the World Bank Group assisted 40 projects using credit through ARDC for on-farm development and other activities. These projects involved World Bank assistance of $2,000 million with a credit component of about $1,200 million. ARDC implemented these projects, which support sectoral development, with emphasis on institution building, extension of technical services, improvement of small farmer coverage and reduction in regional imbalances. The proposed National Bank for Agriculture and Rural Development (NABARD) which would absorb ARDC would have a much wider role in integrated rural development. Besides refinancing to commercial banks' term lending and cooperative banks' production and investment

/1 Ibid.
credit, the new institution would undertake direct lending on its own or under consortium arrangements with member banks. It would also attend to developmental policy, planning and operational matters relating to credit for agriculture and allied activities.

The Indian banking system is developing arrangements to mobilize a substantial portion of the resources needed for agricultural financing with minimum supplementary contributions from the central bank or the government. Short-term production credit for agriculture is being provided by commercial banks largely from deposit resources since no RBI refinance facility is available for this purpose, except for a small limit up to 50% of very small loans in rural areas. A significant portion of commercial banks' long-term loans also is financed from deposit resources, though in recent years their recourse to ARDC for long-term refinance has been growing on account of expanding demand on their resources from other sectors in the economy. The slightly lower cost of ARDC resources in relation to the average cost of deposits also works as an incentive to banks to avail themselves of ARDC resources and expand agricultural lending.

Interest Rate Spreads and Transaction Costs

Interest rates on agricultural subloans are currently positive in real terms. Interest spreads are usually adequate to cover transaction costs but subsidies do enter through government transfer of low cost funds to cooperatives and cross-subsidization by commercial banks of transaction costs on agricultural lending from surpluses on other types of lending. Subsidization of transaction costs is tolerated since agricultural development receives high priority in national plans.

Conclusion

This overview of agricultural credit in Korea, the Philippines and India cites efforts being made in these countries to develop, expand and revitalize institutional credit systems. The major conclusions which seem to emerge are: (a) Credit outlets should be as near the farmers as feasible, on the basis of business norms and types of services to be provided to the community. Credit outlets should not function as mere conduits for subloan disbursements but provide comprehensive services, with emphasis on deposit mobilization, timely and adequate supplies of inputs, and tie-up with marketing arrangements. Unless a credit system provides an efficient village level institution, credit programs, however viable, are not likely to succeed. (b) Real interest rates are important for deposit mobilization; (c) Interest spreads available to credit institutions should be adequate to meet transaction costs, including the cost of carrying arrears and bad debts. If the spreads are not adequate and interest rates to subborrowers cannot be raised on considerations of sectoral or socio-economic priorities, explicit ways should be found to compensate credit institutions for negative margins through government subsidies or through provision of low cost funds. Credit institutions should not be asked to absorb losses in the name of.
development priorities unless such losses are small in relation to overall profits. (d) Farmers should receive both production credit and investment credit through one source. This should reduce transaction costs; facilitate composite assessment of subborrowers' resources, credit needs and repaying capacity; and improve supervision on use of funds and collection performance. (e) Government intervention in credit institutions' operations should not compromise institutional autonomy or result in political interference in day-to-day operations of the credit institutions and collection efforts. (f) Credit institution performance seems to be unrelated to the question whether they are in the public, private or cooperative sector. (g) Due to the inherent risks and uncertainties of agriculture, arrears in loan collections are unavoidable. However, arrears should not jeopardize credit institution viability and the development objectives which the credit institutions are expected to serve. Credit programs should therefore contain built-in arrangements to withstand a certain level of arrears and for rescheduling of subborrowers' commitments in the event of unforeseen situations, such as natural calamities, with appropriate flexibility in resource management in the credit institution. (h) In countries in which several credit institutions participate in agricultural lending programs, an effective coordinating mechanism becomes essential for credit policy and program planning, resource mobilization and institution development. It is clear that credit policies which work well in one country will not necessarily be effective in others, in view of diverse socio-economic and political conditions. (i) Finally, performance of credit institutions inevitably reflects the impact of general economic policies on rural financial markets.
The three papers have described in considerable detail a broad range of credit experience in a number of countries. Based on these papers, I would like to make some brief general observations of the factors influencing credit and credit institutions. First, the overall economic environment is of major significance. The turbulent economic conditions in Brazil and especially Jamaica led to disastrous credit situations and contrast sharply with the generally satisfactory performance of credit institutions in Morocco and Korea. Secondly, the costs of credit have an important influence on the viability and success of agricultural credit programs particularly when interest rates are kept low. Major costs include bad debts and operating overheads. Operating costs as a percentage are markedly different from country to country reflecting not only the type of lending but also the comparative level of salaries for equivalent type work e.g., Indian banking salaries are much lower than Brazilian salaries and hence overheads for equivalent small loans will be very much higher in Brazil. Such variations need to be taken into account in designing credit projects and the size of borrower that can be serviced. Thirdly, institutional viability is essential to successful credit projects. However, no single type of institution has universal applicability in all agricultural and economic environment. The knack lies in identifying which type of institution can perform most satisfactorily in a particular situation.

Finally, access to credit is an extremely important indicator of the effectiveness of credit mechanisms. The degree of access in Thailand, where more than 45% of farmers in older settled areas are reported to use institutional credit, is well above the average figure in many developing countries which appears to be between 5% and 15%. The question is how access can be increased, and what types of credit systems and institutions are most likely to increase access. The relationship between credit institution performance and the general economic situation is linked with the access issue through the observation that in satisfactory economic and financial environments a variety of institutions may be able to operate well and expand access. But, where there are serious general economic problems, institutional choice becomes more critical and the expansion of access more difficult.

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RAPPORTEUR'S COMMENTS

by

J. D. Von Pischke*

Following the Chairman's comments, several speakers subsequently supported his observations, noting that the success of agricultural credit is closely related to the performance of other services to agriculture, and to overall attitudes relating to the role of finance and commitments to financial contracts.

During the discussion three major issues were addressed by a number of speakers from the floor. These three issues were the role of the informal sector, the role of interest rates, and a systems approach to rural finance.

Discussions of the role of the informal sector focussed on the issues of access, performance, and linkages with the formal financial sector. An important lesson which was cited from observations of informal sector performance is that it provides convenient access to funds for large numbers of rural people. These transactions appear to be conducted by lenders in a profitable manner, as suggested by the fact that these lenders are generally prosperous individuals in the local community. The relationship between wide access and lender performance suggests that, from the point of view of the borrower, access is more important than the rate of interest charged, creating opportunities for financial intermediation.

Links with the formal sector may be viewed in several ways. One linkage which may involve credit project funds is the possibility that the injection of liquidity into the rural economy through a project has an impact on the overall supply of credit, which in turn influences loan terms and conditions in the informal financial market. Another linkage between formal and informal credit is a competitive one. Competition for clients between lenders in these two sectors may provide a basis for the argument that farmers should be able to satisfy their demand for credit from a single institution offering on a variety of terms and conditions. Integration of various types of credit under a single intermediary can help protect formal sector lenders, which are slower and less responsive to borrowers, from competition from informal sources. Speakers generally agreed that competition in the provision of rural financial services was a positive factor in development through its tendency to integrate fragmented markets, guide interest rates towards efficient levels, and expand borrower choice and access.

The interest rate issue was discussed at various times during the session. There was general agreement that higher rates of interest on institutional credit are often warranted, especially to support the

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financial viability of intermediary agencies. The high cost of formal financial intermediation in rural areas was noted by several speakers as one justification for interest rates higher than customarily have been charged in agricultural credit projects. Another dimension of the role of interest rates was stressed in discussions of opportunities for savings mobilization. Several speakers indicated that much greater attention should be accorded to savings mobilization, both in sector work and in project design, and that higher interest rates for savers should encourage the institutionalization of savings.

A focus on rural financial systems or rural financial markets, rather than merely on agricultural credit, was supported by a number of speakers. At least four justifications for looking at rural finance as a sector or subsector were provided. These justifications may be listed as orientations or objectives suggested for financial intermediaries and for Bank-supported projects. The first orientation is institutional and stresses the viability of financial institutions in general and the quality of their performance. It was noted that institutional performance has varied greatly across countries and through time, even for the same type of institution providing agricultural credit, and that more should be known about the determinants of institutional success measured in financial terms. Speakers taking this point of view argued that viable financial intermediaries are required in order to expand access and to preserve levels of service already provided. Issues raised by this orientation include the costs of providing service, levels of interest rates and arrears on loans outstanding.

The second orientation suggested by speakers was borrower orientated rather than activity oriented. Speakers taking this view suggested that the rural household or firm is a more useful unit for analysis and basis for project design than simply crops or specific agricultural operations. Access to financial services could be expanded by looking at the overall situation of borrowers and potential borrowers, and designing projects and policies which would better serve larger numbers of rural people. Consideration of a broad range of rural activities, through analysis of households and firms, would more closely integrate subproject finance and the development process.

Several speakers took a slightly different approach to the institutional and borrower orientations by raising the issue of rural financial flows. A flow orientation would naturally lead to consideration of savings mobilization as well as of the financial requirements associated with various production and commercial objectives. Examination of rural financial flows would also indicate links between savings mobilization, investment and demand for credit; and formal and informal finance.

A service orientation to rural financial markets was proposed by other speakers. The service orientation stresses the importance of classical retail banking functions, including a broad range of services for clients. This approach is quite different from the crop-specific orientation of many of the conventional agricultural credit projects undertaken with Bank support. An institution modeled on the service orientation would provide many different types of credit useful to the rural community, as well as an array of services designed to mobilize different types of deposits and facilitate financial transactions.
The thrust of many statements from the floor was that agricultural credit project performance has in many cases been unsatisfactory in certain respects. A broader view of credit, as something produced by financial markets rather than as something supplied to farmers, appears to provide a basis for more effective use of finance in rural development. More effective use would include increased rural access to financial services, stronger rural financial institutions, and efforts to mobilize rural savings as well as disburse credit.
Closing Address

by

Montague Yudelman*

Welcome to the closing session of the Third Annual Agriculture Sector Symposia. There will be two speakers, myself followed by Mr. Clausen. I expect to take about twenty minutes. Then Mr. Clausen will speak and following tradition, he will be pleased to answer questions.

I propose to talk about the following topics: The world food situation and what the Bank has done in agriculture in recent years; I'd like to conclude by saying a few words about some future problems as I see them.

First, however, following custom, I'd like to tell you who we are. This is one of the few occasions where everybody in agriculture comes together, so if you'd look around you you'll see the people you work with. There are now 420 staff members in 26 divisions in headquarters and about 50 in 4 divisions overseas who work in agriculture. About 470 people in all. One third of us in agriculture come from the developing countries, two thirds from the developed countries, which is a substantial change from the ratios of about ten years ago; the numbers of people from developing countries having increased substantially. Six percent of us are women, this is below the Bank average and should be a matter for concern. The age distribution of those in agriculture is quite interesting -- with 3% below 30 and 5% over 60 and, of the rest, slightly less than one third are between 30 and 40; slightly more than one third are between 40 and 50; slightly less than one third between 50 and 60. So you can see a good seasoning. As far as professions are concerned, approximately half of the people in agriculture are trained in economics and finance, the other half are technical people with a good leavening of engineers and agronomists.

Since we deal with agriculture, it is appropriate that we reflect on what kind of a world are we going to be working in in terms of the food situation. I would like to approach this by discussing the supply and demand of food and international trade in agriculture.

First, as far as the supply is concerned, this year as in recent years, agricultural output, especially food grains, has kept ahead of population growth. The reason for this lies largely in the tremendous increase in production in North America -- a very good harvest in North America. There have been generally good harvests in Latin America, parts of the Middle East, and good harvests in East Asia and some parts of South Asia. The places where production has lagged have been in Africa where per capita agricultural output fell and, in an almost statistical impossibility, the Soviet Union has had a third substantial crop failure in a row. Nonetheless, despite the fact that there's been this large failure in the Soviet Union and Africa and short falls in one or two other places, the price of grain has fallen. It's now 20% lower than it was a year ago, which, in some respects, indicates the efficiency of the marketing systems, especially the international trading system.

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On the demand side -- the consumption increases that have taken place have followed previous patterns: as incomes have risen, especially in East Asia, Latin America and the Middle East, a large part of this increase in demand is being used for animal feed or to make white bread, consumed by urban consumers. As a matter of fact, one of the speakers of the Symposium on livestock made the point that by the middle of the 1980s he expected that more grain would be consumed by animals than by human beings; this is a trend that is accelerating. Two points on the demand side. One, as incomes have risen, demand has grown very rapidly as people are moving into higher quality diets, largely meat and white bread. Secondly, in many countries where there's a low income situation, the people are poor, they've remained undernourished and effective demand has not increased substantially. Though undoubtedly the fact that grain prices are falling has helped poor people purchase more and so consume more. One consequence of this change in the supply and demand picture, as it has unfolded, is that the international trade situation has changed from that of the past. Today, to all intents and purposes, there's only one surplus producing area of any real substance in the world, that's North America. For the rest, the other countries, have increasingly become importers; they fall into five categories: the developed countries, the OPEC countries, the middle income developing countries, the very poor countries, and the socialist countries.

In the last year or two the internationalization of the grain trade has continued. Today about 16 out of every 100 bags of grain that is grown enters international trade. Two hundred million tons of grain were traded last year; half of that went to developed countries, half to developing countries. Eighty million tons of that going to developing countries went to the middle income and richer developing countries. Twenty million went to the poorer countries with ten million on concessional terms. And among the poorer countries importing grain are those in the Sub-Saharan African region which imported four million tons of grain. So from a global point of view the deficits in the poorest countries and particularly Sub-Saharan Africa are manageable. They consume a very small part of total grain imports. We should also reflect on the meaning of the internationalization of the grain trade in the development picture at large. Clearly there is a tremendous dependence on North America. This may not necessarily be bad; but, from the physical point of view, if you have a succession of bad harvests in North America, especially in the rain fed agriculture of the middle west, there could be very serious consequences for the globe compared, for instance, with the failure of a monsoon where the consequences would be manageable. Because of this it behooves everybody concerned with agriculture to follow the dictates of the World Food Conference and try to do everything possible to diversify sources of supply and increase production in the developing countries, the Bank's principal clients.
Before I go into that, perhaps I could say a word about the future. I'd like to draw on what Dr. Borlaug said. As a Nobel laureate he's allowed to say things that some of us can't. One of the things he emphasized was that you shouldn't leave the burden of feeding future mankind solely on the shoulders of the agriculturists. He made a very strong plea for more work on population control -- demographic control. He made the point that the world's population will increase between one and a half billion to two billion people by the year 2000 which is only 18 years away. That works out roughly to an additional 80 million people a year to be fed; 60 million of them in the developing countries -- a tremendously formidable task. However, he also made the following point: in the last 30 years agriculture production has increased as much as it had in the preceding 3000 years. So, while there's been a population explosion, there has also been a tremendous explosion in production in recent times. This explosion in production has come from what we might call the application of science to agriculture and a recognition of the importance of agriculture. The change came through the use of purchased inputs, chemical pesticides and so forth along with large investments in infrastructure. And as we look at the investments that have been made we can consider the technological possibilities for the future. From the technocratic point of view it is quite clear that it's possible to feed this increased population and even more. I think it was Professor Raj Krishna in his presentation, who stressed the importance of technological policy and the tremendous increases in capital that will be required to meet the challenge that we face in the years ahead. He maintained that there had been tremendous under investment in agriculture and the needs were very substantial but, like Borlaug, he argued that we really do know how to deal with the problem, i.e. the problem is manageable. One of the points I would like to emphasize is that fertilizers, improved seeds and water have played a tremendous role in the increases in food production that have taken place. When you look at the consumption of fertilizers on a global basis you realize how low it is in the developing countries. For example, fertilizer consumption in North America is higher than in all of Africa and Asia together, excluding China. Yields as a whole in the developing countries are half of those in the developed world. Technocratically the problems can be dealt with, but everybody in this room knows that it takes more than technocratic solutions to deal with these issues.

What has the Bank's role been in dealing with the agricultural problems confronting the world? I'll start with the last fiscal year -- the Bank had a record year in lending for agriculture. We loaned 3.6 billion dollars which was 31% of the total lending of the Bank. The 3.6 billion dollars, taken together with the co-financing and much more the investment by the host countries, represented a total investment of 10 billion dollars, which is a substantial sum. If you take the investment of the last five years in the Bank and IDA, together with the local contributions, that comes to a figure of about 30 billion dollars or even a bit more. And I would venture to suggest that this must be anywhere between 5 and 15% of total public investment in agricultural development in the countries with which we deal (excluding China).
What have we lent for? Where did the money go? Last year the largest part went for irrigation — still the largest component in our lending — with about one third of all our lending for agriculture going for irrigation. The second largest part was for area development, boosted by the large projects in Nigeria, which accounted for about 25% of our lending. Then we've lent, on a descending scale, for agricultural credit, agricultural research, forestry, perennial crops and so forth. But to all intents and purposes our lending is dominated at the moment by irrigation and by area development.

What was the size of our loans last year? They ranged from the largest loan of 325 million dollars which was for agricultural credit in Mexico to the smallest for 2 million dollars which was for rural development in Western Samoa. There were many in between. The distribution was one over $300 million, one over $200 million, three over $100 million and then a large number of lesser loans.

How did the lending go by region? There were 86 projects in agriculture last year and there were 13 in East Africa, for $257 million; 11 in West Africa, for $456 million; 12 in EMENA for $609 million; 12 in LAC for $923 million; 15 in East Asia for $648 million; and 23 in South Asia for $968 million. Obviously the average size of the loans varied as conditions varied from region to region. Now, to turn to our borrowing countries. Looking at the most recent five year period: the ten biggest were India, $2.6 billion; Indonesia, $1.3 billion; Mexico, $1.1 billion; Romania, $741 million; Philippines, $728; Brazil, $535; Yugoslavia, $543; Thailand, $435; and Nigeria, $415; and Turkey, $405 million. Those are the ten largest borrowers. With the exception of India they are all Bank clients, rather than IDA borrowers. Now, the smallest clients in ascending order were: Central African Republic, $2.5 million; Maldives, $3.2 million; Swaziland, $4 million; Gambia, $4.1 million; the Comoros Islands, $5.2; Lesotho, $6; Botswana, $6.5; Jordan, $7.5; Western Samoa, $8; and Haiti, $10 million. These numbers give some idea of the range of borrowing by our client countries for agriculture.

In this fiscal year of 1982, we're having a bit of a lag in lending for agriculture. (We've already lent $700 million for agriculture). However, as you know, lending tends to vary on a year by year basis. This year, as far as I can see, it looks as though we will be lending 3.2 billion dollars which will probably be about 25% of total lending. And this year for the first time in agriculture — the area development projects will supplant the irrigation projects as the largest single project type in our lending program.

I would like to comment on a few of the features of our lending. First, I emphasize the point I've just made about the decline in the proportion of lending for irrigation. Twenty years ago more than half of our lending was for irrigation. This has now declined to about 30% and will be going down even more this year. At the same time, the lending for area development has gone up from 8% to 34%. This reflects the expansion of new style rural development projects, trying to reach more people with a concomittent investment in area development. In recent years we've had the beginnings of a substantial lending program for forestry, rising from almost no lending to close to 3% and projected to go much further. I would draw
your attention to the importance of forestry and fuel wood as part of our energy program and I sincerely hope -- and I carry a message from the Senior Vice President of Operations -- that we will see an acceleration of the lending in this category. It is very important, especially for the fuel scarce poor countries. The other important expansion in lending that's taking place is for research and extension. Once again this is very important and I think that we are responding to the wishes of the Board and others. We are recognizing the importance of research as part of the technological solution of the problems of agriculture, and lending has increased quite substantially. I think, given the needs -- the importance of increasing yields -- this is an important category and is to be encouraged.

Now, I'd like to say a word about the impact of all this lending. What are the results of the efforts of you people in this room? What can we say about it? Well, everybody in this room knows how difficult it is to assess the impact of a project; the problems of measuring it in isolation; the problems of determining the institutional impact of the loan -- all this apart from trying to measure the productive impact of the loan. Bearing this in mind, I've chosen three items from OED reports that I think will give us some cause for some satisfaction. The first is the recent OED report, the 7th annual review of OED, which pointed out that 11 agricultural projects supported the irrigation of 1.4 million hectares with a substantial impact on production. According to the OED -- and I know that many people in this room think they are very critical -- the incremental food grains alone were estimated to be 2.1 million tons. As far as we can estimate, that's an increase high enough to feed or provide the basic carbohydrates for over 10 million people. So here we have the case where 11 projects, irrigation projects, primarily in rice producing areas contributed to an increase in food that's enough to sustain over 10 million people. The second thing I'd like to point out comes from the same report, which pointed out that 142 agriculture projects have benefitted close to 30 million rural people, 36% more than expected. We've helped some 30 million people enjoy a better life through being more productive. Third and finally, I turn to the OED analysis of the rates of return on our projects. Everybody in this room appreciates the problems of undertaking rate of return analyses, the difficulties of making estimations, and especially point estimates of the impact of the loan some five or six years ahead. Be that as it may, and recognizing the difficulties both ex-ante and ex-post estimation, I would like to draw your attention to analyses done by the OED of seven billion dollars worth of investment in agriculture and rural development which is a sample that is large enough for us to draw some conclusions. Their conclusion was that 40% of that investment gave a return of better than 20%; and 40% -- almost the same amount -- gave a return between 12 and 20%. In other words, 80% of that vast investment gave a return greater than 12% to the economy. Eight percent gave a return of 11% and 8% less than 7%. While the results weren't all we might have wished for, we can draw some satisfaction from the fact that at least 80% of that investment gave a very substantial rate of return, and added substantially to the economies of the countries concerned. In addition to this, I would like to point out that generally the projects that were intended to help small farmers, the area in which the Bank has pioneered, gave very much the same results as the other projects.
Thus, in some respects, we are being vindicated, having waited for five or six years for the results of the development strategy as enunciated in Mr. McNamara's speech in Nairobi some nine years ago -- a strategy which called for focusing our efforts on small farmers.

Now, for a look ahead. I'd like to mention a couple of things in the realm of general policy that I think you should know. First, I think that we can take it as read - and I'm sure that Mr. Clausen will endorse this - that agriculture will continue to be an important part of the Bank's lending. Mr. Clausen has told the agricultural managers sometime back, agriculture and energy would be priority areas. Secondly, I don't think we need to make a fetish of the fact that we do focus on small scale producers and that we will continue to focus on small scale producers. As Dr. Krishna said in his presentation, 90% of the labor force in the rural areas of Asia are on small farms and 50-90% of the farms are small. I think the orientation towards small scale producers is now an accepted part of our strategy - I don't think we have to keep on enunciating it. I expect this to continue. I think there are exceptions though. I think that there are parts of Latin America, parts of the Middle East, where focusing on small scale producers may make less sense than in other parts of the world. But generally, I repeat that I expect we will continue along the lines of recent years. Third, in line with the general thrust of the Bank, we will work hard to increase co-financing in agriculture.

I'd like to correct the widespread misinformation or assumption that there's something special about agriculture that prevents the private sector from entering into co-financing arrangements; especially projects that deal with small scale producers. That is not the case. Up until three years ago, there was almost no private co-financing in agriculture though there was plenty of public co-financing. But in the last three years there's been 750 million dollars of co-financing with slightly more than half of this being private co-financing. And I think what's been done is important because this will be an area which, by necessity, we will be emphasizing more in the future, because of resource shortages within our institution.

What kinds of problems will we have to deal with within agriculture as we look ahead? First, I think it's correct to say that the problems of landless rural poor and part time farmers will become more acute. As you know, most of our own efforts have been focused on raising production of those who do control an asset; but this problem of helping the poor small owner or the landless is going to be even more pressing as the years go by. One of the suggestions that was made by Professor Krishna was that there was more scope for employment creation in productive public works in the rural sector. I think this is something we'll have to look at a little harder in the future. The second thing is; we will have to pay more attention and concern ourselves to a greater extent with the whole issue of delivery systems. We have to be more cost effective than in the past. It is very easy to increase recurrent expenditures but far more difficult to generate revenues to pay for these costs. One of the things that we're proposing to do is to have a seminar with some of our clients to discuss the impact that we've had over recent years with the different extension systems that have been practiced. That
should point the ways to improve our performance. We also know its all very well to have a technocratic solution for dealing with increasing production but everybody here knows that the tremendous problems of distribution of this increased output. I think we will do more about that.

I think too that we have to continue our efforts in promoting applied research. Once again, as was discussed by some of our speakers in the Symposia we have to have the appropriate technical policies to generate needed technical solutions. Finally, of course, everything we've said doesn't preclude the most important thing of all - everybody in this room knows that the solution to most of these problems lies in the countries themselves, lie in the role of the governments, lie in the economic policies that they follow and that the best contribution we can make to fostering good policies is through good dialogue and through good sector work.

Before I finish, just let me recap what I've said. I started off by telling you how many people we are and what ages we are, and our nationalities. Second, I talked about the world food situation - that we are not in a critical situation - that the world agriculture system has performed quite well - that the international trading system has coped effectively with the shortages that occurred in the developing world and elsewhere but that the world has become increasingly reliant on North America; this in itself is not necessarily a bad thing but can be dangerous in physical terms if we have weather problems in this part of the world. I've also talked about the internationalization of agriculture trade; the fact that it's growing, that international security demands that there be a very effective international trading system and this has developed. One of the things that we can look into in the future, is how to improve the trading facilities in the developing countries themselves; the use of futures markets and so forth. Work on this has begun already. Then I talked about the Bank - that we had an exceptional record year in lending for agriculture; $3.6 billion. Talked a little bit about what the money went for, where it went, who the big borrowers were and who the small borrowers were, and what we lent for. Finally, I mentioned some of the impacts of these loans and finished off with a brief discussion of future problems. I would like to add one further comment. I think everybody in this room can feel very proud of what we've done. I know that you men - and women - are pretty sceptical about numbers and achievements; and, the general style of the Bank is to be self-deprecating; but, I think there are occasions - and this might be one - that we can pat ourselves on the back. I think that we have made a contribution to improving production and some of the results that I talked about are very substantial. We have helped a lot of governments, we have helped a lot of people to eat and live better and I think all of us can take a great deal of satisfaction from that. Thank you very much.
Closing Address

by

A. W. Clausen*

This is a pleasure for me to appear before you this afternoon. Listening to Mr. Yudelman and knowing of the record -- the outstanding record of our Agriculture and Rural Development Program -- it's very impressive and I'm very pleased to be a member of an institution that has responded to the challenge of food production and rural development opportunities the way that our institution has in the decade of the 70's. I note too that such a record doesn't just happen automatically. It takes people. It takes -- if you'll forgive the expression -- very good people and that's another reason why I'm very pleased to meet with all of you very good people around the subject matter of agriculture and rural development.

Your record is very good and I sincerely hope that you derive a great deal of personal satisfaction from participating in an activity which really has raised the output of millions of farmers, has increased the availability of low-cost food for millions of consumers, and has raised the standard of living of so many people, and yet we are just beginning the job. I would endorse what Monty Yudelman has said, sure we can feel very satisfied, and we should feel very satisfied because there is a rich reward in not only working for the World Bank but there is a rich reward in working for agriculture given the needs of the world currently and in the future. And so, recognizing that need, it is very clear that agriculture is the priority. You really can't say it is the priority but it is a priority and I don't know of any other priority that the Bank has that is more important than agriculture and rural development. The point is that we can't afford to relax our efforts in any way because the mountain is still there to be climbed -- [and to be mastered] and our role here in the World Bank is to be the pace setters and to be the innovators and to exert a role of leadership -- to be the standard of excellence that we are and to continue that and to try to improve upon that standard if we can.

Agriculture and food production involves the individual and even though we deal with a great many clients, countries, and therefore there are a great many different styles, and ideologies of governments, when you pierce through the kinds of governments -- democratic, non-democratic, bureaucratic, monolithic and go to the individual entrepreneur -- that is the real aspect of agriculture and rural development and here again I am very pleased to find that this institution has that premise so firmly in its discipline and in its philosophical approach. We want to keep very much in mind that the small scale producer is going to be very much a part of the solution.

We have all heard of budget constraints, limited resources, and it is true that one of our big problems is budgetary constraints and the lack of resources. Monty Yudelman said that the principle resource that we deal with as a development bank are the resources found in the indigenous country itself;

* President, World Bank
its people, its government policies, the development monies that the individual
government can bring to bear in the agriculture and rural development sector.
If we have budget constraint problems in donor countries as well as in developing
countries, we have to do our job far more efficiently and effectively and elo-
quently than we have been doing in the past. These constraints put a focus on
coin-financing.

I am pleased in the last two or three years that there has been an
increase in co-financing of agricultural projects and I would sincerely hope
that this group of professionals would continue the work in that direction.
When you look at the resources that can be brought to bear -- government
resources are clearly limited and our Bank Group resources are limited, then
we have to be terribly innovative as to how we can extend or expand these
resources by joining with suppliers of other resources. Our most important
resource is people and the professionalism and knowledge and experience and
reputation. If we put all that together and try to leverage our own resources
with more financial resources elsewhere, it puts the issue of co-financing in
a different light. We are thinking in terms of internal management performance
guidelines to reflect the importance we attach to more co-financing. I think
we maybe have got some internal obstacles in the way of co-financing -- in the
way that we allocate our time for stewardship. Sure it takes more time to get
co-financing but then if our job really is to be a catalyst for economic develop-
ment in third world countries, we should spend the time where we can marshall
the greatest dollar resources that we possibly can on the problem and save if
we can -- use less of our financial resources -- save it elsewhere to do the
same job someplace else. That's our challenge, that's our opportunity.

There is a very big problem for agriculture when you think in terms
of another couple billion people that are going to be here on planet earth
over the next ten -- I should say the next twenty years or so. It puts
another focus on our work here at the World Bank. Not only must the world
produce enough food, it must be sustainable over the long haul. And that
presents us with the concern for conservation of the natural resource base that
we have to work with. There's soil erosion in far too many places on planet
earth and some countries in particular. Soil and water resources are both
finite and let's make sure that we can do whatever we can to better manage
those resources; and, that we don't permit over-exploitation as has been
occurring in some parts of the world. It's a very difficult task, but here
again I'm pleased that we do recognize this problem in the Bank.

I want to compliment you and thank you. Fiscal 1981 was an out-
standing year. Agriculture remains our high priority. We're going to have
to be lending about 30% of Bank and IDA to agriculture and rural development --
31% last year. There'll be ups and downs but not very much down and not very
much up given other sectors which we need to pay attention to. Energy is the
one which is very key -- may I say critical. I think agriculture is very key.
Maybe on the short haul a bit less critical. Problems and the complexities in
the days ahead are going to be there. And maybe they're going to be getting
more difficult here and there. Certainly more difficult when it comes to
internally allocating the scarce commodities that we have; scarce commodities
of people and professionals and the scarce commodities of dollars that go with
those people and professionals. So have a happy new year and have a good 1982 --
all of it -- not just through June 30.
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