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CHAPTER 5

THE NEXT STAGE OF AGRICULTURAL DEVELOPMENT: IMPLICATIONS FOR INFRASTRUCTURE, TECHNOLOGY AND INSTITUTIONAL PRIORITIES

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China in the 1980s has simultaneously entered a new stage of food consumption development and a new stage of technical transformation of its agricultural sector. These two transitions, particularly as they are occurring approximately within the same period, require an adjusted perspective on agricultural development in China, dictating new priorities for policy, especially in the areas of technological change, and the development of institutions and infrastructure. Since new priorities are required, the definition of successful performance in the agricultural sector must change and new indicators of success must be adopted.

Some observers of Chinese agricultural development believe that China's recent rural reforms, initiated in the late 1970s and developing further during the 1980s, have been responsible for creating a number of difficult social and economic problems ultimately impeding further agricultural growth. Others have concluded that the reforms themselves were the primary cause of extremely rapid agricultural growth during the 1980s. Those who believe the first proposition would suggest a retrenchment toward policies and institutional arrangements of the 1970s in order to return to a slower, but steadier pace of progress in key agricultural categories. Those who adhere to the second may suggest that it was retrenchment during the second half of the 1980s which caused the slowdown in agricultural growth and that what is required to rekindle rapid agricultural development is a reversal of this recent trend in order to press forward as rapidly as possible with further liberalization measures.

This paper takes a different view from either of these positions concerning the most productive policy orientation for the 1990s, inasmuch as it is based on a different interpretation of past, including recent agricultural growth. In this view, the dominant economic development in the agricultural sector is China's entry into the second stage of food consumption development and technical transformation. Successful development in these stages required reform of the 1960s and 1970s rural institutional and

policy orientation. These rural reforms have been instrumental in setting appropriate conditions for rapid growth in economic crop and rural non-agricultural categories, but their effect on staple crop production growth has been mixed.

Rapid growth in staple crop production during the late 1970s and 1980s has been primarily a process of cashing in on the fruits of investments in technical change undertaken since the 1950s, by relieving the final constraint to their full realization—insufficient availability of soil nitrogen (1). With the rapid removal of this final obstacle since the second half of the 1970's, the difference between actual and potential yields from HYV staple crops, based on earlier investments in water control and extension of high yielding, fertilizer-responsive seed varieties, rapidly narrowed throughout China's major growing areas; yield growth, calculated in terms of national averages, accelerated to high and unsustainable rates, and then inevitably, slowed down. While this "cashing in" process is not yet complete, further growth in cereal yields will depend increasingly, upon the slower pace of technical change and of efficiency improvements in advanced areas associated with the second stage of technical transformation; and the slower pace of institutional and infrastructural development necessary to help bring China's less advanced areas through the first stage of technical change.

China now faces a tactical dilemma: the second stages of food consumption development and technical change require market-oriented institutional reforms, aggressive development of complementary infrastructure, and supportive policy; yet these activities will tend to undermine continued rapid growth in staple crop production under the present system based on market restrictions and preferential treatment for particular staple crop producers associated with the procurement process. Slower growth in staple crop production will tend to undermine the basis for rapid growth in non-foodcrop and non-agricultural sectors.

Resorting to recentralization and retreating from market reforms will tend to reduce rural economic growth in non-staple crop categories, and may even slow the rate of allocative efficiency improvements in staple crop production. Trying to press forward with reforms in non-foodgrain categories while attempting to solve problems of incentives for staple crops producers with market restrictions, preferential treatment and selective subsidization will be inefficient and increasingly costly — perhaps ultimately leading to reductions in research and capital construction investment categories critical to technical change in agriculture and the national integration of markets.

The solution to this dilemma lies not with subsidization of staple crop producers through input or product markets or through the attempted reinstitution of bureaucratic controls over staple crop production, but through a much greater focus of attention on capturing efficiency gains in allocation through the simultaneous expansion of the staple crop procurement system and fertilizer distribution system in areas of high marginal returns to fertilizer use; expansion of the role of fertilizer and staple crop markets supplementing parastatal allocation, distribution and procurement activity; and aggressive development of associated infrastructure and supportive policy. The solution also requires a much greater focus of attention on key improvements in technical efficiency and quality of inputs associated with staple crop and livestock product development (2).

The Strategic Position of Foodgrain Production Development

During the 1960s and 1970s, foodgrain production development was the focus of agricultural development strategy. It can be argued that this strategy could have been executed more quickly and efficiently, that the tactics employed to achieve strategic success included those for which costs in terms of rural development in non-foodgrain categories were unnecessarily high and unjustified by their effectiveness, and that insufficient national (especially capital) resources during the period were devoted to the task of agricultural (including foodgrain) development, relative to investment in other sectors of the economy. But it cannot reasonably be argued that within the agricultural sector, foodgrain development was not clearly the strategic focus of agricultural policy during the 1960s and 1970s (3).

It is almost equally clear that this strategic focus was a sensible one, although, as suggested above, it may have been taken to counterproductive extremes. It is argued here that the continued exclusive emphasis on foodgrain production in agriculture is misplaced. This must give way to primary emphasis on increased agricultural output value within (an increasingly liberalized) system of market prices which reflect relative scarcities and preferences in Chinese society, and the withdrawal of labor for non-agricultural development.

Since agricultural output value, measured in constant contemporary prices, has continued to rise at a brisk pace in China, even into the late 1980s, since these prices reflect, to an increasing degree, relative preferences and scarcities in Chinese society, and since rising agricultural output value has been consistent with a large withdrawal of labor from agriculture for non-agricultural development, then Chinese agricultural development,

even into the late 1980s, must be regarded as successful. Thus, the recent obsessive concern with stagnation in foodgrain output, to the point of leading to a retreat from market liberalization measures and an attempt to drive rural labor back into staple crop production, is misplaced. After all, elimination of an obsessive and costly concentration on foodgrain production growth was a fundamental objective of reform measures.

Yet continued development of staple crop production, and its more effective use in livestock development, remain important secondary objectives during the second stage of food consumption development and technical transformation of agriculture; and it is this aspect which currently requires a somewhat greater, but more efficiently directed emphasis.

The Theoretical Context of Modern Technical Change in Chinese Agriculture: The first stage

The key elements of an agriculture-based strategy of economic development were articulated between the mid-1950s and the mid-1970s (4). W. Arthur Lewis defined the critical role as a wages good (5). Johnston and Mellor delineated the necessity of productivity increase in agriculture and the role of technology (6). On the most simplistic level, if a peasant economy is to move toward greater concentrations of employment in non-agricultural activities, it is essential that productivity of remaining farmers increase to feed the growing ranks of non-agricultural workers. There will not only be increasing demand for food from population growth and to increase the level of health and the productivity of labor, but also from additional demand accompanying higher real incomes required to attract non-agricultural workers. When average incomes in a country are low to begin with, increments to income will be spent primarily on food, raising the demand for food rapidly as development progresses, despite declining farm populations available to supply it. Among food commodities, rapidly rising production of staple foodcrops such as cereals and root and tuber crops are most essential in the earliest stage, since they form the largest share of diets among poorer peoples.

This means that technical change for increasing the productivity of labor in agriculture, especially foodcrop production, is essential. Without it, supplies will be insufficient to meet the growing demand for food, and food prices will rise, implying the necessity of higher wages — reducing savings, capital formation and growth in non-agricultural sectors. Moreover, higher prices will have little aggregate production impact since most land is already allocated to staple food crops, and the productivity of

surplus labor which might be applied, in the absence of technical change is likely to be low.

If wages and prices are administratively controlled, and food is forcibly procured and rationed, incentives to increase production in both agriculture and non-agriculture are likely to suffer. In particular, farmers have reduced incentive (or surplus income) to invest in technical change to increase production beyond their own needs.

In a land-abundant country, productivity growth can proceed with aggressive reclamation and mechanization, but the problem is more complicated in the case of a land scarce peasant agriculture. This is China's situation: although a large country, soil and climate conditions are inadequate for farming across a large portion of the country, while reasonably good farmland may be limited to around 10 percent of China's land area.

Throughout the poorer economies of Asia characterized by extreme land scarcity, the importance of concentrated attention on technical change in staple foodcrops is even greater, since these are the most land efficient means of supplying calories. With land as the most binding constraint, the focus at the early stages of rapid growth in land-scarce developing countries must be upon those elements of technical change which provide increases in staple crop yield per unit of land, rather than mechanization to replace labor. In China's case, this was especially so, since the adopted development strategy focusing on capital intensive heavy industry provided little urban employment opportunities in the manufacturing sector, and restricted urban service development and consumer handicrafts, which might have provided tertiary sector employment for rural migrants.

Ultimately, the rate of yield increase must be sufficient to bring about rising per capita production levels and increased food marketing per urban capita, and this normally means growth in labor productivity. But these elements are also dependent upon various other demographic and institutional developments that may be logically separated from agricultural technical change. So how should technical change be measured? With Chinese restriction of rural-urban migration, increases in aggregate productivity of labor, when measured, as is customary, in terms of growth in total farm production per agricultural worker, need not reflect increases in potential productivity of remaining farmers that would be revealed were surplus labor released for employment elsewhere.

It is growth in this potential productivity, not easily measurable for China during the 1960s and 1970s, that is one suitable indicator of technical progress at the basic stage. If actual aggregate productivity of farm labor does not increase, it may reflect poor labor allocation policies,

effective migration controls, inadequate work incentives, and idle rural labor, rather than a lack of progress with agricultural transformation which raises potential productivity and prepares the way for large labor exodus from agriculture (should non-agricultural employment be available), without farm production penalty.

Even yield growth is not an ideal indicator for two reasons. Problems with incentives may inhibit suitable application of labor for optimal yield growth despite technical progress. Second, optimal yield growth is only achieved when all of the necessary components are in place. Technical transformation of peasant agriculture is a time consuming and complicated process, even at the most basic level. A country may be seen to make considerable progress with several of the necessary components, but achieve smaller yield increments due to poorer progress with one or more of the remaining ones. Thus it is necessary to examine not only yield growth, but progress with individual components of technical change.

The essential ingredients of land-augmenting technical change, required by most developing countries in Asia, have been delineated by Ishikawa, and tracked during earlier periods for India, Japan, Taiwan and Mainland China (7). Among all indicators associated with progress in agricultural development, only three are indispensable to rapid and prolonged growth in yields at the initial stage: improved water control, abundant supplies of fertilizers and high yielding seed varieties responsive to these inputs. While introduction of one or more of these three normally provides some growth in average yields, there are much greater returns when all three are provided appropriately. These are the fundamental ingredients of the "green revolution," which has provided rapid growth in cereal yields throughout most of Asia and elsewhere in the developing world.

Proper policy and institution building at this initial stage then requires the establishment of reliable and rapidly growing delivery systems for water, HYVs and fertilizer. This means establishment of broad-based agricultural research, extension and seed multiplication and delivery systems, development of fertilizer production capacity and/or long-term, rapidly increasing fertilizer import commitments, establishment of a broad network of fertilizer distribution outlets and water authorities capable of constructing irrigation and drainage projects. It also means appropriate development of systems for education, research and information gathering, power, telecommunications, transport and local administration to adequately back up this effort. Finally it means supportive policy and a framework of rural and national institutions which can finance these

systems and allow farmers to finance the adoption of inputs, reduce their risk of adopting new techniques, and provide a suitable market for their output.

This entire complex of activities need not be so government dependent as it appears. Technical change in agriculture has transpired in some countries without such a pervasive public role, but over a much longer period of time. The necessity of rapid transformation of peasant agriculture in China's case dictated an active governmental presence in agriculture regardless of the government's ideological orientation. Indeed an active public role was instrumental at various stages of transformation for many "non-socialist" economies, including those of the United States, Japan and Taiwan.

The principal criteria for judging technical change at the initial stage of modern agricultural development in a large but land scarce peasant economy therefore include yield growth of principal staple foodcrops, and various indicators related to the three fundamental inputs. The latter include growth in irrigated area, multiple cropping, capacity of irrigation and drainage machinery in use, fertilizer use, area sown with high yielding and early maturing staple crop varieties, and so forth.

Should yield growth greatly exceed the growth in these input indicators, it might be concluded that factors other than technical change were at work. Should yield growth fall short of what might be expected from the evident pace of technical progress, the quality of the inputs, the efficiency of their use, the strength of the backup systems and other factors may be examined to explain the anomaly. Finally, the adequacy of the overall pace of technical progress and yields in terms of China's development strategy, may be evaluated by examining the growth of production per capita nationally, and for greater detail, by growth in marketings per urban resident and in production per agricultural laborer.

The Second Stages of Food Consumption Growth and Technical Transformation

A second stage of agricultural development may be defined in a number of ways. One may focus on the levels of per capita supply of basic staple crops, as has been done by Kojima(8). In Asian agricultural economies, when aggregate staple crop production per capita reaches the neighborhood of 300 kgs./capita/year, emphasis on improvements in quality and diversity of diet increasingly displaces concentration on elevating caloric intake by the most readily available means. The exact points of transition vary with climate, the distribution of physical work loads, dietary customs

and income among the population, governmental policy, and so forth, but the shifts associated with this transformation are striking for most rapidly developing countries. In terms of Figure 1, this means that countries entering the second stage of food consumption growth are apt to follow an intertemporal path with declining positive slope, which may ultimately turn negative.

Agricultural requirements of the second stage of food consumption development in a poor land-scarce economy include rapidly rising yields of a wide variety of non-staple crops and rapid increase in the production of livestock products. Although direct consumption of staple foodcrops will not increase as fast as income in the second stage, and will eventually decline, the need for continued rapid growth in staple crop yields is greater than ever for five reasons:

1. Providing calories by means of livestock products is far less land efficient than providing them directly—between four and twelve times the quantity of staple (feed) crops may be required per 100 calories of meat consumed relative to providing those calories via direct consumption of staple (food) crops; a similar point may be made about the land efficiency of supplying calories via oil crops;

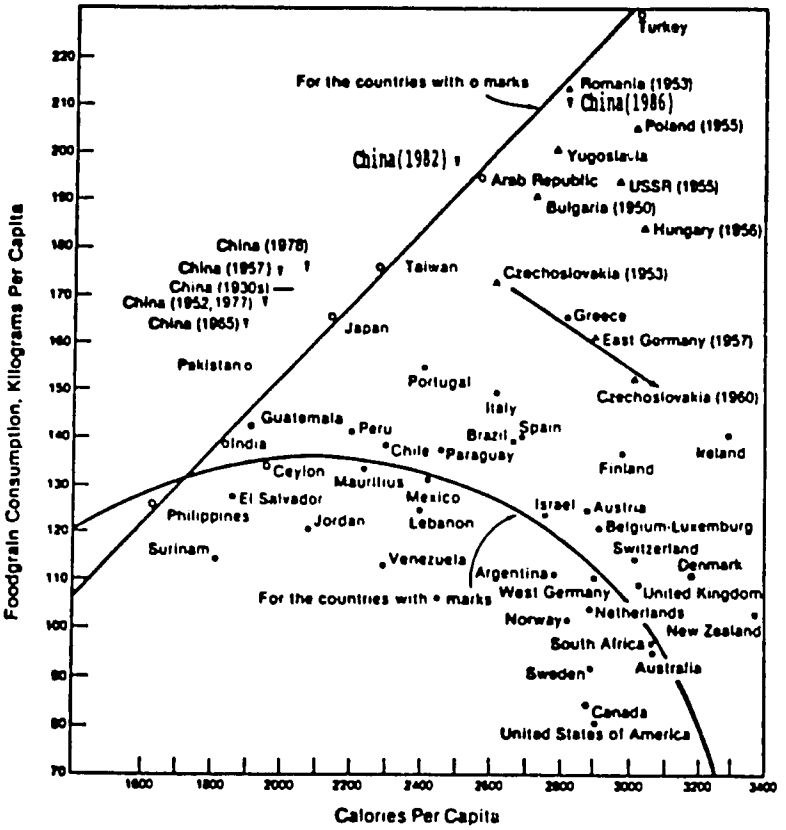
2. There will be continued growth in staple crop demand associated with population increase, and with public efforts to increase consumption levels of the poorest citizens — without food surpluses, large-scale poverty alleviation is inevitably curtailed, even in socialist countries, whether in the form of food production assistance or food subsidies;

3. As people are becoming satisfied in simple terms of sufficient calories, a larger proportion of sown area is likely to be reallocated away from staples toward non-staples;

4. Surpassing the second stage threshold of staple crop consumption is apt to be accompanied by an acceleration in non-farm employment and migration with associated reduction in cultivated area and/or multiple cropping, particularly on lands near cities and towns, which, in a peasant economy will often include high quality land; and

5. Even increases in the direct consumption of foodgrains (measured by the vertical axis in Figure 1) have remained quite high as China has entered the second stage of food consumption growth. As the points for other countries in Figure 1 demonstrate, this pattern is typical of Asian countries and socialist countries; China qualifies in both categories. When added to the indirect demand for staples via rapidly increasing consumption of livestock products, this means that total increased demand in China for staple crops will be especially high, as the country enters the second stage.

Figure 1. An international cross-section relationship between per capita grain consumption per year, and per capita calorie intake per day of all foods



Notes: The figures for per capita foodgrain consumption are calculated as the sum of the weights of processed foodgrains consumed directly by humans, and one fourth the weight of root and tuber crops. To conform with other international data, the entries for China omit soybean consumption and have re-evaluated root and tuber crops from one-fifth to one-fourth natural weight. Consumption per capita of foodgrains in Chinese data includes rice and millet at "trade grain" weight (partially processed paddy and millet weight). Rice has been converted to processed weights according to FAO convention at the time the international data were published (67.5% paddy weight). The 1982 calorie figure is calculated from the most authoritative data base yet generated in China, by the country's premier nutrition research

organization, although estimation procedures have not been reviewed in detail for possible biases. The international data are for 1965 unless otherwise specified.

Sources: Bruce Stone, "China's 1985 Foodgrain Production Target: Issues and Prospects," in Anthony M. Tang and Bruce Stone Food Production in the Peoples's Republic of China Research Report No. 15 (Washington, D. C : IFPRI, 1980), p. 93. For China, the 1982 and 1986 figures have been added and the 1952-1978 figures have been recalculated on the basis of population and consumption per capita figures in ZGTJNJ 1987, pp. 89, 711, adjusted population data in ZGTJZY 1988, p. 14, and crop production data in ZGTJNJ 1987, p. 170. It was assumed that 50% of soybean production (average of cited and previous year) were included in SSB foodgrain consumption per capita figure, on the basis of Alan Piazza, Trends in Foodgrain and Nutrient Availability in China 1950-81 World Bank Staff Working Paper No. 607 (Washington, D. C.: The World Bank, 1983). 70 percent of root and tuber crops in 1978 are assumed included in the SSB direct foodgrain consumption figure and 80 percent for previous years, for the purpose of recalculating foodgrain equivalents; these were adjusted to 50 percent for sweet potatoes and 60 percent for white potatoes in 1982 and 1986 on the basis of Charles Gitomer and Bruce Stone, "Sweet Potato and White Potato Development in China," a paper prepared for the International Potato Center, IFPRI, Washington, D. C., November 1, 1988. The 1982 average calorie consumption figure (2485 kcal) is based on nutritional material collected with the 1982 census and calculated by the Chinese Academy of Preventive Medicine; provided to author by Dr. Chen Chunning, President, May, 1986 and confirmed June 9, 1988, Beijing. Calories not accounted for among the SSB data categories are assumed to derive from liquor, dairy products, fruits, vegetables and other miscellaneous categories. Estimates for other years for these categories are indexed against the 1982 residual figure.

So the tactical aims of successful agricultural transformation in the second stage of food consumption growth include rapidly rising yields of non-staple crops and continued rapid progress in staple crop yields. But they also include increased attention to growth in labor (as well as land) productivity, and immediate efficiency improvements in the livestock sector.

Indicators of technical transformation and principal components include those scrutinized for the first stage. But as Figure 2 indicates, there must be increasing emphasis on other criteria, particularly when the second stage of technical transformation coincides with a second stage of food consumption development. Entry into the former may be defined as the point at which increases in efficiency and quality of the three critical inputs become more important, more feasible, or more cost effective than continued growth in their gross supply.

Figure 2. Objectives, critical components and requirements for the first and second stages of agricultural technical transformation and Food consumption development in land scarce peasant economies

Stage	Principal Objectives	Critical Technical Components	Principal Success Indicators	Institutional Needs
First Stage of Technical and Food Consumption Development	↑Staple crop yields ↑Staple crop production per capita	Water control -Staple crop HYVs -Fertilizer use -Early maturing varieties 1/ -Cultural practices	↑Staple crop yields ↑Staple production per capita ↑Irrigated area ↑Flood control area ↑Capacity of irrigation and drainage equipment ↑High and stable yield area ↑Multiple cropping index ↑Fertilizer application ↑Area under HYVs	-Water engineering construction organization -Local water distribution authorities -Fertilizer distribution network Seed production, distribution and extension system -Agricultural research system -System for input purchase financing -Staple crop purchasing system -Some transport, power, educational and statistical system infrastructure
Second Stage of Technical Transformation and Food Consumption Development	Same as first stage, and ↑Yields and production per capita of non staples ↑Production per capita and efficiency in livestock sector ↓Labor per unit of staple crop production	-Same as first stage, and -Stress tolerant staple crop varieties -Non-staple crop HYVs -Higher quality varieties -Weed control -Pest and disease control for crops and livestock -Improved livestock breeds -Better livestock management Animal nutrition Mechanization	Same as first stage, and ↑Non-staple crop yields ↓Feedgrain/meat, milk, egg output conversion ratios ↑Completion of ancillary facilities on irrigation projects ↑Within-project distribution of water ↑On farm water management ↑Balance of fertilizer nutrients ↓Nitrogen losses ↑Georgaphic distribution of fertilizers ↑On-farm analysis of nutrient needs ↑Farm chemical use ↑Biological control of pests and diseases ↑Seed breeding for local environments ↑Experimental yields of new HYVs ↑Mechanization ↑Fuel use for farm tasks ↓Labor application to farming	

Stage	Principal Objectives	Critical Technical Components	Principal Success Indicators	Institutional Needs
Market-Related Technical Change Associated with Second Stage	-Prevent local or temporary demand constraints from lowering supply growth and pace of technical change -Allocative efficiency for inputs to food production process	-Transport infrastructure -Communications infrastructure -Rural power -General education -Rural motor vehicle stocks -Fuel supply network -Rural credit -Fertilizer stock management and facilities -Others		

Note: [1/]China's considerable breeding concentration on early-maturing varieties is not duplicated elsewhere, but is a typical extension of land and capital-scarce, labour-abundant factor proportions.

Source: Bruce Stone, "Developments in Technology," *The China Quarterly*, Special Issue on Food and Agriculture in China During the Post-Mao Period, No. 116, December, 1988, pp. 768-770.

For example, as irrigation and flood control development proceed, the most cost effective investment opportunities are gradually exhausted. In the second stage of irrigation development, further increases in irrigated area require more expensive basic structures or are apt to benefit land with less production potential than projects initially pursued, reducing their attractiveness and claim on the national budget. At the same time, costs for all projects are increasing due to rising opportunity costs for labor, while even without considering wage rates, the costs of repairing and maintaining the existing system rises as the system grows. Yet, with success in reaching the second stage of food consumption development, public budgets for irrigation development may not grow as quickly as in the past, or may even fall.

All of this suggests an inevitable increased emphasis on efficiency of irrigation and flood control networks relative to further construction of basic systems. The appropriate foci include completion of ancillary facilities on existing systems, improved quantitative and temporal distribution of water within command areas, more reliable delivery of water, better water quality, and improved on-farm water management. Only the first of these is statistically captured by increases in "effective irrigated area" (youxiao guangai mianji). Appropriate criteria for assessing aggregate success in the other areas are more elusive, although continued growth in operating capacity of irrigation and drainage equipment, expansion of "high and stable yield fields" (gaochan wenchan tian) and increases in the rate of "irrigation guarantee" (guangai baozheng lu) are relevant.

Likewise, the second stage of fertilizer use development is marked by the growing importance of a proper balance in nutrient supply, which differs according to local soil conditions and cropping systems, and of efficiency in fertilizer nutrient uptake per unit applied. Even with fertilizer-responsive varieties, as nitrogen application reaches higher levels, response rates to incremental applications decline, due to growing deficiencies in other nutrients. This inhibits further technical transformation and yield progress. Solutions relate to more sophisticated application methods, and greater variety, higher quality and more timely availability in fertilizer supplies, as well as more precise and more locally specified analysis of nutrient requirements.

While the first stage of seed varietal change is likely to emphasize fertilizer responsiveness, higher yields under optimal conditions, and/or more rapid maturity to facilitate increases in cropping intensity, the second stage is marked by increased attention to breeding for very specific local

conditions: greater attention to stress tolerance, grain quality and adjusted maturities to accommodate local cropping systems and environmental peculiarities.

Each of these "second stage" emphases is information-intensive in several dimensions and thus requires more extensive and more sophisticated agricultural research, information gathering and extension systems. Taken together, they eventually necessitate broader and deeper development of farmer education.

During the first stage, the most critical areas of farm process mechanization were more or less limited to irrigation and drainage equipment and other selective items to facilitate multiple cropping, which increases labor application per unit of land. In the second stage, a more broad-based effort is required to free up labor for non-agricultural pursuits without farm output loss. In China's case, one of the most critical processes to mechanize is the collection, transport, mixing and incorporation of organic manures. This is an extremely labor intensive process which is already declining in suburban areas as labor's opportunity costs rise and with increasing availability of chemical fertilizers. Yet without adequate manure work on Chinese soils chronically depleted of organic matter, returns to chemical fertilizer use are likely to decrease over time.

Hand weeding is another major labor consuming task which is likely to suffer as labor costs increase. With China's high rates of fertilizer application, mechanized weeding, herbicide use, or some other technical expedient, such as the use of plastic soil mulch for weed control, will be essential to maintain yield levels.

Land scarcity, rising per capita consumption of meat, milk and eggs, and the high feedgrain costs of livestock products during the second stage combine to dictate the necessity of emphasizing technical transformation in the livestock industry immediately. The principal aim is to reduce feed consumption per unit of livestock commodity produced. A few aggregate efficiency indicators include average meat yield per carcass, aggregate slaughter rates, average milk yield per lactation and the inverse of the proportion of breeding sows to year-end stocks. The more each of these rates can be raised, the less concentrate feed is required per unit of consumable livestock product.

It is not inevitable that the second stage of food consumption development coincide with the second stage of technical transformation. But they seem to do so in China's case and are, to some extent, related. Both signal the end of extreme supply scarcity as a pervasive economic condition in food and agriculture. During the second stage in food consumption

development and in technical transformation, chronic supply scarcity gives way to a period when supply constraints intermingle with periodic or localized demand constraints, for specific types and quantities of farm products, specific fertilizer products, and so forth. While the transition between these states need not be sudden, it is apt to be more so in the case of centrally planned development.

The most fundamental implication of this shift is that it becomes increasingly important to supplement central planning and centralized procurement and distribution with market elements. This is necessary in order to manage the rapidly proliferating complexities of the market; to link up, expeditiously, areas of surplus and deficient supply and demand, without burgeoning state resource requirements; to more efficiently allocate resources related to these necessary shifts in production make-up; to maintain incentives; and to free up planners and administrators to concentrate on the more critical social and economic issues which markets are less capable of solving.

In China, the process of integrating relatively free market elements into the state-controlled system of economic interactions is underway. This has profound implications in many spheres related to agricultural development, including institutional adjustments affecting technical change, needed infrastructural investments and associated policy reforms.

While it will not be possible to discuss these issues at length, it may be suggested that an additional important criterion for judging progress in technical change during the second stage consists of China's performance in institutional adjustments required to achieve that progress in a subsequent period. Likewise, the evaluation of technical progress within a period depends not only on the value of each target variable in the current period, but upon groundwork laid to affect it in subsequent periods.

Finally the general movement into a more market-oriented economy involves technical change in a variety of rural infrastructural categories such as transport, telecommunications, power, fuel distribution, credit and other financial services, education, publishing and so forth. Even with the most supportive current period policy, there may be failure to equilibrate supply and demand across time and space related to inadequacies in any or all of these infrastructural areas. Such failure will tend to inhibit sales and the predictability of sales, and therefore investment, the adoption of new techniques, and ultimately yields levels. Such infrastructural development will also underwrite rural non-agricultural growth crucial for sustained growth in rural incomes, which provides steadier growth in demand for agricultural products and maintains incomes in farming

without governmental subsidization.

But several of these categories of infrastructural investment have long gestation periods. Thus ease or difficulties with market clearing in the current period may be related to aggressive or inadequate investment in these categories during past periods. Likewise an evaluation of current performance in technical change should not ignore infrastructural investment which facilitates future technical progress.

This section demonstrates that evaluation of progress in technical change related to agriculture during the second stage of technical transformation and food consumption development is considerably more complex than an evaluation of the first stage, which may, without too much distortion, be reduced to a review of a few basic indicators. Proper preparation for the second stage, however, may dictate additional requirements for first stage developments, in view of the long gestation period implicit in several infrastructural (and to some extent institutional) categories critical to the second stage.

Pricing Policy in the Transition Economy

Agricultural pricing policy is receiving increasing attention in China and the "irrational" price structure is routinely blamed for a variety of economic and societal ills inside and outside the sector. While a comprehensive treatment of pricing policy falls outside the scope of this article, several features of an appropriate pricing policy follow directly from an appreciation of China's position at the second stage of food consumption development and the second stage of technical transformation.

1. Movement toward market pricing for most commodities becomes increasingly important to sustained and efficient development in agricultural output value.

2. To the extent that public marketing institutions still dominate purchases of basic grains, meats, and important inputs such as fertilizer, coordination of administrative price changes for these commodities is preferred.

3. To the extent that public marketing institutions for these critical commodities still play an important role, small regular adjustments in these prices and their relationship to each other is preferable to prolonged periods of price rigidity, followed by large swings in price adjustments for particular commodities at unpredictable intervals.

4. Fiscal and monetary policies and institutions realizing low rates of inflation are essential.

5. Concentration in public policy on the provision of sufficient pecuni-

ary incentives for adequate staple crop growth through efficiency improvements and productivity growth via technical change is preferable to subsidization of staple crop producers via farm product purchasing or input distribution parastatals. Conversely, however, sudden and significant erosion of returns to staple crop producers via these institutions is to be avoided.

These measures will serve to allow increasing liberalization of markets in non-essential commodities and marginal markets in essential commodities while safeguarding the stability and predictability of returns to producers of basic staples and livestock products still affected by public procurement.

Chinese Performance With Basic Technical Change: Staple Food Crop Yields and Production per Capita

Aggregate yield increase is available from a variety of sources, but in a land-scarce economy with relatively egalitarian distribution of farmlands, only technical progress is capable of providing prolonged and rapid yield increases for major crops. Technical progress in a pre-industrial peasant agriculture may be defined as the increased use of modern inputs (chemical fertilizers, farm chemicals, high-yielding varieties, hydraulic engineering, mechanization, etc.), improvements in modern inputs used, the manner in which they are combined, or the application of scientific methods to improve the productivity of these and traditional (pre-modern) inputs.

Other sources of yield increase include: better weather, greater application or effective application of labor and traditional non-labor inputs, more effective combination of these inputs or geographic relocation of various crops to more favorable production areas not based on scientific evaluation, and rural organizational change.

The most intriguing of these is organizational change. No country has experimented with rural organization so often, so radically or on such a broad scale as has China between the 1940s and 1987. It is commonly believed that organizational change at various times has exerted important effects (both positive and negative) on Chinese agricultural production, including foodgrain output. But it is important to categorize how this influence may operate. First and foremost, it may accelerate or inhibit the dynamic process of technical change. Second, it may affect the other yield influencing categories.

In this paper it is argued that technical change is the major source of growth in staple foodcrop yields during the People's Republic period. This

has been especially and increasingly so since the 1960s. To the extent that rural organizational change has been contributory, it has done so primarily via affecting the productivity growth associated with that process (9).

During the 1950s, organizational change in the form of land redistribution which provided more efficient combinations of land and labor, and the provision of a national purchasing system for farm products, reducing market risk, were important sources of staple crop growth. They combined with restoration of water control systems, selection and dissemination of best farmer and imported seed varieties and increased labor and organic manure application to bring about rapid growth in foodgrain yields.

During the 1960s and 1970s, while increased application of traditional inputs, especially labor and organic manures, combined to contribute, technical change, in the form of the extension of superior farming techniques, improved water control and growing application of chemical fertilizers, became the increasingly dominant source of yield improvements. During the 1980s, further varietal improvements and unprecedented increase in the quantity and quality of chemical fertilizers applied have been responsible for staple crop yield growth reaching record rates from the late 1970s through the mid-1980s, despite the massive removal of farm labor from staple crop production.

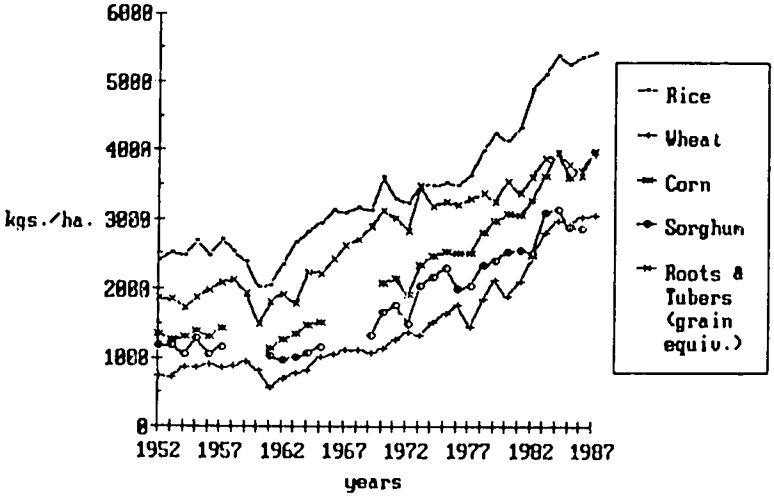
While further varietal improvements and increased fertilizer use have remained the main source of growth in the late 1980s, the slower rate of yield improvement since the mid-1980s has been due to: the exhaustion of a large share of the unexploited yield potential of formerly underfertilized HYV's; deterioration in price incentives to concentrate inputs, especially labor and chemical fertilizers, on staple crops, as opposed to other crops and farm activities (10); failures in farm product, farm input and farm credit markets associated with mismanaged reforms, attempted recentralizations and decreasing administrative control over local units associated with these critical institutions (11); and the relatively poor performance in phasing in efficiency improvements as an alternative source of productivity growth (12). Contrary to popular assumption, the second two difficulties are likely to have been at least as important as the first two.

China was already engaged in modern technical change during the 1950s but that effort, although accelerating, affected significant proportions of farmers in only a few categories. After the catastrophic famines (1960-61), China became committed to technical transformation on a comprehensive and coordinated basis throughout the country. For the next 1 1/2 decades progress in each of the basic categories was rapid, accelerating and relatively uninterrupted. During the last decade, growth in a few

of these categories halted, while continuing in others (13). In this section the effectiveness of technical change as measured by the important proxy of yield growth is compared for the Maoist period and the recent reform decade.

Figure 3 shows average yields of China's staple foodcrops for which growth has been the most rapid. From a technical point of view, and in terms of international experience, these are the foodcrops for which large yield increases through technical change are most readily available (14).

Figure 3. Rice, wheat, corn, sorghum, and root and tuber yields in China, 1952-1987



Notes: Root and tuber fresh weight yields are divided by four into approximate cereal equivalents for the dominant crop (sweet potato). Currently published Chinese yield and production data are recorded at one-fifth weight and must be multiplied by 1.24.

Sources: Root and tuber crop yields for 1984-87, and all rice and wheat yields, and most corn yields with the exception of 1961-62, are calculated from production and area data in ZGTJNJ 1984, p. 138, 141; ZGTJNJ 1987, p. 164, 170; and ZGTJNJ 1988, p. 25-26. Root and Tuber crop yields are based on official series adjusted for statistical consistance and published in Bruce Stone, "An Analysis of Chinese Data on Root and Tuber Crop Production", The China Quarterly, September 1984, p. 596-97 (Series B). Sorghum yields, except for those for 1961-62, are calculated from ZTNT, Zhongguo Nongye di Guanghui Chengjiu 1949-1984, p. 42-47; ZGNYNJ 1985, p. 148; ZGNYNJ 1986, p. 183; and ZGNYNJ 1987, p.216-17. Corn and Sorghum and yields for 1961-62 are from Nongxuyuyebu Jihuasi, Nongye Jingli Ziliao 1949-1983, p. 147-48

The contribution of yield-increasing technical change to foodgrain production growth is even greater than the impression provided by Figure 3, since area sown with staples has been increasingly allocated to these rapidly growing cereal crops over time. According to Chinese definition, these crops provided 79.8 percent of national foodgrain production in 1952, 94.0 percent in 1978, and 92.4% in 1988 (15).

An examination of Figure 3 suggests four general observations: 1) the yield patterns of these crops are strikingly similar; 2) they reflect sustained and fairly rapid growth for almost three decades; 3) ignoring the poor weather years 1959-61, there appear to be at least two important points of inflection for the major cereals (rice, wheat and corn), one between the late 1950s and mid-1960s and another in the mid-to-late 1970s; and 4) only the first point of inflection is relevant for sorghum and sweet and white potatoes—if anything, there is a slight deceleration of yield growth in the root and tuber crops from somewhere in the mid-1970s.

For preliminary analysis, linear trends are calculated for three periods: 1952-65, 1965-78 and 1978-87. 1978 is the typically selected demarcation between the Maoist period and post-Mao reform period. 1965 is chosen as a date subsequent to recovery from the natural catastrophes and associated famine of the early 1960s, and subsequent to the commitment to comprehensive technical transformation of agriculture. From this date forward, it is suggested that technical change is the dominant source of yield growth, as opposed to recovery, land reform, formation of producer's cooperatives, people's communes and so forth. The 1949-51 period is omitted since official yields for these years are believed to be underestimates (16).

Table 1 confirms that there indeed has been rapid yield growth for each of these crops at least since the mid-1960s. Based on Table 1 alone, one would conclude that yield progress in the post-Mao period has been faster than the previous era for the three major cereals, though relatively similar for sorghum and for sweet and white potatoes.

But in each case the point of inflection seems to pre-date 1978. If a series of linear trends for the middle and later periods are fitted taking each year in the 1972-78 period in succession, the r^2 values (17) are all above 0.94 for rice, 0.90 for wheat and 0.89 for corn. r^2 values are actually highest for the recent period when the division is at 1972 for corn (0.941), 1973 for wheat (0.923) and 1975 for rice (0.95).

The best linear fits for the middle period occur when the breaking points are somewhat later: 1975-76 for wheat, 1975-77 for maize and 1977-78 for rice. For sweet potatoes and white potatoes, the best linear fits for both periods are achieved when the breaking point is in the 1973-75 range. The

Table 1. Linear regression growth rates for yields of major foodgrains, 1952-87

Years	Rice	Wheat	Corn	Sorghum	Sweet & White Potatoes	Millet	Soybeans	Misc. Beans and Cereals
					(kilograms/hectare/year)			
1952-65	11.2	2.5	12.2	-6.4	14.8	-21.1	-8.7	34.0
								-
1965-78	57.8	60.4	92.5	91.6	79.7	34.0	14.2	-14.7 (13.3)
1978-87	179.8	153.8	128.8	90.7	70.1	36.4	48.9	76.1 (24.0)

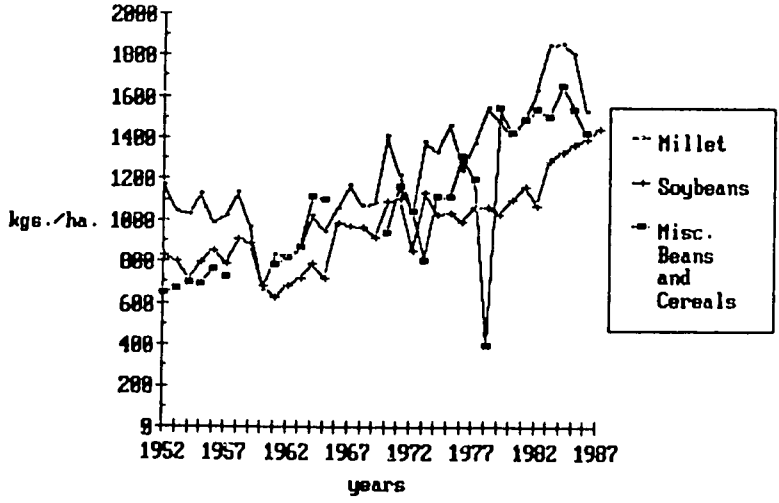
Note: The figures in parentheses have been calculated omitting the particularly low yield in 1978, which may be partially due to a statistical aberration. Sums of errors from overestimating production in any or all of the other foodgrain categories and from underestimating total foodgrain production cumulatively contribute to underestimation of production, and consequently yield, in this residual category. Yield estimates for other crops are calculated by aggregating crop cutting data. Yields for this residual category are calculated from residual production and sown area data.

reason for the relative ambiguity about the most appropriate breaking point is that a linear trend is really not ideal for the mid-1970s; the data more closely describe a hyperbolic acceleration typical of technical change.

The results of this exercise suggest that there is no sharp inflection point for yields beginning in the reformist era. Instead there is a dynamic acceleration in yields beginning in the early 1970s for wheat and corn, and in the mid-1970s for rice. And thus the causes of this acceleration are likely to be found in technical developments originating during previous decades.

Figure 4 graphs yields of the slower growing foodgrain categories. Although, at least after the 1950s, both levels and growth rates of average yields are consistently lower, the intertemporal patterns of yield progress for even these crops similar to those of the faster growing categories. This conclusion is verified in Table 1. Less dramatically than for the major cereals, and with some exceptions, there is evidence of yield acceleration in the 1960s and again in the 1970s. Year-to-year variability is greater for millet and the residual bean and cereal category, large portions of which are grown on marginal land without irrigation. The reallocation toward corn and wheat of the better farmlands among the traditional growing areas for millet and soybeans accounts for the negative growth trends for their yields during the 1952-65 period.

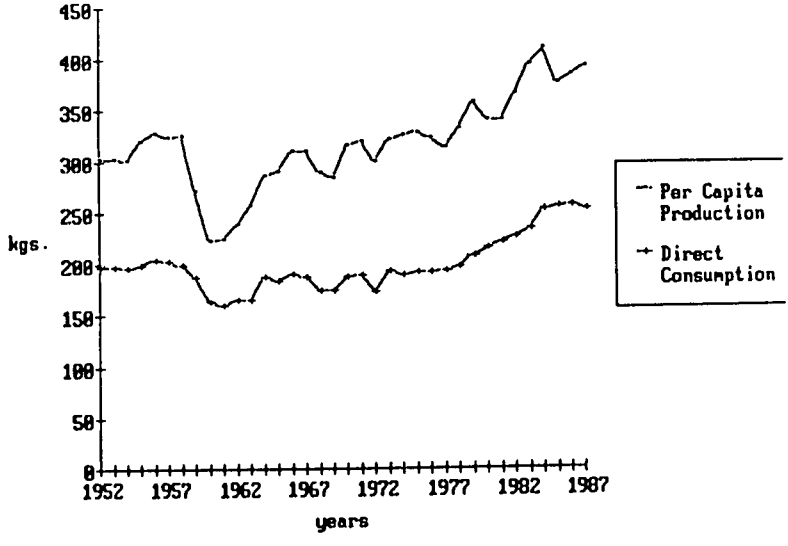
Figure 4. Millet, soybean and miscellaneous bean and cereal yield in China, 1952 - 1987



One may conclude from this disaggregated review that yield progress has been fairly rapid since the mid-1960s for rice, wheat, corn, sorghum and sweet and white potatoes, and has been especially rapid for the three major cereals during the last decade. Yield trends for even the slower growing foodgrain categories have picked up in the recent period. But the clearest points of inflection for these accelerations do not coincide with the establishment of the production responsibility system (early 1980s) or even the beginning of the reform period (1979). The relationship of these inflection points in the early-to-mid 1970s to the various categories of technical change are examined in other publications (18) and the conclusions briefly reviewed in the next sub-section. But first, what of the adequacy of technical change?

Despite the increasing success with cereal yields during the Maoist period, Figures 1 and 5 remind us that it has only been in the post-Mao period that yield growth has been fast enough and population growth slow enough to provide sizable improvements in per capita foodgrain production and consumption. Figure 5 shows that despite the loss of life during the famine period, the setback during these years left China, even after production recovery in the mid-1960s, with a long slow road to recoup per capita levels enjoyed in the late 1950s. These were finally surpassed in the post-Mao period with the cumulative effect of a more successful birth control

Figure 5. Per capita production and direct consumption of foodgrains in China, 1952-1987



Notes: Production per capita data are provided at unprocessed weights, while consumption per capita data represent partially processed foodgrains. In both cases, soybeans are included and sweet and white potatoes valued at one-fifth fresh weight. Foodgrain consumption per capita data therefore exceed those provided in Figure 1 for which adjustments have been made to conform to international statistical convention.

Sources: ZGTJNJ 1984, pp. 141, 477; ZGTJNJ 1987, pp. 89, 170, 711; ZGTJZY 1988, pp. 3, 14, 26, 30, 95.

policy initiated in the early 1970s, the acceleration in yields of the three major cereals and a large increase in foodgrain imports dating from 1977.

One must conclude that despite success in generating yield growth during the second half of the Maoist period, the pace of technical change was inadequate to reach China's strategic objective of rapid growth in per capita food supplies. Certainly it has taken longer than Chinese authorities had desired in order to enter the second stage of food consumption growth, when large proportions of the rural labor force could be released to pursue non-agricultural developments. But it is not yet clear, however, that the pace of technical change itself may be regarded as slow. At very least, the blame must be shared by the immense setback in progress during the years of famine and rural dislocation in the early 1960s and by the lack of serious attention to birth control until the early 1970s.

Performance with the Basic Components of Technical Change

China's performance with the fundamental components of technical change at various periods has been reviewed in detail elsewhere (19). The review suggests that important seed technology in the presence of improved water control (Table 2) coincided with the initial points of acceleration for rice, wheat, maize and sorghum, which fell within the Maoist period (Table 3). Yet provision of adequate fertilizers to approximate yield potential of these varieties was not available until the transition years between the two periods, accounting for the significant acceleration in yields around the beginning of the post-Mao period (Figure 6).

The acceleration of staple crop yield growth was possible to maintain with the increasing availability of fertilizers in the post-Mao period provided by: 1) rapid growth in high quality imports; 2) large quantities of urea produced in China's first 13 large-scale synthetic ammonia/urea complexes; and 3) continued rapid expansion of the small plant sector and improvements in their products, packaging and associated application methods (20).

Table 2. Basic indicators of water control development, 1952-87

Years	Effectively Irrigated Area a/			High & Stable Yield Area b/	Multiple Cropping Index c/	Number of Tubewells		Small Hydropower Stations in Rural Areas		Electricity Consumed in Rural Areas d/	Motors for Agricultural Drainage and Irrigation	
	Total	Power-Irrigated Area Total	Power-Irrigated Area Share			Out-Tot.	Fitted	Nos.	Generating Capacity			
	--(mill. ha.)--		(percent)	(mill. ha.)		(1000 units)		(units)	(1000 kw)	(100 mill. kwh)	(1000 units)	(100 mill. watts)
1952	19.959	0.317	1.6	--	130.9 f/	--	--	98	8	0.5	--	0.9
1957	27.339	1.202	4.4	--	140.6	--	--	544	20	1.4	40	4.1
1962	30.545	6.065	19.9	--	136.3	--	--	7,436	252	16.1	367	45.2
1965	33.055	8.093	24.5	--	138.3	100	--	--	--	37.1	558	66.7
1970	36.000	14.992	41.6	25-30	141.9	--	--	29,202	709	95.7	1,471	134.2
1971	36.441	16.601	45.6	--	144.7	590	--	40,040	817	104.5	1,640	146.0
1972	38.005	17.517	46.9	--	147.0	800	--	47,227	902	132.8	2,078	181.3
1973	39.223	19.782	50.4	33	148.2	1200	--	52,765	1,060	139.9	2,880	254.6
1974	41.269	21.664	52.5	34	148.8	1600	--	61,378	1,277	156.1	3,422	300.6
1975	43.284	22.889	52.9	34	150.0	1700	--	68,164	1,445	183.1	3,891	357.9
1976	44.981	24.228	53.9	--	150.6	1800	--	74,125	1,610	204.8	4,262	398.4
1977	44.999	24.349	54.1	--	150.5	--	-	79,047	1,868	221.9	4,695	441.6
1978	44.965	24.895	55.4	22 f/	151.0	2300	--	82,387	2,284	253.1	5,026	482.3
1979	45.003	25.321	56.3	f/	149.2	--	2100	83,224	2,763	282.7	5,384	523.8
1980	44.888	25.315	56.4	f/	147.4	2599	2089	80,319	3,041	320.8	5,630	549.0
1981	44.574	25.231	56.6	--	146.6	--	2081	74,017	3,360	369.9	5,672	551.5
1982	44.177	25.145	56.9	--	146.8	2621	2095	66,256	3,530	396.9	5,803	564.1
1983	44.644	25.265	56.6	--	146.4	2621	2410	62,328	3,463	435.2	6,077	577.3
1984	44.453	25.062	56.4	32.771	--	2675	2400	60,062	3,615	464.0	6,150	577.7
1985	44.036	24.629	55.9	33.038	147-48	2628	2370	55,754	3,802	508.9	6,163	575.5
1986	44.226	25.032	56.6	32.871	149-50	2674	2364	54,136	3,879	586.7	6,507	604.4
1987	44.403	24.825	55.9	33.155	150-52	--	--	51,978	3,941	658.8	6,839	625.8

Notes:

a/Youxiao guangai defined as "level land which has water sources and complete sets of irrigation facilities to lift and move adequate water for irrigation purposes under normal conditions" (ZGTJNJ 1981, pp. 521-22). Power irrigated area includes area serviced by electric and fuel-injection facilities. Share of irrigated area with power facilities within total irrigated area are provided in the third column.

b/ "Fields with stable and high yields despite drought or excess surface water" (han lao baoshou gaochan wenchen tian) are normally expected to have adequate facilities to withstand a once in 10 year drought or flood without crop damage. In some places, the requirements are more stringent. In Guangdong, 100 day drought resistance capability is required. Fields so designated are also supposed to surpass National Agricultural Development Program targets ranging from 3 to 6 tons/ha. for major foodgrains, depending on the region.

c/ (Sown area/cultivated area) x 100. Cultivated area and the MCI have not appeared in major publicly distributed State Statistical Bureau compendia during the 1980s. During the early 1980s, the Bureau was reported to be considering upward revision of the 1986-87 cultivated area figure from less than 100 mha. to "2 billion mu" (133.3 mha.) or to "14% of total land area" (134.4 mha.), based on revised analysis of satellite imagery which had provided an original estimate of around 150 million hectares. While methodological problems remain with satellite-based estimates, the idea that official cultivated area figures are substantial underestimates is widely shared in technical circles, and SSB public distribution of these and MCI data has not resumed. Detailed aerial surveys of two counties in Jilin and Beijing, for example, showed cultivated area underestimated in official data by 7.6% and 25.8% respectively. Guangming ribao has quoted Wang Xianjin, director of the State Land Administration Bureau, as giving 120 mha. and 126.6 mha. as cultivated area figures for 1987-88. The larger would be more or less consistent with the satellite based estimate for 1980-81 and subsequent retirement. The official data, nevertheless, are occasionally published in Chinese books and articles. The MCIs in the 1980s are calculated from these questionable data and the somewhat more reliable sown area figures published by the SSB.

d/ Includes electricity provided by state power grid as well as by rural power stations, excluding electricity consumed by state-owned units located in rural areas.

e/ 133.5 as recalculated to correct for underreporting of cultivated area (Thomas B. Wiens, "Agricultural statistics in the People's Republic of China" in Alexander Eckstein (ed.) Quantitative Measures of China's Economic Output (Ann Arbor: Univ. of Michigan Press, 1980).

f/ The implied decline relative to the mid-1970s may reflect a tightening of standards or improved statistical precision rather than an actual deterioration in facilities. It is significant that there was severe drought on the North China Plain in 1977 and 1978, which may have revealed the inadequacy of facilities throughout the region. In 1979 HSYA was described as approximately that of 1978, and in 1980 as "half China's irrigated area of 700 million mu" (literally 23.3 million ha.) and "less than one-fourth of the total cultivated land"(<24.8 mha.).

Source: Bruce Stone, "Development in Technology, "The China Quarterly, Special Issue on Food and Agriculture in China During the Post-Mao Period, No. 116, December, 1988, p. 772-73.

Table 3. Area sown with hybrid rice, maize, sorghum, and semi-dwarf wheat and rice

	Area under true hybrids			Area under all dwarf and Semi-dwarf Varieties		
	Maize	Sorghum	Rice	Rice	Wheat (<100m)	Wheat (<105cm)
	(percent of total area planted with crop)					
1955-59	a/			a/		a/
1961	20-40			a/		
1962	0-20 b/					
1964			c/	c/		
1965				14	d/	
1966	~40 b/					
1968				f/	e/	
1971		20		f/		
1973	40		f/		g/	
1974				80		
1976			0.4			
1977		40	6.2	80		h/
1978	60		12.6			
1979	65	55	14.9			
1980	69	57	13.9 i/			
1981	72	60	15.4	f/		
1982	75	60	17.0			
1983			20.3			
1984			26.7	~56		(67-75)
1985			26.4	95		
1986		90	28.3			
1987	90		~34.0 j/			
1990 target			~40.0			

Notes:

a/ Experimental breeding work on semi-dwarf rice began in the early 1950s, but the first cross between dwarf and high yielding varieties was accomplished in 1956. Semi-dwarf indica varieties were grown as an early crop in South China in the late 1950s; the first short stature japonica varieties (Nongken #58) were introduced in North China in 1957. The first semi-dwarfs were developed in China by cross breeding in 1959 (Guang Changai); and released in 1961.

Experimental breeding work on semi-dwarf wheat varieties was initiated during the late fifties. Chinese work on hybrid maize began in 1923 and double cross hybrids were first released in Sichuan 1943-45. Work resumed throughout the 1950s in several institutions from which double cross hybrids were released in 1958.

b/ Double cross hybrids were decimated by corn blight in 1961 and 1966; total maize area declined by around 20 percent in 1962, presumably primarily in disease-affected hybrid areas; double cross extension dropped after 1966; single cross hybrids initially extended in 1966.

c/ Work on hybrid rice and broad-scale dissemination of semi-dwarf rice varieties initiated. Short stature (non-hybrid) indica varieties released in South China in 1963.

d/ First Chinese bred (100 cm.) variety of eventual commercial importance (Beijing #10).

e/ Dwarf wheats imported for the Chinese breeding program from Pakistan and elsewhere in 1968, 1969 and the early 1970s; the first Chinese bred variety under 90 cm. of eventual commercial importance (Fan #6) was bred.

f/ Cytoplasmic male sterile, maintainer and restorer lines necessary for producing hybrid seed developed 1970-73. IRRI's IR#8 was first planted in China 1968 and eventually used as restorer line for hybrid rice breeding; 3,335 varieties and advanced lines provided to China by International Rice Research Institute between 1971 and 1981.

g/ Large quantities of dwarf wheat seed imported from Mexico for direct planting 1972-74; maximum sown area reached 800,000 hectares, then declined sharply due to environmental stresses not problematic in Mexico; subsequent emphasis turned to Chinese-Chinese or Chinese-foreign crosses except in a few western regions.

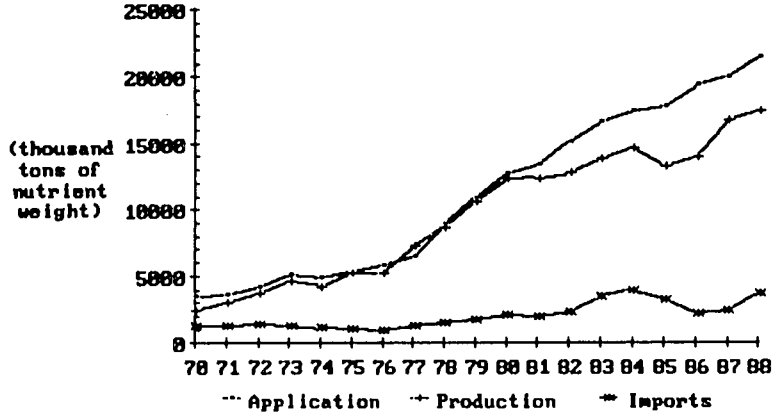
h/ Chinese crosses with imported Mexican varieties and other Chinese bred semi-dwarfs were sown throughout main winter wheat producing areas, and on 2 million hectares (~ 40% of national spring wheat area) in the northeast spring wheat region.

i/ Hybrid area was cutback in principal (lower Yangzi Valley) growing area due to susceptibility to yellow dwarf virus and discovery that in some localities increased hybrid yields did not compensate for losses on alternate crops as the maturation period for hybrid was normally longer than the crop it replaced. Rapid growth resumed in subsequent years with aggressive extension of new sub-tropical hybrids in South China (especially Guangdong and Sichuan). Some japonica hybrids were already extended in 1979-80: 43,000 hectares, with Liyou 57. These were not always successful and the total area under all japonica hybrids declined to 33,300 hectares in 1981. But more suitable varieties were developed and by 1986, 261,000 hectares were planted with japonica hybrids.

j/ Another large expansion of hybrid area in 1987; total reached "one-third" of China's rice area. Area increased 95 percent over the previous 5 years to almost 11 million hectares. Hybrid area grown as early rice grew substantially as new varieties proved superior to non-hybrids up to 30° N, compared with previous hybrids limited to 23°N. Better single-season hybrids for highland areas also extended.

SOURCE: For complete references, see Bruce Stone, "Developments in Technology," The China Quarterly, Special Issue on Food and Agriculture in China During the Post-Mao Period, No. 116, December, 1988, p. 792-794, as updated and amended with data appearing in Zhongguo NongXuYuyebu Jihuas [Chinese Ministry of Agriculture, Animal Husbandry and Fisheries, Planning Dept.], Nongye Jingji Ziliao 1949-1983 [Economic Materials on Agriculture, 1949-1983] (Beijing: Ministry of Agriculture), p. 285; Li Meisen and Zhao Lijian, "National Conference on Hybrid Rice Development," Agricultural Yearbook of China 1988, pp. 95-96.

Figure 6. China's production, application and imports of manufactures fertilizers, 1970-1988



Notes: Imports figures from 1970 to 1984 are converted from standard weight to nutrient weight estimated by multiplying by a constant factor of 0.21. Import figures from 1985-88 are converted from product weight to nutrient weight estimated by multiplying by 0.43.

Sources: Application figures for 1953-56 are from ZGHQH, p. 6-7; Figures for 1978-88 are from ZGTJZY 1988, p. 34 and ZGTJNJ 1989, p. 183; all others are from NYJJZL 1949-83, p. 292, ZGTJNJ 1987, p. 139 and ZGTJNJ 1989, p. 183. Import figures thru 1984 are from ZGTJNJ 1984, p. 410 and ZGTJNJ 1985, p. 516. Imports from 1985-1988 are from ZGTJNJ 1987, p\ 601, ZGTJNJ 1988, p. 87 and ZGTJNJ 1989, p. 643. Production yields are from ZGTJNJ 1984, p. 227, ZGTJNJ 1985, p. 348, ZGTJNJ 1987, p. 238, ZGTJZY 1988, p. 34 and ZGTJNJ 1989, p. 300.

The agricultural research and extension system has continued to supply larger areas with high-yielding fertilizer responsive crop varieties. Irrigated area expansion stagnated during the last decade because of declines in national and provincial government funding of new construction; the inability and/or lack of will of many local administrations to adequately fill this gap; and the increased difficulty of managing recurrent costs in operating systems, as well as larger scale renovation and maintenance, occasioned by rural organizational changes and other developments. This lack of net growth in irrigated area was consistent with rapid growth in yields during the last decade inasmuch as there was considerable untapped yield potential in both irrigated and unirrigated areas available with resolution of fertilizer nutrient application constraints (21).

Improvements in Quality and Efficiency of Application and Allocation of Basic Inputs

The most significant progress in this category of improvement have been with the agricultural research system increased provision of stress tolerant varieties and seed varieties with adjusted maturities to accomodate local environmental constraints; and the improvements in the quality of a large portion of chemical fertilizers provided. Yet locally produced ammonium bicarbonate, single superphosphate and calcium magnesium phosphate, though of improved quality relative to the balance of these products supplied fifteen years ago, still have quality problems and still constitute important proportions of fertilizer supplies. Progress with reducing nitrogen volatilization via improved application techniques and specialized equipment has slowed along with transitional problems with farm extension, with the funding of development of serial production of machinery prototypes and with farmer machinery purchase associated with incomplete institutional adjustment to the reforms in rural organization (22).

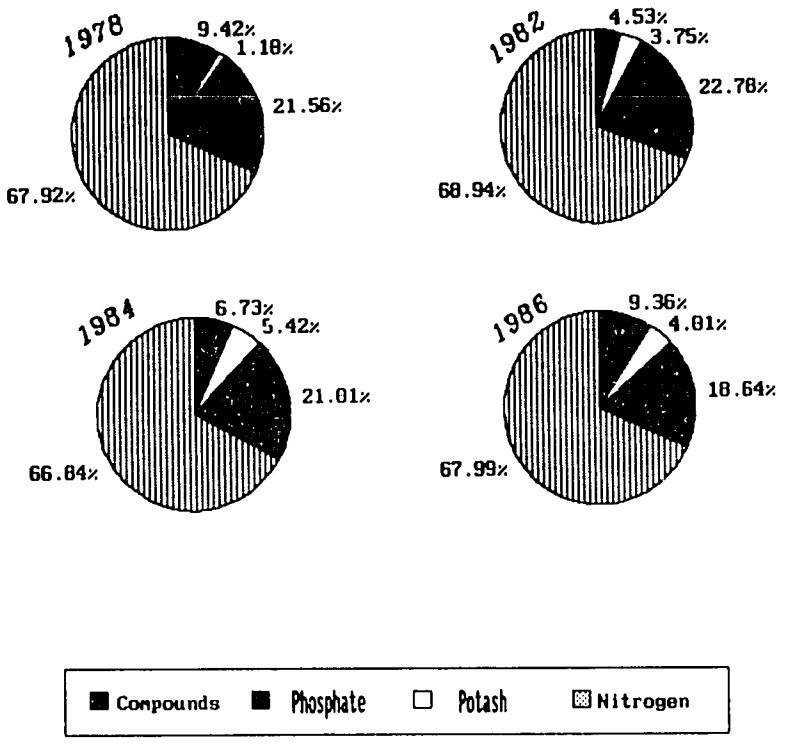
Figure 7 shows that improvements in the aggregate balance of applied fertilizer nutrients towards the recommended ratios, based on Chinese soils and cropping patterns, might have been greater; further improvements in 1987 and 1988 have also been slow.

Figure 8 shows that, unlike the Maoist period, during which time major differences developed among provincial rates of fertilizer application growth, application in almost all provinces grew at relatively similar rates during the last decade, suggesting significant progress with major interprovincial imbalances in access to fertilizers. The exceptions to rapid and relatively steady growth in application have been the major municipalities where labor's rapidly rising opportunity cost has engendered a continuous state of rapid economic growth, usually in directions away from staple crop production; and Qinghai and Tibet — cold, mountainous, sparsely populated herding regions with relatively little agriculture, increased pasture-based specialization in animal husbandry, and a variety of special problems.

While the data must be treated with considerable caution, Table 4 indicates that the recent rapid growth in fertilizer application extends even to China's poorer counties. In many regions, such counties are associated with lower potential for fertilizer-based development, but still have often exhibited high marginal response rates, due to exceedingly low availability of supplies during previous periods.

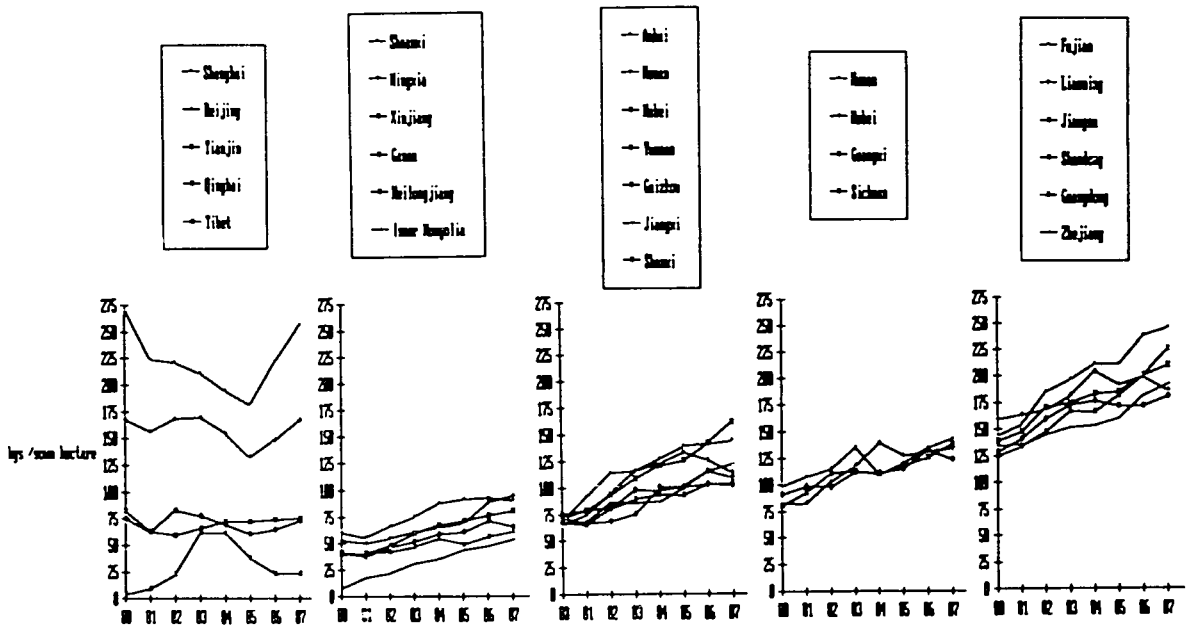
But while there have clearly been interregional improvements in

Figure 7. China's nutrient application proportions, 1978 - 1986



fertilizer distribution, within-region and within-county allocative efficiency will ultimately depend upon development of fertilizer markets. Here the record is not so positive. Despite an abortive market reform in 1985-86 based on the legalization of inter-farmer sales and of quasi-market-oriented direct distribution of a portion of the output from China's important small and medium scale plant sector, the 1987-89 period has been marked by bureaucratic recentralization of the fertilizer trade, accompanied in many areas, by especially high and highly variable marginal prices, due to incremental charges added independently along the distribution pipeline. This development will remain antithetical to achieving optimal growth in aggregate productivity through improved allocative efficiency.

Even during the short quasi-market-oriented period, the suddenness of the imposition of fertilizer market measures, coupled with radical reform, administrative failure, and confusion in the farm goods and farm credit markets, and an import moratorium causing acute supply constraints in



Source: Bruce Stone, "Developments in Technology," *The China Quarterly*, Special Issue on Food and Agriculture in China During the Post-Mao Period, No. 116, December, 1988, p. 806.

Figure 8. Provincial fertilizer applications per sown hectare, 1980-1987

Table 4. Comparison of officially designated poor counties (663) with all counties in China: various categories of agricultural performance and input use, 1980-87

	1980	1985	1987
FERTILIZER USE (kgs. of fertilizer nutritients per sown ha.)			
NG	56.4	84.5	92.3
PPG	66.3	85.4	98.0
NAV	89.0	123.6	137.8
RURAL USE OF ELECTRICITY (kwh/sown ha.)			
NG	105.2	158.0	187.8
PPG	108.8	162.9	214.1
NAV	220.3	354.3	454.5
RURAL USE OF ELECTRICITY (kwh/rural resident)			
NG	17.3	24.6	28.5
PPG	19.2	28.1	35.4
NAV	39.6	61.0	76.9
CULTIVATED AREA WITH EFFECTIVE IRRIGATION (percent)			
NG	16.9	11.8	16.1
PPG	25.0	16.0	21.8
NAV	45.3	45.5	46.3
AVERAGE FOODGRAIN YIELDS (kgs./sown ha.)			
NG	2,129	2,583	2,566
PPG	2,192	2,880	2,893
NAV	2,732	3,483	3,637
FOODGRAIN PRODUCTION PER CAPITA (kgs./rural resident			
NG	296	315	310
PPG	321	376	373
NAV	392	454	472
AGRICULTURAL OUTPUT VALUE PER RURAL RESIDENT (constant 1980 Rmb)			
NG		248	250
PPG		294	300
NAV		349	372

NG = 300 poor counties supported by the national government
PPG = 363 poor counties supported by the provincial and prefectural governments
NAV= National average of all 1986 counties and 378 municipal areas (1987)

Notes: A number of strong reservations must be considered in drawing conclusions from this comparison. First, officially designated poor counties include large groups of counties that are not especially poor in the Chinese context, and exclude some groups which are quite poor. Second, the 663 poor counties constitute almost one third of China's total and one-fifth of China's population -- therefore comprising an appreciable portion of the national averages included; the comparison thus considerably underestimates the differences between "poor" and "other" counties.

Third, benchmark year comparisons are always problematic. 1980 was an especially poor weather year while 1987 weather was good. 1985 weather was relatively poor, and there was considerable and costly confusion in markets for farm goods, fertilizer, and credit, coupled with public financial retrenchment. Thus the 1980-85-87 temporal comparison overstates positive trends for all groups.

In terms of inter-group comparisons, stronger than average performance by poor counties in several categories may reflect greater vulnerability during periods of poor weather, financial retrenchment, and input shortages (1980 and 1985), to a greater extent than constitutes evidence of any phenomenon of poor counties "catching up" with the average might be inferred from a superficial glance at the data. Finally, sown area and especially cultivated area, are considerably underestimated in China. The proportional underestimation is certainly greater in poor areas.

"Foodgrains" consist of rice, wheat, corn , sorghum, millet and other minor cereals, all evaluated at unmilled weight, sweet potatoes and white potatoes evaluated at one-fifth fresh weight, and soybeans and other bean crops.

"Effective Irrigation" denotes level agricultural land which has water sources and complete sets of irrigation facilities to lift and move adequate water for irrigation purposes under normal conditions. The national increase in the proportion irrigated reflects retirement of cultivated area rather than net growth in irrigated area among official data. The degree of overestimation of official data in this category, however, as declined somewhat during the 1980s.

several highly productive regions, prevented the full realization of the potential productivity gains available though market liberalization measures (23).

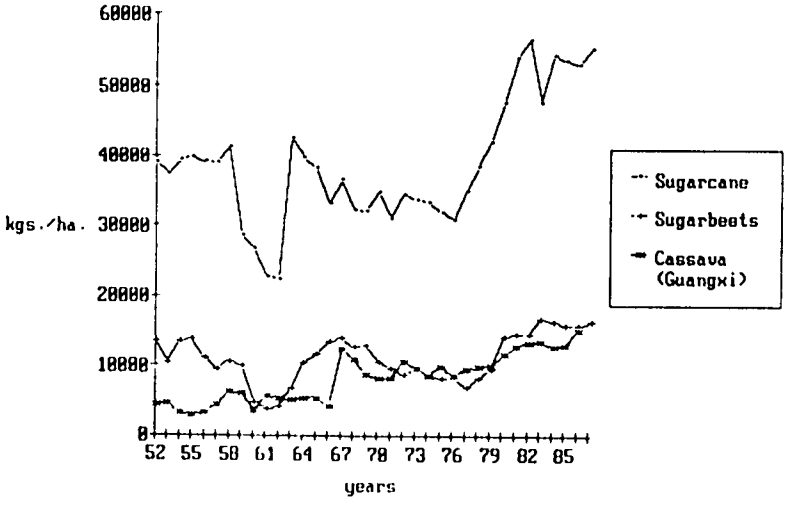
For water control, some of the initial groundwork has been laid for improvements in allocative efficiency among farmers and in on-farm water management, but realization of major productivity gains via this source are still out of reach. Meanwhile the institution of water fees, while a sensible development, has been the occasion of an imposition of large, geographically and intertemporally variable additional charges piled on by local authorities at various levels (24).

Agricultural Growth in Non-Staple Crop Categories

As Figures 9-11 indicate, production, and yields of a host of non-grain crops have increased during the last decade at rates even faster than for foodgrains. An impressive number of these tripled output between 1977 and the mid-1980's. These include cotton (from the 1976-77 avg. or 1968-77 avg. to 1984), peanuts (from 1977 or the 1973-78 avg. to 1985), sesame (from 1976 or the 1975-77 avg. to 1985), sugarcane (from 1973-76 avg. to 1985), and flue-cured tobacco (from the 1979-80 avg. to 1985).

Some crops have achieved even faster rates of expansion. Jute and

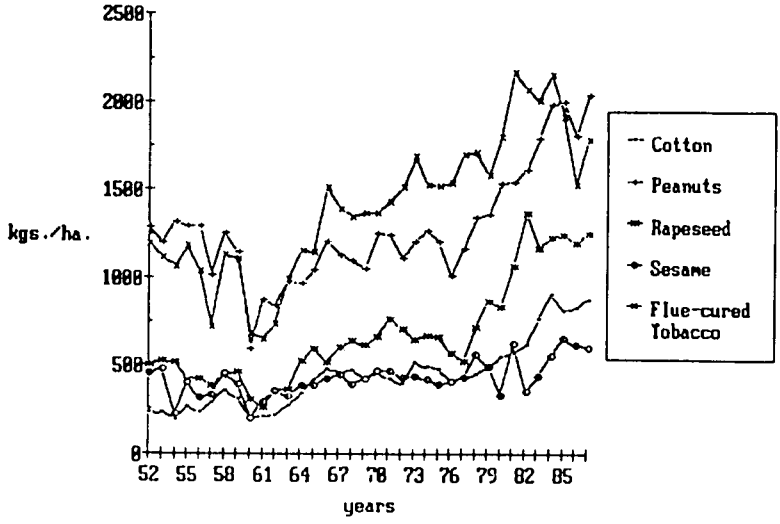
Figure 9. Sugarcane, sugarbeet, and cassava yields in China, 1952-1987



ambary hemp production quintupled the 1976-77 level by 1985, growing 176 percent in 1985 alone over record year 1984. Rapeseed production has quintupled since the 1975-77 period, including 1987 expansion over record 1986 by 12.3%. Production had more than quintupled already between 1976-77 and 1982. Sugarbeet production tripled between the 1977-79 or 1973-79 avg. and the 1983-87 avg., then increased by an increment of 50% in 1988.

For some product categories, the exceedingly rapid rate of growth overloaded processing and/or marketing infrastructure, or in cases of certain lower grade products, temporarily saturated demand. These

Figure 10. Cotton, peanut, rapeseed, sesame, and flue-cured tobacco yields in China, 1952-1987

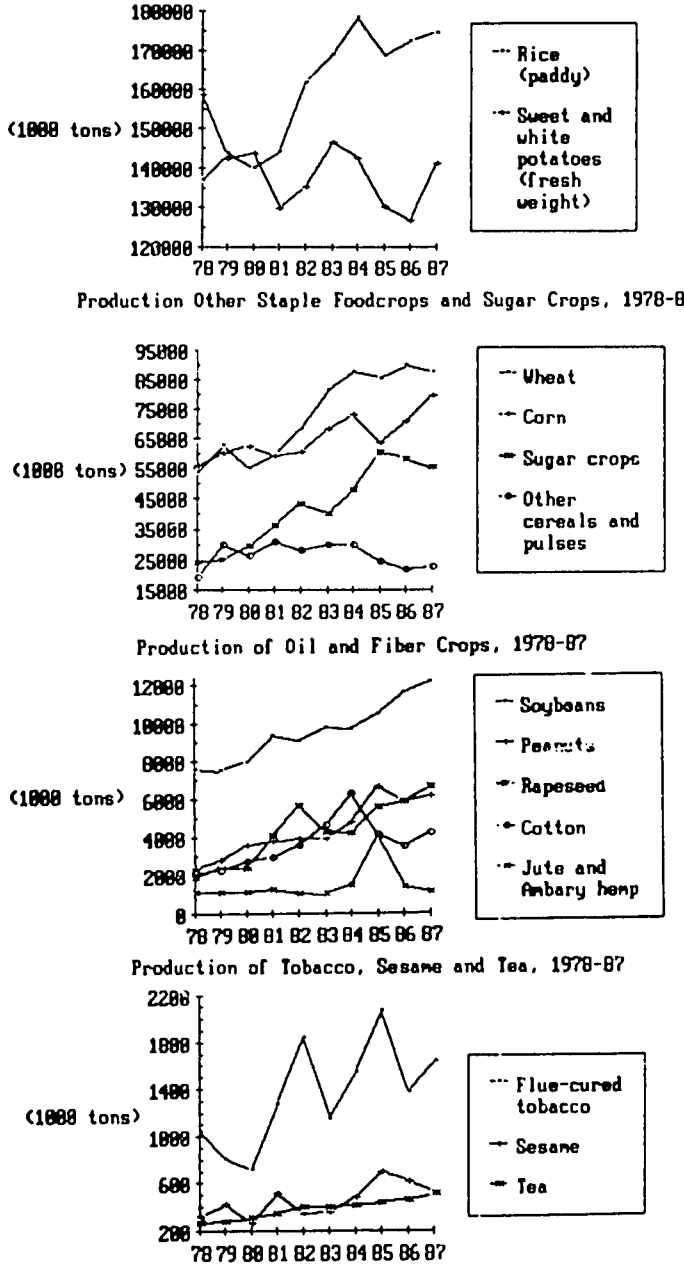


problems were particularly notable for cotton, tobacco and bast fibers. While bast fiber production continued to decline in 1987-88, cotton and flue-cured tobacco output levels both recovered in 1987 by almost 20% based on higher grade products, with tobacco continuing to reach a new production record in 1988. Production, area and yields of all oilcrops declined in 1988 with increased market price incentives as well as administrative emphasis on grains, meat, fibers, sugar and tobacco relative to oil (25).

For other economic crops, the rate of growth has continued almost unchecked. Tea production has tripled since 1973, while setting records each year with annual increments of 7.8%. Fruit production tripled between the 1973-76 average and 1987-88, around half the total attributable to expansion of orchards. Area under vegetables and melons has continued to grow, including a 7-8% increase in 1988. As late as the 1970's, vegetable crops were primarily dependent on organic manure application, and fruit orchards received little manufactured fertilizers. Fertilizer use on both is now rapidly increasing, but remains far below that of developed countries.

The production record may even underestimate success in non-staple crop categories during the last decade. Yield declines for cotton since 1984 reflect not only shifts in fertilizer use on cotton following overproduction in 1984 and subsequent policy adjustments, but a substantial shift away

Figure 11. Production of rice and potato crops, 1978-87



from the two varieties of cotton most popular in North China, toward varieties of higher quality and somewhat lower yield potential. This was achieved via the simple, if painful, expedient of purchase stations refusing to buy those varieties from farmers (26). The proportion of higher quality pork and duck output has increased, while meat production has almost tripled between 1975-77 and 1988. Per capita consumption of eggs has also tripled since 1977-79 and commercial milk production growth rates, albeit from a very low base, have grown even faster (27).

The essence of the production achievement of the last decade has been that this growth has been achieved despite a net reduction of farm labor applied to crop agriculture since the completion of the responsibility system reforms (28). Consequently, rural non-agricultural growth, economic growth in small towns and cities, as well as growth in output in other categories included with agriculture --- forestry, fisheries, and subsidiary farm production --- all grew at record rates (29). This fact suggests that recent efforts to bolster grain production by reversing these labor market trends, may be unnecessary and even ineffective.

Other Second Stage Indicators of Technical Change

The most important of these are a long series of efficiency indicators related to livestock product output. A few of these are presented in Table 5, which shows that while efficiency has improved in most listed categories great potential for improvement still exists. A concentration of public sector effort in the research, infrastructural, and institutional developments associated with improvements in livestock efficiency indicators can greatly enhance the profitability of grain/livestock farming without major product price increases and can substantially reduce the need for prolonged growth in staple crops at a given level of livestock product consumption.

Other technical change indicators have not fared so well. Plastic sheeting remains in chronic scarcity and during some periods, reductions in quality of supplied products have proven unacceptable to farmers (30). The farm chemical market is in disarray. Despite greater variety of farm chemicals through official channels (31), reliance on officially sanctioned production and imports (Figure 12) has declined sharply since 1982,. Yet local surveys indicate an increase in use of unregulated products. For farm chemicals, this development is moving in a dangerous direction. The intensity of interest and successes achieved during previous decades in the generally safer area of biological control of pests and diseases (32) does not seem to be sustained during the recent period.

Table 5. Efficiency indicators in Chinese livestock development, 1978-87

	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987
Slaughter Rates					(percent)					
CATTLE										
China	--	4.2	4.7	4.2	4.2	4.6	4.7	5.6	6.4	--
Austrailia	--		(36.5)		--	--	33.0	30.9	31.6	--
Japan	--		(29.9)		--	--	32.8	33.5	32.8	--
United States	--		(33.3)		--	--	36.3	36.5	38.9	--
SHEEP & GOATS										
China	--	20.8	23.2	23.9	26.0	27.1	30.4	32.1	33.5	--
Austrailia	--		(22.0)		--	--	18.3	18.7	20.7	--
Japan	--		(15.3)		--	--	18.2	20.8	23.1	--
United States	--		(45.1		--	--	60.1	60.3	57.7	--
HOGS										
China	55.2	62.3	62.1	63.8	68.3	68.7	73.9	77.9	77.6	77.6
Australia	--		(161.2)		--	--	174.2	178.7	176.6	--
Japan	--		(195.8)		--	--	184.9	192.6	189.8	--
United States	--		(145.6)		--	--	151.1	157.1	152.9	--
Carcass Weights					(kgs.)					
CATTLE										
China	--	77.4	80.9	82.4	85.8	90.7	96.3	90.2	95.5	--
Australia	--		(176)		--	--	184	186	187	--
Japan	--		(337)		--	--	349	352	360	--
United States	--		(271)		--	--	265	275	275	--

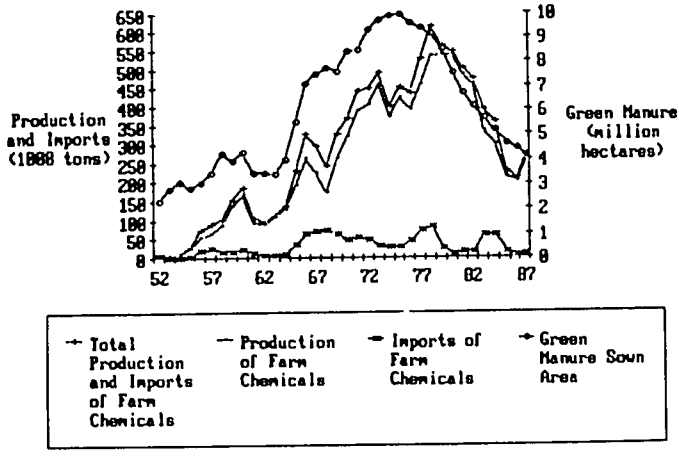
(Continued)

	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987
SHEEP & GOATS										
China	--	10.7	10.5	10.6	10.7	11.1	11.5	11.7	11.9	--
Australia	--		(18.0)		--	--	18.0	18.0	18.0	--
Japan	--		(23.0)		--	--	25.0	26.8	28.0	--
United States	--		(25.0)		--	--	25.0	26.0	26.0	--
HOGS										
China	49.0	53.4	59.8	61.0	63.4	63.7	65.5	69.3	69.8	--
Australia	--		(56.0)		--	--	58.0	58.0	60.0	--
Japan	--		(74.0)		--	--	74.0	74.0	74.0	--
United States	--		(78.0)		--	--	78.0	79.0	80.0	--
Stock Proportion of Breeding Sows					(percent)					
China		8.1	7.1	7.0	7.5	7.3	7.2	7.7	7.1	
Milk Output per Dairy Cow					(kgs./head)					
China		1921	1780	1850	1980	1940	1636	1536	1570	1788
Milk Output per Milch Goat					(kgs./head)					
China						153	168	169	184	

Notes: Figures in parentheses represent 1979-81 averages.

Sources: Calculated from or rounded from data appearing in ZGNYNJ 1980; ZGNYNJ 1981, pp. 46-49; ZGNYNJ 1983, pp. 70-79; ZGNYNJ 1984, pp. 110-21; ZGNYNJ 1985, pp. 172-78; ZGNYNJ 1986, pp. 207-18; ZGNYNJ 1987, pp. 252-64; ZGTJZY 1988, pp. 28, 29, 31; Food and Agriculture Organization of the United Nations, **FAO ProductionYearbook 1987** (Rome: FAO, 1987).

Figure 12. Production and imports of farm chemicals and area sown with green manure crops, 1952-1987



The only mechanization indicators which appear to have increased are those associated with rural transport. But these are from very low base levels. The stock of trucks for agricultural use has increased 700% during the last decade, but still remains around 600,000. The stock of combines has doubled, but only to 35,000. All in all, horsepower of agricultural machinery has increased 126%, including growth in stock of the most popular item --- small scale tractors --but there is still only around one per 70 farm workers (33). Meanwhile, fuel supply to farmers is in chronic overall shortage, has been subject to large year-to-year variation, and trends in farm-bound supplies in several fuel categories have actually declined (34). Rural stocks and biogas generating pits fell by 14% between 1985 and 1988 (35).

Infrastructrual and Institutional Development

Outstanding developments in institutional areas include significant improvements in the collection, systemization and publication of increasing categories of relevant statistics; and development of the soil testing and fertilizer trial network. The machine parts and fuel supply networks are developing from a very inadequate base. Repair has been fundamentally privatized. The meteorology network has been rather good for some time, and its collected data are increasingly available. Improvements in fertilizer and farm product stock management among parastatals have understandable had difficulty keeping pace with rapidly increasing tonnage, sophis-

tication and network expansion requirements. Farmers water management organizational development and an animal breeding and weight station network are still at very rudimentary stages and China is still a long way from instituting a site-specific system for analysis of crop nutrient requirements, which will become increasingly important as the country is compelled to depend more and more on efficiency improvements to achieve growth in staple crop yields without price subsidization. General agricultural extension, as noted above, is experiencing difficulties adjusting to the post-reform era.

The capacity of small rural power plants has increased by only 100% during the last decade, while power consumption in rural areas has grown by 180%, suggesting increased grid allocations to rural areas (36).

The communications and transport infrastructure, while receiving greatly increased national and local attention during the last decade, is still suffering from inadequate development during previous decades. With accelerated rural development, some liberalization of trade, and growth in stock of carriers, freight traffic has quadrupled since 1978 (37). Civil aviation routes have also quadrupled from a low base. Growth in highways and railway lines has of course been much slower (38), but local road development has been rapid in some localities. Still demand for transport and cargo services has run substantially ahead of supply so that transport infrastructure has remained a constraint, tending to prolong the low level of national market integration, which has proven an increasing impediment to steady and predictable growth in sales and, therefore, production in several agricultural categories.

The portion of capital construction expenditures devoted to transport, post and telecommunications (primarily transport) has increased from 11-13% during the 1970s, to 14-16% during the later part of the 1980s, but has declined from 15.9% to 13.7% since 1985 (39). Analysis of international experience suggests that a further increase to at least 20% would probably be warranted in order best to facilitate agricultural and rural non-agricultural growth, with appropriate synergistic expansion in the urban economy (40).

Agricultural loans have quadruped since 1981, but are still inadequate via approved institutional channels. There have been several crises in the rural credit market occasioned by pressure on the Agricultural Bank of China, which must finance farm procurement and also holds rural credit cooperative deposits (41). The supplementation of rural credit to fill this unsatisfied demand by unregulated sources has been blamed for excessive inflationary pressure and has occasioned the current governmentally

induced recession in rural development to attempt to bring inflation under control. So the lack of a properly regulated, but adequately developed, rural financial system is perhaps the greatest immediate problem for sustained rural development in view of the unfortunate side effects of the government's imprecise inflation-control tools.

Education has developed significantly at the upper levels in China, with large percentage increases in the numbers, enrollments and graduates of institutions of higher learning, specialized schools, agricultural middle schools and vocational middle schools. But these still affect a relatively small proportion of the population. Numbers of secondary and primary schools have actually declined during the last decade. And while this may be an improvement consistent with consolidation, economies of scale and improved facilities, enrollments and graduations from primary and secondary schools as a whole have declined (42). Of course, these declines are concentrated in rural areas where the opportunity cost of child labor has increased greatly, without commensurate increase in the conduit of immediate opportunities for graduates within rural areas or for migration to cities. Yet this perverse educational trend can ultimately inhibit both agricultural growth in this increasingly sophisticated era, and the proliferation and efforts of rural, non-agricultural entrepreneurs and developers.

Conclusions

China in the 1980s has already entered a second stage of food consumption development and a second stage of technical transformation of its agricultural sector. The critical requirements of the second stage are more numerous and complicated than the first stage focus on growth in staple crop yields via development of area under irrigation and high-yielding staple crop varieties and rapid growth in fertilizer use. Consequently the stagnation during the last half of the 1980s in foodgrain production growth and since 1979 in aggregate area irrigated is less problematic than it would have been in an earlier decade. Diversification from an earlier over-concentration on foodgrain production was, after all, a policy objective of the recent period. Since agricultural output value has continued to grow at a reasonable pace even in the later part of the 1980s, and extremely rapidly since 1978 as a whole, and since this growth in and diversification toward higher valued farm products has been accompanied by continued growth in foodgrain yields, if not production since 1984, the entire period must be regarded as successful.

Yet continued growth in staple crop production via further yield increases remains of some serious importance even during the second stage,

so resumption in foodgrain yield growth during the 1990s without jeopardizing the diversification and quality improvement process will be necessary. This must be accomplished not via recentralization and reliance on price subsidies to market-oriented producers, which can only be successful in the short run, but via a much more focused effort upon development of the critical technical change requirements of the new stage. While progress in several of these more numerous categories has been good, China will continue to suffer in the immediate future from insufficient development in key institutional and infrastructural categories during past periods. Thus, even greater concentration will be required in these areas during the first part of the 1990s to protect the rate of growth in the second part of the decade and after. Finally, the successful Chinese research focus on yield-increasing and early maturing staple crop development must be intensified and expanded to include a greater concentration of effort on efficiency improvements in the livestock sector. And progress with efficiency in water and fertilizer use development will need to be pursued in a more focused and energetic fashion.

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14. These contrast with legumes, soybeans, and other coarse grains such as millet, for which yield increases have proven more technically difficult to obtain.
15. "Foodgrains (liangshi)" include rice at paddy weight, wheat, corn, sorghum, millet, other minor cereals, soybeans, broadbeans, peas, mung beans, other minor bean crops, and, valued at 1/5 fresh weight, sweet potatoes and white potatoes. Kang He et al, Agricultural Yearbook of China, various issues.
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