CHAPTER XI

POTENTIALITIES FOR RICE EXPANSION: YIELDS

Although the production of rice in parts of the East has tended for some time to lag behind the growth in population of rice-eating countries, nevertheless Monsoon Asia is not without potentialities for expanding its rice output. It may be true, as various geographers contend, that any "great expansion of Asiatic agriculture or intensive land use would seem impossible. The habitable lands of Asia have long been fully occupied."[1] However, a "great expansion" might not be required in order to provide sufficient food for a population increasing under conditions of the foreseeable future.

When one considers that many observers believe it feasible to double the paddy production of all southern Asiatic rice-producing countries, even including China, one can readily visualize what this means in terms of potential rice supplies. Mukerjee[2] has stated that "Indian crop yields can be at least doubled by the use of improved seeds and methods of tillage, fertilisers and by the utilisation of idle or semi-idle labour." Similarly, Thompson[3] believes that "the yield of agricultural products in China can be doubled. . . . . the possibility of agricultural expansion . . . . is . . . . very large." When Zimmerman[4] studied Thai agriculture in 1930–31, he foresaw the possibilities of doubling yields generally and increasing the actual area of wet rice by a third or a half, over a 25–40-year period. The same general observations can be applied to

[1] Samuel Van Valkenburg, "Agricultural Regions of Asia. Instalment I," *Economic Geography*, July 1931, VII, 220.

[2] Mukerjee, *Food Planning for Four Hundred Millions*, p. 128.

[3] W. S. Thompson, "The Outlook for the Improvement of Standards of Living in China," in *An Experiment in the Registration of Vital Statistics in China*, by C. M. Chiao, W. S. Thompson, and D. T. Chen (Scripps Foundation for Research in Population Problems, Oxford, Ohio, 1938), p. 83.

[4] C. C. Zimmerman, *Siam: Rural Economic Survey, 1930–31* (Bangkok, October 1931), p. 321.

Burma, French Indo-China, the Philippine Islands, and other rice-growing countries to the south.

Even in Japan, already by far the most intensively farmed country of Monsoon Asia, the "generally quoted estimate, endorsed by Professor Nasu, gives 25 per cent. as the potential future increase in the per *tan* production of rice obtainable 'through the gradual improvement of social and economic conditions as well as by constant effort to improve technical skill in farming work.' "[5]

The apparent differences in points of view expressed by these quotations, and the seeming inconsistency between the limitations to Asiatic agricultural expansion in general and the potentialities for enlarging the rice output in particular are partly explained by differences in concepts. "Potentialities" may be viewed in terms of how nearly present output approaches the physical limits of production under optimum economic conditions and, clearly, "potentialities" may also refer to the probabilities for expansion under varying other sets of economic conditions. Here, and in the following chapter, we are not concerned with prospects for rice expansion under any assumed set of economic conditions, but solely with the question of physical possibilities—the various steps that might be taken to increase the rice output if economic circumstances permitted.

Rice production may be increased by improving the yields obtained, by enlarging the area sown, or by a combination of both methods. Yields may be enhanced by applying more labor to present lands, improving the soil through fertilization, crop rotation, better breeding and selection of varieties suited to the type of soil and climatic conditions encountered, and by better management of all these factors. Bringing more land into rice production depends upon its availability, adaptability, location, and numerous other factors—possibly the

[5] G. E. Hubbard, *Eastern Industrialization and Its Effect on the West, with Special Reference to Great Britain and Japan*, assisted by Denzil Baring, with a conclusion by T. E. Gregory (issued under the auspices of the Royal Institute of International Affairs, London, 1935), p. 147.

substitution of mechanical for man power, and so on. The practicability of all of these general methods for expanding the rice output depends, in varying degrees, upon what is economically feasible. This chapter is concerned primarily with rice yields per unit of land area, some of the more important factors affecting yields, and the bearing of present and potentially procurable yields, considering only the physical limitations, upon aggregate rice supplies. Chapter xii will examine the potentialities for rice expansion through the opening up of new lands suitable for rice, or the conversion of older areas into paddy fields.

PRESENT YIELDS AND TRENDS

Diverse natural conditions and cultural practices within Monsoon Asia produce wide variations in the annual output of paddy obtained from given units of land. Yields range from the meager returns secured from upland (nonirrigated) fields in parts of Java, Indo-China (e.g., Laos), and many islands of the Philippine group, to the heavy production of the intensively farmed, irrigated paddies of Japan, the latter being many times as great as the former. Trends in yields over the past 20 years, in so far as they can be determined by the data at hand, have also been markedly different from one rice-growing region to another.

The data briefly introduced in chapter iii (Chart 3, p. 61) give, for all 12 of the important rice-producing countries of Monsoon Asia, a general indication of the different levels of yields obtained. Even on the basis of averages for whole countries, the wide range of productivity from one to another is clearly suggested. Average yields in Japan run about four times as large as those in Indo-China. In China (also a nation practicing intensive agriculture) yields are apparently quite high and are comparable with those obtained by the Japanese in Chosen and Taiwan. The drop to the average level of the countries farther south is rather great. British Malaya produces a little more than 10 quintals of cleaned

rice per hectare, whereas yields in Java,[6] India, Burma, and Thailand fall a little short of this figure. Yields in the Philippines are considerably lower but surpass those obtained in Indo-China. Production statistics for Ceylon are of doubtful accuracy, but there is little question that here the native rice grower gets a smaller output from his land than in any other country.[7]

In chapter ix attention was called to some of the qualifications that seem desirable in appraising the statistical record of various countries. These qualifications are more important in considering trends in yields than in indicating general levels. We accepted as credible in their general behavior the official statistics of Burma, Japan, India, Java, and the Philippine Islands (Chart 21, p. 198), but raised a number of questions regarding the interpretations that should be attached to the records for other countries.

Within the group of countries for which the statistics appear to be satisfactory, a definite and consistent upward trend in yields over the past 30 years is indicated for Japan; there appears to be a slow downward trend in the level of yields in Burma and probably also in India; but in Java and the Philippines the data are inconclusive. Accident of weather plays a part in average yields computed for all countries and may give misleading indications of trend for shorter periods, but the above generalizations are based upon a 30-year record, as presented in Appendix Table III, and may therefore be accepted with some confidence.

Of the countries for which the statistical record appears faulty in certain respects, Indo-China shows a downward trend

[6] Data on yields in the Outer Provinces of the Netherlands Indies are not at hand. In some districts they are reported to run higher than in Java, especially in Bali and on the west coast of Sumatra. See A. M. P. A. Scheltema, "Rijstproducties op Java en Madoera," *Landbouw* (Buitenzorg), 1928/29, IV, 780. This article also contains a useful map showing the yields of irrigated rice by "districts" (the smallest administrative unit) of Java and Madura, based on data for 1922–27 (opposite p. 780).

[7] Lack of an adequate water supply in many places, poor soils, and inability to employ a system of crop rotation are more responsible for the low yields of rice in Ceylon than any outstanding weakness in the cultural practices of the native grower. Transplanting is apparently not as universal as in most other Asiatic rice-growing countries.

in rice yields per hectare over the past 30 years, and the data for Thailand suggest a similar tendency over the past two decades; the Japanese colonies of Chosen and Taiwan show a consistent upward trend in the yields obtained, and although the amount of improvement may be exaggerated by lack of comparability in statistics over the period of three decades, the increase is probably real; in British Malaya the trend in yields has changed direction, but has been definitely upward since 1930–31;[8] and, finally, the statistics for Ceylon do not permit of any speculation as to trends.

In Asiatic countries as a group, little progress has been made during the past few decades in the improvement of rice yields. The exception is the Japanese Empire, where government-sponsored efforts at scientific agriculture have produced some notable results. More recently, during the past decade, yields appear to have risen in Burma, Indo-China, Malaya, and Java, but over a longer period there is strong suggestion of a downward trend in all three of the major exporting countries and probably also in India.

Outside of Monsoon Asia, in the newer rice-growing regions of Western countries, although production is small, rice yields tend to be higher and also tend to increase.[9] The gen-

[8] For many years the rice situation in British Malaya has been a reflection of the fortunes of the rubber and tin industries. Rice growing seems to be neglected, yields tend to fall, and annual imports are larger when conditions are good in other types of enterprise. Rice production is stimulated and imports are curtailed in periods of poor demand for the Peninsula's export commodities or, as in recent years, during periods of political uncertainty when ideas of self-sufficiency in foodstuffs have a strong appeal.

The neglect of rice cultivation was referred to in the annual reports of both the Straits Settlements and the Federated Malay States as early as 1915. The former report remarks: "From rice, a Malay might expect, if the season did not fail, to make, with the united labour of his wife and family, a bare livelihood: a small rubber plantation yields him enough to make him a comparatively rich man; and instead of the dried fish and the cloth garment that were all that he could afford as a rice-grower, he eats imported rice and dresses himself and his family in silks. Such of the rice-fields as are not cultivated are lying fallow, and cultivation can be resumed when desired" (Straits Settlements, *Annual Departmental Reports . . . . for the Year 1915* [1916], p. 74).

[9] In quintals of cleaned rice per hectare, average rice yields for the five-year period 1930–31 to 1934–35, for selected countries outside Monsoon Asia, were as follows: Spain, 38.6; Italy, 29.6; Egypt, 18.4; United States, 14.6; Brazil, 8.8; and Madagascar, 7.7. Spain and Italy secure yields considerably higher than those in Japan, but production—even in Italy, by far the leading rice-growing country of Europe—is on a much smaller scale. Spain has long held the distinction of securing the highest yields of rice obtained anywhere in the world. This result has been attributed to heavier manuring, bet-

eral level of agricultural practice is lower in Asiatic countries than in most Western rice-growing areas, and it is probable that some exhaustion of the soil is occurring in the older cultivated lands. Soil fertility apparently may be maintained at a certain level by the practices commonly followed in many parts of the Orient, and by the natural recuperative powers of the land, especially during the dry season. To raise this level, however, requires artificial fertilization, and this practice is generally beyond the limited financial resources of the Asiatic grower.[10] Furthermore, only a small amount of livestock is available to the Asiatic. In some areas, the absence of adequate irrigation facilities or flood-control systems, and the extension of rice growing onto unproductive lands, have contributed toward holding yields down to a relatively low level. The practice of double cropping affects yields. When more than one rice crop is raised during a year, the yield of the second harvest is usually somewhat smaller than the first.

Suitable soil, drainage, an adequate amount and distribution of rainfall, freedom from diseases and pests, and so on, are all natural conditions contributing to good yields. Selection of seed adapted to soil and climate, amount of labor applied in the preparation of the land and care of the crops, and the manner in which such labor is applied (i.e., proce-

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ter cultivation, the use of improved varieties, and the prevalence of transplanting; but yields are doubtless higher also because the acreage is small and limited to very fertile land. Spain is one of the few Western countries in which rice is transplanted from the seedbed; the same practice is now general on more than one-third of the Italian rice acreage. Good and increasingly larger yields are being obtained in Egypt, which surpasses all Asiatic countries except Japan. The United States, as a rice producer, seems to rank with the Japanese colonies and with China in respect to yields, while Brazil and Madagascar secure unit yields more nearly comparable with those obtained in the poorer areas of southeastern Asia and adjoining islands.

[10] Sometimes, however, the use of fertilizer does not seem to pay. In Java, for example, it is understood that the natives can secure the necessary credit for making purchases if they wish, but except in the growing of truck crops, like onions and shallots, the application of fertilizer is not considered profitable. Likewise, soils on the western side of the Malay Peninsula are only slightly responsive to manuring, and the increases in yields that can be obtained are not economic (see p. 255). In many parts of Thailand and Burma, the cost of suitable fertilizers is too high to justify their use under present conditions.

dures in transplanting, crop rotation, fertilization) are all cultural practices having an important influence on rice yields. The number of crops grown each year, and the proportion of the crop that fails for one reason or another, similarly affect the levels of yield.

The departments of agriculture of most Oriental rice-growing countries have long given attention to the improvement of varieties and of methods of cultivation, but the task of educating the native rice growers away from the ancient practices is as difficult as an attempt to modify customs. The principal reason for the restricted use of fertilizers in Monsoon Asia is undoubtedly economic, but technical reasons are also involved and must be considered. Some further appraisal of the roles of seed selection, transplantation, and crop rotation in increasing yields is likewise desirable.

IMPROVED YIELDS THROUGH SEED SELECTION

It has been said that the number of varieties of rice exceeds the number of varieties of all the other cereals combined. The existence of so large a number of varieties provides "unlimited material for the breeder, and an opportunity for improvement in any desired direction by careful selection."[11] The development of high-yielding and otherwise desirable strains from the thousands of varieties of rice found in the Far East is usually the result of a method employed by botanists known as pure-line selection. This is merely the scientific outgrowth of the ancient practice of always saving the best part of the crop for seed. When little further progress can be made by selection alone, a process of hybridization, or cross-fertilization of two plants of different strains of the same or different varieties, is used to further improve the quality of paddy seed.

It might be relatively easy to develop varieties that are heavy-yielding, and thus to increase rice production in the field, but there are many other considerations. Any discus-

[11] Copeland, *Rice*, p. 132.

sion of varieties raises the question of what criterion should be adopted in determining desirability — what constitutes "quality," what are the objectives of rice breeding, and what, if any, significant physical and chemical differences exist between different varieties.[11a]

With most characteristics of a given variety of rice, desirability is relative both to the physical environment and to prevailing technology. High yield is a desirable characteristic, and different varieties differ greatly in this respect. But the same variety gives different yields under different physical conditions. A maturation period suited to local climatic conditions is desirable, but this obviously means that a variety with a given maturation period is desirable in some places but undesirable in others. Tightness of grain is of some significance in harvesting; some varieties shatter more easily than others. But the extent to which tightness of grain is desirable depends to a large extent on the methods of harvesting.

Climatic differences are of considerable importance. Some Japanese varieties will start growing at temperatures under which varieties commonly grown in the tropics cannot grow at all. Varieties grown in California must be resistant to low night temperatures. However, climatic conditions are by no means the only factor involved. Even in regions of very similar, in some cases almost identical, climate the same varieties will not necessarily grow equally well. Agricultural officers in Asiatic countries are now very cautious about recommending for a given district the adoption of a variety that has given exceptionally high yields in another district.

To the typical Asiatic rice consumer, flavor seems to be the strongest basis for preference. Flavor depends upon many factors, but it is probable that the taste preferences of particular groups are related to the varieties of rice that are adaptable to local conditions (p. 140). If this should be cor-

[11a] For a discussion of the many complex and variable factors involved in a problem of this type, see C. L. Alsberg, "The Objectives of Wheat Breeding," WHEAT STUDIES, June 1928, IV, 269-88.

rect, it is conceivable that preferences of consumers may change as the work of discovering and introducing improved varieties of rice progresses.

In agricultural departments and experimental stations throughout the Orient, the work of selection and breeding has been going on for many years.[12] But even after varieties have been perfected for different soils, climates, and uses in consumption, the further task of education remains before the average grower can be induced to change his customary methods. The distribution of free seed is often difficult owing to the farmer's ignorance of correct cultural practices or his reluctance to assume the risk of trying something "new" until results have been clearly demonstrated by field tests in his neighborhood. Selection and seed-testing farms are common in India, Ceylon, Java, Malaya, Indo-China, and Japan.

When governments launch agricultural programs that involve something more than mere recommendations to the grower, progress can be more rapid. The Japanese program of rice development in Chosen and Taiwan was far more than an educational campaign to acquaint the farmer with the merits of using certain varieties of paddy seed. In 1935 more than 65 per cent of the first rice crop produced in Taiwan was of Horai varieties, the trade name applied to varieties acclimatized to Taiwan; and in Chosen it is estimated that over 70 per cent of the area sown to rice consists of improved varieties.[13] In instances where the government's recommendations were not enough, this result was achieved by coercion.[14] In both Chosen and Taiwan discriminatory forms of taxation have been instrumental in forcing farmers to grow the varieties desired by the government authorities. In contrast with developments in the Japanese Empire, yields in India have

[12] According to a tabulation in Jones ("Improvement in Rice," pp. 453–54), some 52 institutions and stations were conducting rice-improvement work in nine countries of Monsoon Asia and 25 such places were doing similar work in fourteen countries located in other parts of the world.

[13] Jones, *op. cit.*, p. 437.

[14] Lee, *Land Utilization and Rural Economy in Korea*, p. 57.

been stationary or slowly declining for many years. There has been no lack of a government effort to raise the paddy output above the low level of the past few decades, but either the task has been too difficult or the effort has not been effectively organized. At a meeting of the Rice Committee of the Imperial Council of Agricultural Research late in 1939, it was stated: "Despite the fact that the Council has been financing rice research for the last ten years and new and better yielding varieties have been evolved, the total area [in India] under improved rice represents only six percent of the total area under this crop."[15]

Indo-China is another example of a country where efforts have been made since the first World War to improve the rice output per land unit without noticeable success. Every governor-general since that time has attempted to improve, as well as increase, the colony's rice crop. In the construction of flood-control and irrigation projects and in the extension of the area devoted to rice, considerable progress has been made, especially in Cochin China.[16] But developments in seed selection and fertilization seem to have lagged behind. The failure to achieve greater progress in yields has probably been due to administrative deficiencies. A central rice station, created at Cantho in 1927, distributes each year an average of eight tons of seed. An *Office du Riz* was opened in 1930, yet to date there is little statistical evidence of much improvement in paddy output in relation to the area under rice.

Every government is confronted with a difficult problem when it attempts to modify ancient practices of native rice growers. Non-Oriental administrations especially encounter obstacles. Perhaps the French are less effective colonial ad-

[15] U.S. Dept. Comm., Bur. Foreign and Domestic Commerce, *Foodstuffs Round the World*, Feb. 2, 1940, p. 3.

[16] Despite such progress, much remains to be done in educating the ignorant peasant in the maintenance of canals, ditches, and other works after they have been completed. The sides of the canals crack in the dry season and are softened by the rains so that much water is lost by seepage, or the walls are destroyed by slipping. After a series of years of normal rainfall, however, the peasant becomes careless in upkeep, as irrigation then seems to him to be unnecessary.

ministrators than the British or Dutch. One writer observes: "To Westerners, crop failures from flood are laid to a natural force. To the Indochinese, they are due to the failures of the emperor and his court to obey the dictates from heaven."[17] This suggests the difficulties of a colonial administration in which very little responsible government is exercised by the native peoples.

In British Malaya agricultural officials have encountered considerable difficulty in securing the co-operation of Malay paddy growers in experimental work. The Malay is alleged to be a lazy fellow who looks with suspicion upon any activities that might result in changing cultural practices in the direction of more manual work, longer hours, or an extended season of farm labor. Although the water buffalo is a useful work animal in connection with paddy culture, the introduction of more cattle is resisted. The possession of such an animal usually means that the Malay husband is required to work; without one, his wife and family are able to perform most of the necessary labor.[18]

It is not our purpose to review the work of variety and seed selection that has been going on for many years.[19] The important points to bear in mind are that, with few exceptions, yields have not been greatly improved during recent decades, and that the potentialities would seem to be much greater than

[17] T. E. Ennis, *French Policy and Developments in Indochina* (Chicago, 1936), p. 10.

[18] These observations are those of a British government official with long experience on the Peninsula. They are in harmony with other informal expressions of opinion received in Malaya in 1939–40. See also Federated Malay States, *Report of the Rice Cultivation Committee* (1931), I, 41. The committee, referring to the preparation of rice paddies by allowing the buffaloes to trample the fields, has this to say:

"How far this trampling process is in reality an economic necessity and how far it is born of the tendency which exists among cultivators to do the work of preparation of land with the expenditure of the least possible amount of effort is by no means clear. It is stated that it depends on the character of land, but it seems not improbable that it may depend to a considerable extent on the character of the inhabitants. It is noteworthy that, where conditions are least secure and assured, the habit of preparing the lands by allowing buffaloes to trample them is most prevalent."

[19] Those interested in this subject are referred to Copeland, *op. cit.*, pp. 101–64; and Jones, *op. cit.* Current reports of progress in rice research in specific countries are to be found in government publications, annual reports, or journals; e.g., for Malaya see R. B. Jagoe, "Padi Selection and Varietal Trials, 1938–1939," *Malayan Agricultural Journal*, December 1939, XXVII, 468–512.

the results thus far achieved. The knowledge exists, strains have been developed, and in many countries it is principally a matter of introducing varieties best suited to local conditions. Opportunities for improving yields through better seed selection appear very substantial throughout all of the rice-growing portions of southeastern Asia. In the Philippines, for example, it is estimated that rice production could be increased 10 per cent merely by replacing low-yielding varieties of rice in certain provinces with superior seeds.[20] One of the reasons for the large proportion of "brokens" in the finished product turned out by the major rice exporters is the lack of uniformity in the quality of paddy. Even if the seed used were not superior but selected only for uniformity, important advantages would accrue in milling.

When growers more generally follow the practices recommended by scientists, one may reasonably expect results to be shown in the yield statistics.[21] The potentialities are real, whatever the prospects for early improvement. Variety and seed selection, however, is only one phase of the problem—one factor among many affecting the quality and volume of paddy output from given plots of land.

TRANSPLANTING PRACTICES AND YIELDS

Over the greater part of Monsoon Asia where rice is grown, the seeds, after being soaked and sprouted, are sown in specially prepared seedbeds or nurseries, where the plants are allowed to grow for periods ranging from four to eight weeks, probably most often for six weeks. They are then transplanted by hand from the seedbed to the paddy field. Both technical and economic considerations explain the prevalence of this

[20] Philippines Dept. Agr. and Comm., *The Rice Industry in the Philippines* (1939), p. 18.

[21] An example of the type of advice quite generally at the disposal of rice growers sufficiently well educated to understand it may be found in B. R. Bautista, *The General Practice of Lowland Rice Farming in the Philippines* (Philippines Dept. Agr. and Comm., Bur. Plant Industry, Farmers' Circ. 39, 1937). Without a great amount of field work and education among farmers based upon the knowledge gained, such government publications become references for students rather than circulars of direct usefulness to farmers.

practice in Oriental countries, and the influence upon yields appears to be both direct and indirect. Generally, but not always, the physical yield per unit of area is greater when the practice of transplanting is followed, but transplanting also permits more flexibility in the timing of cultural operations and a better distribution of labor. Unquestionably, transplanting is a practice that has been found to be profitable over a very long period of time, under conditions prevailing in Monsoon Asia.

Thus, Grant[22] says of Burma:

> The results of experiments carried out by the Agricultural Department show that on the most common types of soils where the water can be fairly well regulated at the beginning of the season the transplanted crop will give a yield of about 300 lbs. to the acre more than is obtained from broadcast sowing at the rate of 50 lbs. to the acre which is the optimum rate. In Arakan the results showed that there was little or no difference in yield between transplanting and broadcast sowing. However, the practice of transplanting has the advantage of enabling the cultivator to give good cultivation to the whole of his holding when the seedlings are growing in the nursery, which is not possible if the whole of his crop is to be sown broadcast and the seed is to be got into the ground in time. Transplanting appears to be the more reliable method over a number of years, particularly in low-lying areas where the crop in the early part of the season is liable to be damaged by floods, and on areas where the early rains are sometimes scanty or badly distributed.

In some parts of Japan rice has been sown directly on the paddy field as thickly as is customary with transplanted rice, and the yields have been approximately the same. Furthermore, although there is no transplanting in California, yields there compare favorably with those obtained in parts of the Orient (other than Japan) where yields are fairly high. Hence the practices correlated with transplanting must be important in explaining its prevalence in many regions.

One of the most definitely established advantages of transplanting is the control afforded over weeds, the extra labor cost involved being largely offset by savings in weeding.[23]

[22] *The Rice Crop in Burma*, p. 15.

[23] The cost of production per unit of paddy output is lower for lowland-rice culture than for upland. In the Philippines, according to estimates of the Bureau of Agricul-

Not only are weeds inherently better controlled in water than on dry land, but transplanting makes easier such weeding as is necessary. While the seedlings are growing in the nursery, the paddy field may be cultivated and cleared of weeds; and after transplanting the regular spacing of plants makes weeding during the growing period an easier task.

Transplanting also permits the plants to be more evenly spaced than they would be from broadcast sowing. There appears to be some experimental evidence of an optimum spacing, but the optimum varies with a number of environmental factors. Differences in spacing tend to be offset to some extent by differences in tillering, the amount of which is partially adjusted to the space available. Similar yields may be obtained from stands of different densities.

In regions where soil and market conditions are suitable and the supply of land is small in relation to the supplies of the other factors of production, transplantation has the advantage of leaving the fields free for other crops during the month or six weeks in which the seedlings grow in the nursery. This period may be essential to the maturing of a crop sown earlier.

Thus, on about 30 per cent of the rice land of Japan, barley, naked barley, and wheat are also grown. While the rice seedlings are growing in the nurseries from about the end of April until about the middle to the end of June, the other crops continue to grow on the land to which the rice is subsequently transplanted, until they are ready for harvesting about the end of May and the beginning of June. Without transplanting the rice seedlings, it would be impossible to bring the cereals grown on these lands to maturity, the month of May being essential to the ripening of the crops.

In China, similarly, the "planting of rice in seed beds while winter crops are still growing, and later transplanting the rice seedlings after the harvest of the winter crop, is the chief fac-

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ture, the cost for the lowland form of culture "would still be less if, all other costs remaining as they are, transplanting cost three times what it does" (Copeland, *op. cit.*, p. 234).

tor making double cropping possible in the northern part of the Rice Region."[24] Thus, transplanting is a practice sometimes explicable in terms of the whole agricultural system of a region.

Transplanting makes possible better labor distribution. Perhaps even more important, it gives the farmer in many regions greater leeway in planting; if for any reason the weather is unfavorable, he can postpone planting by waiting until the seedlings are larger. Probably one of the reasons for transplanting is to get a uniform stand. If the seed is planted directly in the paddy, some of it tends to be smothered in the mud, for the rice plant requires oxygen to germinate. One reason why farmers in California are sowing with airplanes is that they are able to drop the seed on the flooded field, and it is not so likely to be smothered in the mud.

Transplanting requires a large supply of labor. In places where the supply is scarce in relation to the supplies of the other factors, transplanting is not likely to be profitable even if it could be definitely shown that considerably increased yields would result. It is hardly conceivable that the practice will ever be adopted in the United States or Australia. But in places where agricultural incomes and wages are relatively low, the practice is likely to continue indefinitely, because of the advantages in land utilization, weed control, and soil cultivation.

Although transplanting is the typical practice in the rice-growing areas of Monsoon Asia, broadcast sowing is found in certain districts—sometimes owing to a local scarcity of labor, and sometimes partly because of the nature of the soil or the absence of sufficient water. However, since the proportion of the total Asiatic paddy crop that is sown broadcast is not known, there is practically no basis for estimating the rice-yield potentialities of an extension of the practice of transplanting. It is reasonable to assume that transplanting is now the custom in Monsoon Asia wherever circumstances permit

[24] Buck, *Land Utilization in China*, p. 216.

it, and that in regions where the practice is not common, economic rather than physical limitations operate against it.

On lands where at present only one rice crop and no other crop is grown each year, some of the chief potential advantages of transplantation cannot be realized. Future changes that may involve an extension of the practice are unpredictable. Some potentialities for bettering rice yields by this method undoubtedly exist, but their magnitude remains unknown.

SYSTEMS OF CROPPING AND ROTATION

In Monsoon Asia generally the land available for growing food crops is used as intensively as circumstances permit. Double cropping is common in many places (chapter iii, pp. 43–47), and multiple cropping is prevalent, especially in the Sino-Japanese portion of the rice belt. Unless some provision is made for maintaining fertility, such constant and intensive use of the land must inevitably exhaust the soil, and soil exhaustion must eventually be reflected in rice yields. Soil fertility may be maintained through fertilization (discussed below, pp. 251–62) and by a planned system of crop rotation in which the plant foods taken from the soil by one crop are restored later by an alternating crop.

Although growing more than one rice crop on the same land within a single year, or growing rice and some other cereal such as wheat or barley as a winter crop, or growing rice, some other cereal, a legume, or a truck crop is a rotation of crops, it is not a system of crop rotation in the Occidental sense. It would be less misleading to refer to such rotations within a single year as an alternation of crops, or double, or multiple cropping. Most frequently the chief purpose of these successive plantings is to make maximum use of the land, rather than to restore or increase soil fertility.

Crop-rotation systems in the Occident may be designed to balance the labor load and to maintain or improve soil fertility, but always aim to secure the maximum return consistent

with such objectives. The requirements of different crops and the amount of plant foods absorbed vary widely, but with some knowledge of these differences it is possible to grow a series of crops in different years on the same land without exhausting the soil. The root systems of plants require different depths of soil for establishing themselves; advantage may be taken of this in utilizing different layers of the soil in the planting succession. In some cases the usefulness of a rotation system in checking the ravages of plant diseases and insects, or the growth of noxious weeds, may be as important as the maintenance of soil fertility. With irrigated-rice culture, however, these latter considerations do not seem to be dominant.

Compared with temperate regions of the Western world, tropical and subtropical countries in general have been slow to work out genuine systems of crop rotation, although the advantages to be derived are many, and the beneficial effects on yields have been amply demonstrated. There are a number of reasons for the relative scarcity of well-established crop-rotation systems in Monsoon Asia. This is not to say that rotations are not common in numerous localities. The rotations that are found in Monsoon Asia are, in fact, many and varied, but the number and importance of those that are based upon considerations of scientific maintenance of soil fertility are impossible to estimate.

Data are notably lacking upon the variations in rotation practices from one part of a country to another. The most comprehensive information at hand upon cropping systems comes, surprisingly enough, from China. Buck's[25] investigation reveals information on the cropping practices found in all of the main agricultural regions of the country (Map 2, p. 32), but there are 547 "most common ones." Even when such data are available, it is obviously impossible to generalize in the absence of any measure of the frequency of the various systems or the area and production affected.

[25] *Land Utilization in China: Statistics*, pp. 253–69; and *Land Utilization in China*, p. 239.

Considering Monsoon Asia as a whole, it seems that in regions where any crop rotation at all is practiced, food crops are more commonly rotated with rice than are nonfood crops, and cereals are more commonly planted after rice than are legumes. Furthermore, fallowing as a means of restoring vitality to the land is far less common than in Western countries. Pressure to utilize the land to its fullest for food production is such that in the densely populated older parts of Monsoon Asia the amount of land that lies fallow from choice is practically nil. A certain proportion of the available acreage is unused during the winter, but usually because climatic conditions do not favor the growing of subsidiary crops. Finally, although such rotations as are reported may encompass a period of as much as half a dozen successive years, factors other than soil and climatic conditions are probably decisive in determining the crops that the farmer actually plants.

In Japan the chief cereal crops planted on paddies and subsidiary to rice are naked barley, common barley, and wheat. These are planted following rice, year after year without rest for the land. In some parts of the country one or more rapidly growing truck crops (e.g., radishes, eggplants, melons) may be produced in addition to a winter grain crop. No true system of crop rotation is generally employed, and soil fertility is maintained by the extensive use of fertilizers. In localities where climatic conditions are unsuited to winter grain, a green-manure crop may be planted on the paddies (see below, p. 255).

Parts of China present the same general situation as Japan.[20] In the Yangtze rice-wheat area, wheat or barley are commonly planted after rice, and also green beans and field peas. Rapeseed, tobacco, broad beans, soybeans, sesame, and sweet potatoes are other crops found in rotation with rice here and in areas to the south and west. In addition to

[20] There is some rotation of soils as well as crops in China, such as the exchange of soils between mulberry orchards and rice fields. Soil used for each crop is apparently beneficial to the other and is laboriously transferred.

tobacco, some nonfood crops such as opium, flax, and cotton, and various fodder crops are also rotated with rice in China. The variety of crops grown is large, the combinations are numerous, the cycle of years covered is most commonly from two to six, and rotations involving a fall crop planted after a summer crop in addition to a summer crop planted after a winter or spring crop appear most often in the southern part of China, in the double-cropping rice area (Map 2, p. 32).

In Chosen the winter cereal crop is ordinarily barley, wheat, or naked barley, as in Japan. Legumes are often planted for green manure on paddies located where climate and soil are unfavorable to other grains. Multiple cropping with vegetables is also common near the cities, but where the land is used so intensively certain vegetables are not allowed to mature but are used as green manure. Chosen may be included with Japan and China as countries with sufficiently similar natural conditions and intensity of land use that the problem of maintaining or improving rice yields becomes more a matter of fertilization than of scientific crop rotation.

The crops that are grown in any given locality are determined very largely by the suitability of the land, the character of the climate, the yields obtainable, the maturation period, and the availability of markets. Crops that might be grown may be more numerous or different, but the farmer's choice is influenced by the consumption requirements of his own household and by the necessity for some cash income. Because of this need for cash, prevailing market prices may well become the basis for selection of crops to be grown in addition to rice, especially in parts of the Sino-Japanese rice belt where natural conditions are favorable to the cultivation of a variety of crops.[27] Only if everything else is equal may consideration be given to long-term profitability of the cropping system accruing from the proper maintenance of soil fertility.

[27] The most important cash crops in China are opium, peanuts, rapeseed, cotton, soybeans, wheat, green beans, kaoliang, field peas, and sweet potatoes, all of which enter into crop rotations.

In other parts of Monsoon Asia where the use of fertilizers is far less common, where conditions are often less favorable for double or multiple cropping, and where rice yields average considerably lower, it would seem that planned systems of crop rotation would be of greatest importance. In India there appears to be far less diversity in cropping practices than in China. Various beans, pulses, and tubers are rotated with rice in both the rice and millet areas of India (Map 3, p. 34). In parts of the United Provinces, Bihar, and Bengal, rice matures in 60 days so that there is room for a multiplicity of crops. In these areas legumes, grown in both winter and summer, are common in crop rotations—apparently more so than in China or Japan, where the value of legumes for restoring the soil has also been recognized for centuries, but where cultivation of more important food crops, using fertilizer, is chosen instead. Wheat, gram, hemp, oilseeds, and jute are found in various rotations in India, but we are not in a position to judge the representativeness of particular combinations. One gains the impression that definitely established crop-rotation systems are rare, that examples cited as typical of a certain region in a certain province of India are by no means representative, and that scientific application of methods for maintaining the productive powers of the land has not proceeded far.

In other parts of Monsoon Asia, especially the southeastern portion where rice is grown continuously on the same land without any restoration of the plant food removed, the soil tends to become so depleted that yields reach a minimum. Much of the paddy land of Burma, Thailand, Indo-China, and British Malaya has lost its original fertility. Little or no manure or fertilizer is applied to the paddy crop in these countries, and no system of crop rotation is practiced on an important scale.[28] For many years, silt deposits from flooded

[28] There are some exceptions, e.g., in Malaya. The so-called *tenggala* system of cultivation involves the growing of varieties which flourish equally well under flooded field conditions and when the land is dry. At the end of not more than four successive crops of

rivers and some fallowing have constituted the chief means of renewing the soil. The period of winter fallow following the rice harvest is regarded as essential to maintenance of land productivity when no fertilizer is used.

Rotations of the type found in parts of India and China are not feasible in all rice-growing countries of the Orient, especially in most parts of the Indo-Chinese Peninsula and the Philippine Islands. In the Philippines, the pronounced wet and dry seasons and the absence of adequate irrigation facilities preclude the growing of many nitrogenous crops that might be plowed under in order to replenish the soil.[29] In Burma also, although investigations have been made, it has not yet been found possible to raise a green-manure crop; the soil dries out too rapidly after the monsoon, and at the beginning of the monsoon is submerged so quickly that the only plants that can be raised at that time are semiaquatic grasses.[30] In these countries a relatively higher proportion of the rice fields are in fallow during part of the year so that some gains are forthcoming without special planning or care. But even whenever and wherever the rotation of crops on paddy lands is feasible, the practice is often not popular, as is the case in Ceylon.[31]

In Java, however, not only double and multiple cropping of the land are found, as in the Sino-Japanese portion of the rice belt and in parts of India, but systems of crop rotation seem to be more highly developed than in most tropical countries. Part of the explanation for the greater prevalence of

paddy, the land is allowed to revert to grassland, cattle-grazing land, or secondary jungle for about four years (Grist, *An Outline of Malayan Agriculture*, p. 126).

[29] P. A. Hill and K. O. Moe, *The Rice Industry: A Handbook for the Producer* (Muñoz, Nueva Ecija, P.I., 1920), p. 83. For the same reasons, multiple cropping and a second rice crop each year has not been a successful practice in most of the Philippines. ". . . the second or forced crop is planted during the season of high dry winds and oppressive heat which cause the plants to be stunted through excessive evaporation" (p. 61). In Japan, southern China, northern Indo-China, and Java, multiple cropping is feasible due to the more equable climate characteristic of these areas (see pp. 43–47).

[30] Grant, *op. cit.*, p. 22.

[31] H. A. Pieris, "The Cultivation of Vegetables as a Rotational Crop in Paddy Land in the Kandy and Matale Districts," *Tropical Agriculturist, The Agricultural Journal of Ceylon*, January 1940, XCIV, 27.

such systems is probably the advanced state of cultural practices developed in connection with plantation agriculture, and part of the explanation seems to lie in the system of land tenure found in Java (p. 169 n.). Natural conditions are favorable to the growing of many crops, irrigation systems are well developed, the soil is suitable for dry crops as well as irrigated rice, and on much land rice is rotated with crops like maize, soybeans, and groundnuts. In the sugar-producing areas, government provisions of tenure force a rotation in which sugar is grown on rice land for one year in three or four, rice three times in two years if ample irrigation is provided; other crops in the rotation scheme may be maize, cassava, soybeans, sweet potatoes, and groundnuts.[82]

Although average yields of rice per land unit for Java as a whole are not especially high (Chart 3, p. 61), it must be borne in mind that the upland or nonirrigated rice areas are a larger proportion of the total area under rice (a little over 10 per cent) than in most countries and that the low yields of the upland crop bring down the averages. Without the crop rotations found in Java, yields of the irrigated portion of the crop would probably be little higher than those prevailing in the export countries of the Indo-Chinese Peninsula, for the use of fertilizer in Java is not common and, despite noteworthy success in scientific improvement of varieties of plantation crops, very little has been done in this direction for rice.

For Monsoon Asia as a whole, it may be said that considerable potentialities are present for the improvement of rice yields through scientific rotation with other crops. Such physical potentialities cannot be appraised at all precisely, and there is little point in attempting to be specific, for their realization depends upon too many economic factors, the consideration of which at this time would lead to an evaluation of prospects rather than of potentialities. The extension

[82] Lord, "The Improvement of Rice Cultivation in Malaya, Indo-China and Java," p. 344. In Taiwan also, there is some compulsory rotation of sugar with rice and another cereal in areas adjacent to government dam projects.

of double cropping in many parts of Monsoon Asia with suitable climatic conditions depends upon proper drainage and irrigation, and in some places upon a more adequate supply of labor and work animals. Similarly, the establishment of systems of crop rotation over a period of years depends not only upon these same factors but upon the presence of markets whether local or foreign.

In other words, physical conditions alone do not prevent more rotations and ensuing higher yields in many parts of the Asiatic rice belt. Other factors of production are either absent or not found in proper distribution. Rice is a crop which seemingly does not exhaust the soil completely, although continuous cropping for many years reduces unit yields to a very low level. The protection against loss of soil fertility is to be found in suitable crop rotations or fertilization. In the Sino-Japanese portion of the rice belt, intensive use of the land for many crops without great soil depletion is due to a generous use of manures and fertilizers. Elsewhere in Monsoon Asia, but particularly in the newer rice regions of the Indo-Chinese Peninsula, the growing of many crops is less common, rice is generally the sole crop cultivated on rice fields, fertilizers are not generally employed, and yields have declined to a very low and apparently stable level. In such places the potentialities for improvement through crop-rotation systems are greatest. But in the same places fertilization would also accomplish the purpose of maintaining and increasing the productiveness of the land.

USE OF FERTILIZER IN MONSOON ASIA

The extent to which fertilizers are used on rice fields varies considerably in different parts of eastern and southeastern Asia. Over extensive regions scarcely any fertilizer is applied, and only the plowing in of the stubble and of the weeds that grow while the land is fallow contribute to the restoration of the soil. On the other hand, in Japan large quantities of commercial fertilizers and of "natural" manures are regularly

applied to the soil.[33] In other areas fertilizers are used here and there in varying degrees.

Japan has an important and increasing business in the production of commercial fertilizers. Until a few years ago substantial quantities were also imported; there has been a tendency for the use of soybean cake to decline, and the importance of Manchurian supplies of this fertilizer is on the wane.[34] Ammonium sulphate is proving more economical and more effective as a nitrogenous fertilizer than soybean cake. The extensive use of fertilizers is essential to the attainment of the high yields per hectare that are obtained throughout Japan, and until the outbreak of hostilities in China and the reorganization of the Japanese national economy on a war-time basis, the supply of chemical fertilizers was adequate. In Chosen, besides compost and green manure, ammonium sulphate, soybean cake, calcium cyanamide, and calcium phosphate are used, but not widely as yet, and the preparation of manure is one of the painstaking jobs of Korean farmers. In Taiwan, however, the use of fertilizers seems to be as general as in Japan.

In China "natural" manures have been used in rice culture for many generations. Night soil, animal excreta, garbage, and organic material are carefully conserved and applied at appropriate times. In addition, peanut cake, soybean cake, and chemical fertilizers have come into use in recent times in some districts. The 1929–33 survey in China under Buck's[35] direction brought to light no significant changes in fertilizing practice, except this use of commercial fertilizers. About

[33] The chief commercial fertilizers used in Japan are pressed herrings, pressed sardines, dried sardines, other fish cakes, bone meal, soybean cake, rapeseed cake, cottonseed cake, other vegetable-oil cakes, ammonium sulphate, calcium cyanamide, calcium phosphate, and potassium phosphate. Calcium phosphate and ammonium sulphate are probably the most representative chemical fertilizers. Natural manures used extensively consist of compost, farmyard manure, green manure, night soil, and vegetables.

[34] Fixation of atmospheric nitrogen has had a rapid and extensive development in Japan. As in many other countries, it has been fostered by the government for military purposes, and its rise probably explains the decline of fertilizer imports from Manchukuo in the form of soybean cake.

[35] *Land Utilization in China*, p. 265.

half of the agricultural land in China is double-cropped; and in the south, where two or three rice crops are grown during a single year, farmers are reported to believe that they can obtain higher yields by applying their fertilizer resources to the rice crop during the summer than by using them on winter crops, e.g., winter vegetables, wheat, barley, beans, and peas.[36]

For the present discussion, the use of manures in Japan and her colonies, or in China—all regions where paddy yields are relatively high—is not of as much interest as are fertilizing practices in those areas where productivity is low and where larger harvests are necessary if the potentialities for increasing the aggregate rice supply of Monsoon Asia are to be realized.

In British Malaya[37] there is some use of burned rubbish, bat guano, cattle manure, and leaves. But cattle manure is scarce, the number of cattle in the country being relatively small. On the whole, very little fertilization is practiced in Malaya, and at first sight it might appear surprising that yields do not decline substantially. In this connection it is important to note that both in Malaya and also in some other regions of southeastern Asia the straw of the harvested crop is left on the ground, and at no time is it usual for the soil of a paddy field to be exposed dry to the sun. Some of the nitrogen and potash and a little of the phosphates are thus restored to the soil. More are restored by grasses and weeds accumulating in the fallow period. But the total amounts returned in these ways are apparently considerably less than the amounts taken out of the soil by the crops. It is stated that instances "are on record of sawahs in Negri Sembilan which have been under cultivation for 200 years without any manure. It is believed that the practise which prevails of allowing grass and weeds to spring up in the sawahs between

[36] F. J. Rossiter, "Agriculture in China," *Foreign Agriculture*, October 1939, III, 448.

[37] For a concise and informative summary of the government's efforts to improve rice production and paddy varieties in Malaya, see the address by J. L. Greig, State Agricultural Officer, Selangor, before the Kuala Lumpur Rotary Club on Jan. 17, 1940 ("Malaya's Staple Food Crop and Measures Taken to Improve Production and Varieties," quoted in *Malay Mail*, Kuala Lumpur, Jan. 18, 1940, pp. 4, 16).

two crops and turning these under when the land is being prepared for planting may suffice to maintain fertility."[38]

If corrections could be made which would enable the effects of short-period variations in weather on annual yields to be separated from the effects of other factors, it would probably be found that yields per unit of area have remained constant over a long period in many regions of southeastern Asia where little or no fertilizer is used. Constant yields have been observed in India and Burma also, but it is apparent from the comments of writers that a completely satisfactory explanation of the manner in which soil fertility is maintained, even at a low level, is yet to be found. Howard,[39] for example, raises the question when he says:

> . . . . this constant drain of nitrogen is not made up by the import of manure, we should expect to find a gradual loss of fertility. Nevertheless this does not take place either in Burma or in Bengal, where rice has been grown on the same land year after year for centuries. Clearly the soil must obtain fresh supplies of nitrogen from somewhere, otherwise the crop would cease to grow. The only likely source is fixation from the atmosphere . . . . It seems probable . . . . that actual fixation must take place in the rice fields . . . . while the land is under water. The most probable seat of this fixation is in the submerged algal film on the surface of the mud.

The author does, however, bring out the importance of green manure, when he says that "the numerous experiments which have been carried out in India point to the great value of organic manure, including green-manure, in increasing production. These results are in accordance with experience, as the benefit of incorporating the weeds into the mud when the rice fields are puddled is well known to the cultivators."[40] Often even where green-manure crops can be grown it is more profitable to grow other crops. In regions of Java where the water supply is not adequate for double cropping with rice,

[38] Federated Malay States, *Report of the Rice Cultivation Committee*, I, 24. This seems probable, especially if the grasses and weeds are largely leguminous.

[39] Albert Howard, *Crop-Production in India: A Critical Survey of Its Problems* (London, 1924), p. 113.

[40] *Ibid.*, p. 117.

crops like maize, peanuts, and long beans are grown during the dry monsoon, although much of this land could produce a green-manure crop.

In Japan and China there is some green-manuring during the winter when rice cannot be grown. In certain areas of both countries, a legume (*Astragalus sinensis*) is grown which is related to the locoweed of the United States.[41] In parts of Japan in April and May when this legume is in bloom, the little bright blue patches are a conspicuous feature of the landscape. Though the practice of green-manuring exists, it is not very extensive in either country, probably because it is more profitable to grow some other winter crop, usually one of the barleys, wheat, or winter vegetables.

A more recent report on the results of research in British Malaya concludes: "After nine seasons' experimental work on the manuring of padi in Malaya, the amount of positive information gained is small, the amount of negative information great."[42] The report goes on to say:

> From the mass of accumulated data one fact is certain and two general conclusions seem justified. The fact is that as yet we have no indication of the nature of the factor which apparently limits the yield of padi in this country; the first conclusion reached is that the padi soils of the western side of the Peninsula are only slightly responsive to manuring, such response as there is being mainly to phosphate manures, and the increases which can be obtained are not economic; the second conclusion is that excellent response to manuring can be obtained on Kelantan padi soil, nitrogen, as well as phosphate, having a marked effect.
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> . . . . . .
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> Much, however, can be done on the eastern padi soils in determining the most suitable and economic fertilizer dressings for the different districts.[43]

In the absence of more exact knowledge on many matters

[41] It might pay the California rice grower to introduce this species of *Astragalus* as a green-manure crop rather than let his land lie fallow now and then. California rice land that has been fallowed one or two years, however, normally produces from 500 to 1,000 pounds more rice per acre, "when sown to the same variety, than similar land on which rice was grown the previous year" (Jones, *op. cit.*, p. 422).

[42] R. G. H. Wilshaw, "Padi Manurial and Minor Cultural Trials, Seasons 1937–1938 and 1938–1939," *Malayan Agricultural Journal*, December 1939, XXVII, 528.

[43] *Ibid.*, p. 529.

in connection with effect of fertilizers on paddy, any campaign to increase their use is premature. Soil and other conditions vary in different districts, and local research of an experimental character is an indispensable preliminary to the successful use of fertilizers. However, once the requisite local information is available there can be little doubt that potentialities for increase of yields will appear.

Whatever the secret of obtaining for generations a constant yield of paddy on the same land without manuring,[44] constant yields under these circumstances are always low yields. If the experience of more northerly countries is any guide, such yields could be doubled by changes in the methods of cultivation, especially the greater use of fertilizers. This view appears to be strengthened by consideration of the situation in the great exporting regions of Burma, Thailand, and Indo-China, where very little fertilizer is at present applied to the rice fields.

In Burma cattle dung is sometimes applied to the seedbeds. In Upper Burma it is occasionally applied to the paddy fields as well. But throughout Burma, and especially in Lower Burma, there is great waste of the available cattle dung. It is stored badly, and much of its nitrogen content is lost through leaching. Probably not more than one-eighth of the supply reaches the soil. As Grant[45] says, "manuring cannot yet be considered to be a feature of paddy cultivation in this country." Ammonium-phosphate fertilizers and bone meal have recently been used somewhat, but not as yet to a significant extent.

The Agricultural Department of Burma has carried out important experiments in fertilization, and the results have clearly demonstrated the practicability of increasing yields by the application of fertilizers in appropriate proportions. The clay and clay-loam soils of Burma are fairly well sup-

[44] In some sections irrigation water may carry with it material (alluvium) of fertilizing value. It is commonly believed that the Nile does this in Egypt. In regions of active volcanoes, Java for instance, volcanic dust is an important fertilizing factor.

[45] *Op. cit.*, p. 21.

plied with potash, so that yields are not improved by adding potash fertilizers. On the other hand, the soils are deficient in nitrogen and phosphate, and substantial increases in yields are obtainable by the application of ammoniacal nitrogen and phosphate fertilizers. These constituents can only be supplied in adequate quantities by cattle manure or by chemical fertilizers. It is said that yields "can be increased by over 50 per cent by applying well conserved dung at the rate of 3–4 tons to the acre."[46] In view of the present wastage of cattle manure, there is clearly considerable scope for its extended use at little or no increase in money cost.

Chemical fertilizers specially designed for rice soils are now on the market. There are two types: one contains 20 per cent of nitrogen and 20 per cent of phosphoric acid, and the other 13 per cent of nitrogen and 45 per cent of phosphoric acid. Yields per hectare can be increased between 30 and 100 per cent by their use. To be effective on rice soils, it has been fairly generally held that nitrogenous fertilizers must be applied in the form of ammonium salts rather than in the form of nitrates.[47]

The experience of Burma has considerable significance for Thailand.[48] In Thailand a little buffalo manure or bat guano

[46] *Ibid.*, p. 22.

[47] In this connection the following comment by Howard (*op. cit.*, p. 114) is of interest and is probably still applicable today: "The sources of all the nitrogen taken up by the rice crop in India, the forms in which it is absorbed by the plant at different stages of its growth, and the complete nitrogen cycle of the rice fields are matters in which we are almost completely in the dark. The only definite facts so far ascertained are: (1) the large amount of nitrogen taken up by the rice crop between transplanting and seed-formation, and (2) the preference of the rice plant for ammonia rather than nitrate as a source of its nitrogen."

[48] W. R. S. Ladell (*The Use of Fertilizers in the Cultivation of Padi, with Appendix Containing Some Soil Analyses and Experimental Results*, Siam Ministry of Commerce and Communications, Technical and Scientific Supplement to the Record 6, April 1930, p. 1) considers the statement of D. Hendry with reference to Lower Burma also applicable to Thailand. It also appears to be largely applicable to Indo-China. Ladell quotes Hendry: "There is an impression abroad that this land receives an annual coating of river silt which enriches the soil and maintains its fertility. But, so far as the main padi is concerned, this is not so . . . .

"The system followed of continuous annual cropping with padi, is exhausting when practically nothing in the way of manure is returned to the soil; but most of the land has already lost its virgin fertility and has been reduced to a level of productiveness which now appears to be fairly constant, a level at which the plant food removed by

is sometimes applied to the riceland, and rice plants are sometimes dipped in a paste of bat guano before being planted on the paddy field. The experience of the Thai Bureau of Agricultural Science indicates at present that buffalo manure has no effect. This may due to the amount of leaching in storage and to the poor diet of the buffaloes, but in any case the supplies of buffalo manure that could be made available would be inadequate for fertilizing more than a small part of the riceland. Bat guano, fish waste, bone meal, and oil cake increase yields, but prices are often too high to make their use profitable. As in Burma, the new fertilizers which combine ammoniacal nitrogen with phosphate have been the most successful.[49]

In Indo-China the peasant is usually content to bury the stubble after harvest and sometimes to keep his cattle on the paddy fields in the fallow period. In some cases manure accumulated in the villages is brought out on the rice fields. There are some low plains in Cochin China, where the soil is of a peaty nature and has a high nitrogen content, but in general the soils of Indo-China are poor in assimilable nitrogen and in phosphoric acid, and to some extent also in soluble potash. The use of commercial fertilizers has been limited almost exclusively to natural phosphates extracted locally. Failure to combine these with nitrogen and potash fertilizers has led to disappointing results.[50] In general, nitrogen and

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the annual rice crop is made good by the natural breakdown of the soil. And we are probably safe, therefore, in assuming that under the present system of cultivation a general average yield of about 1,500 lbs. per acre, apart from annual fluctuations, may be expected to continue in Lower Burma for some considerable time."

[49] The application of potash alone is of no value, and the soils of Thailand appear to be fairly well supplied with potash. The chief deficiency is in phosphate. Liming followed by the application of calcium and ammonium phosphate appear to have given the best results in the experiments conducted at the Government Seed Farm at Klong Rang Sit (Ladell, *op. cit.*, p. 2).

[50] In the south, experiments showed that nitrogenous fertilizers alone do not markedly augment yields per hectare, but that a significant increase in yields is obtained by use of a fertilizer made up of nitrogen and phosphoric acid. When potash is added to this fertilizer, the yield is increased only under certain conditions. Experiments in Tonkin and North Annam show that phosphoric acid alone increases yields to some extent but never profitably. Potash alone has rarely given favorable results. In parts of Tonkin nitrogenous fertilizers alone gave results apparently as favorable as those obtained from combined nitrogen and phosphorous fertilizers.

phosphoric acid combined nearly always give improved yields, and profitable results are often obtained from their use, but combined applications of nitrogen, phosphates, and potash appear to be even better.

In the Philippines there is some use of commercial fertilizers and some use of manure. Sufficient experimentation has been carried on to indicate the general profitability of applying fertilizers. Some of the Islands' soils apparently are not in urgent need of fertilizers, but the older lands require restoration.[51] Best results have been secured from fertilizers carrying both nitrogen and phosphoric acid. The Philippine Bureau of Plant Industry recommends green manures or the planting of secondary crops in rotation with rice when soil conditions permit, and the gradual taking up of mineral fertilizers. According to Bautista:

> Lands with average production of 35 to 40 cavans per hectare need to be fertilized at the rate of 150 to 200 kilos of ammonium sulphate per hectare. Other chemical fertilizers supplying from 30 to 40 kilos of nitrogen per hectare may be used. Complete fertilizer supplying 30 kilos of nitrogen, 30 kilos of phosphoric acid, and 40 kilos of potash may be good also.[52]

> The loss of nitrogen and phosphoric acid can be replaced by the use of green manure, which is done by broadcasting legumes such as mongo, tapilan, and others at the rate of 15 to 25 gantas per hectare; and plowing the crop under while in full bloom or just before the pods are formed.[53]

Officials of the Department of Agriculture and Commerce seem to hold the view that fertilization is not the primary condition to be fulfilled before the existing low yields in the Islands can be increased. Rather they stress seed selection, better

[51] According to J. S. Camus (*Rice in the Philippines*, Philippines Dept. Agr. and Natural Resources, Bur. Agr., Bull. 37, 1921, p. 40), an average production of 40 cavans (1,744 kilos) of paddy per hectare removes 20.64 kilos of nitrogen from the soil, 10.32 kilos of phosphoric acid, and 4.54 kilos of potash. If a similar amount of straw is harvested, 11.0 kilos of nitrogen, 2.44 kilos of phosphoric acid, and 28.03 kilos of potash are also lost.

[52] Bautista, *op. cit.*, p. 13.

[53] *Ibid.*, p. 12.

plowing and preparation of paddy fields, crop rotation, general education on good cultural practices, and similar factors.[54]

Even when cultivators are educated in the use of fertilizers from an agronomic standpoint, the extent to which fertilization will actually be practiced will be determined by the relative prices of fertilizers and of rice. At least in the case of commercial fertilizers which are likely to be of chief importance, the appropriate quantity of fertilizer to use is not a constant but varies with variations in the spread between the price of rice and the price of fertilizer. Obviously the mere fact that the use of fertilizer will increase yields is not in itself an indication that the cultivator will find it desirable to use it. Ladell,[55] writing in 1930 of Thailand, points out: "Before the war the relation between the price of padi and the price of the artificial fertilizers was such that manuring could not be undertaken at a profit, but since the war the position has changed; the price of padi has risen and the cost of the old manures has fallen."

In periods of depression there is sometimes a tendency for the price of rice to fall faster than the price of fertilizer. Thus Yagi,[56] writing of Japan, says:

> The present impoverishment of the farming population is due to the fact that in times of general depression, the prices of agricultural products to be marketed and those of the various factors of production constituting the cost of production do not fall at the same rate. . . . . By way of expediting the recovery of the natural equilibrium between the economic forces generally, the State must do away with all measures designed to help the artificial increase of the prices of fertiliser by big capitalistic interests . . . .

Japanese farmers succeeded in getting a law passed in 1936 forbidding fertilizer manufacturers to fix prices without government approval, but its regulations were widely evaded.

[54] Based upon general impressions secured from discussions with a number of such officials in November–December 1939.

[55] *Op. cit.*, p. 6.

[56] Yoshinosuke Yagi, "A Study of the Cost of Rice Production," *Kyoto University Economic Review* (Department of Economics, Imperial Univ. Kyoto, Kyoto), July 1932, VII, 112.

After the "China Incident" further legislation was passed in 1938 (Sulphate of Ammonia Output, Expansion, and Distribution Control Law), and, since Japan has been on a war footing, the prices of fertilizers used by farmers, like prices of most commodities, have been controlled by the government.

Such changes in relative prices of different commodities cause considerable disturbances in agricultural operations. In so far as they reduce the quantity of fertilizer which it is profitable to use during depressions, their effect tends to deplete the soil and leave it less fertile in succeeding years. Moreover, changes in the relations between the prices of cereals and the prices of fertilizers are not simply cyclical phenomena: they sometimes show evidence of the existence of long-period trends. In Burma, Thailand, and probably elsewhere in southeastern Asia, there has been a long-term downward trend in the price of fertilizer as compared with the price of rice. This is associated with the development of chemical fertilizers; the newer types, combining ammoniacal nitrogen and phosphate, save mixing, and their use reduces transport costs. It is a trend in itself favorable for maintenance or increase of rice yields.

It seems clear that the greatest potentialities for improving rice yields through the more general use of fertilizers are to be found in the rice-producing countries of Monsoon Asia lying to the south of the Sino-Japanese rice belt. Yields per hectare are notably low in all of these countries, and fertilizers are neither extensively nor intensively used in rice cultivation. Ample demonstrations have been given of the beneficial effects resulting from the correct application of appropriate fertilizing agents, although the particular practices to be followed under the wide variety of circumstances in which rice is cultivated have not by any means been completely worked out. There is no question about the great physical potentialities that exist. When experiments with fertilization of rice soils have been found to be uneconomic, they nevertheless have not denied existing potentialities under another set of economic

circumstances. Like practically all of the other factors bearing on rice yields, the use or nonuse of fertilizer is a practice heavily dependent upon a complex array of developments that fall under the heading of prospects.

CONCLUSIONS ON YIELD POTENTIALITIES

Of the general methods for expanding the rice output of Monsoon Asia, that of increasing rice yields per unit of land cultivated seems to hold great promise. Yields potentially attainable, assuming that circumstances permitted rice growers to follow all desirable cultural practices, would enormously increase the aggregate rice supply, perhaps far more than could be accomplished by an enlargement of the area under rice. Of the several methods by which unit yields may be improved that were singled out for specific discussion, better seed selection and more general use of fertilizers would seem to have the greatest potentialities. Introduction of systems of crop rotation and the extension and perfection of transplanting practices hold less promise, partly because they are closely linked with other features of the general agricultural pattern of a region that can only be altered appreciably by the development of engineering works, communications, and markets.

Except within the Japanese Empire, progress has been slow in the introduction of superior seed, a most important factor in yields. The breeding of improved, higher-yielding varieties for special conditions of soil and climate has been carried on to some extent in practically all of the rice-growing countries; yet the general adoption by growers of selected seed has, for understandable reasons, been very slow. Nevertheless, the potentialities would seem quite feasible of attainment under sufficient government sponsorship.

The greater use of fertilizers offers opportunities for materially improving yields, particularly in southeastern Asia, but, largely for economic reasons, the realization of the potentialities appears to be more difficult than in the case of

seed. The production of fertilizers in the future may be so developed as to make practicable their use in large areas not at present employing them. Also various factors in rice-production costs, or the level of rice prices in relation to total production costs, may be so altered as to make the wider use of fertilizers economic. And the establishment of suitable agricultural credit systems with provision for borrowing small sums might lead to a greater use of fertilizers with considerable increase in yields.

Cultural practices can undoubtedly be made more efficient in all countries, but especially in regions like the Philippine Islands,[57] Indo-China, and India. The practice of transplanting depends, among other things, upon an assured and regulated supply of water. Without a further development of irrigation schemes, transplanting will not be feasible over large areas in such countries as Ceylon. An adequate water supply is necessary also for the growing of a multiplicity of crops; if made available in places where there is now a water deficiency during the winter months, further justification would be provided for the extension of transplanting and crop-rotation practices. Certain parts of southeastern Asia, furthermore, are not sufficiently populated or near a convenient source of seasonal labor, or do not possess a sufficient supply of work animals, for cultivation to be as thorough and efficient as it might otherwise be.

The generations have witnessed few important changes in rice culture in Monsoon Asia. In fact, agriculture generally has remained essentially conservative, bound to tradition. Estate production of crops has been developed in a number of countries (Java, Malaya, Ceylon, the Philippines), but the

[57] Favorable natural conditions and political relations with the United States have not made it so necessary for the Philippine Islands to develop more efficient production and marketing techniques. This is being realized today: since agriculture has not been well developed along specialized lines, as in some other tropical areas of the world, the Islands cannot command an important position in world markets. If and when independence of the Islands materializes, protected markets will possibly be a thing of the past, and the Philippines will be required to undergo some important reorganizations in their agricultural economy.

methods of estate cultivation have been applied to rice only in a few cases. Even in the Japanese Empire, where the greatest progress seems to have been made in the development of the rice product and in rice-production techniques, "agriculture is described as 'not yet capitalized,'—a special feature worth recording."[58] "With the exception of the government-owned pasturages and upland farms in Hokkaido, motor-driven machines are scarcely used at all in the cultivation of a Japanese farm."[59]

Some years ago a firm of Chinese merchants started cultivation of rice on a large scale by mechanical means in southern Thailand, and the experiment was apparently successful. Thirty men were able to till an area of 600 acres of paddy, whereas by ordinary methods about 300 men are required.[60] But in considering the possibilities for British Malaya, a government investigation commission stated: "We consider that the government should give encouragement to projects of this description . . . . on the ground of expense, we are unable to support the proposal for a large scale demonstration . . . . persons who are interested . . . . would do well to pay a visit to Southern Siam . . . . and possibly to French Indo-China, where, we understand, an American firm of implement makers has also established a demonstration station . . . ."[61] When a government very much concerned with expanding rice production does not feel that it can afford to support a large-scale demonstration of mechanized rice grow-

[58] Shiroshi Nasu, *Land Utilization in Japan* (prepared for the Third Session of the Institute of Pacific Relations [Tokyo, 1929]), p. 81. However, in recent years there has been an extension of mechanization in harvesting and milling operations and an increased use of prime movers for pumping water for irrigated crops. "Between 1927 and 1937 the number of prime movers on farms—mostly electric motors and oil engines —increased from 51,628 to 187,813" (Miriam S. Farley, "Serious Shortage of Agricultural Labor in Japan," *Far Eastern Survey*, Oct. 11, 1939, p. 242, quoting the *Oriental Economist*). The war with China, beginning in 1937, put a stop to progress in mechanization which might under normal conditions, as pointed out by the *Oriental Economist*, "have a far-reaching effect on the destiny of the agricultural and all other industries of Japan" (*ibid.*).

[59] Nasu, *loc. cit.*

[60] See Federated Malay States, *Report of the Rice Cultivation Committee*, II, 178.

[61] *Ibid.*, I, 35.

ing, it is doubtful that under present conditions many individuals or firms will go far in venturing their capital.

Development in cultural practices generally would be reflected in enlarged paddy production. There seem to be considerable potentialities in this direction even in countries where rice yields are at present relatively high, and substantially more over extensive areas of southeastern Asia. The utilization of idle or semi-idle labor in some places, as in India, and the introduction of machinery in other places where there is a scarcity of seasonal labor, as in parts of the Indo-Chinese Peninsula, would permit more thorough cultivation with resulting beneficial effects on unit yields.

In most areas, however, labor is so abundant and capital so scarce that mechanization on any large scale is both improbable and undesirable. In densely populated regions, the social problems that would be created by depriving farm labor of the opportunity to subsist would tend to make conditions worse. Improved rice varieties, better seed, and the more general use of appropriate fertilizing agents offer greater promise than mechanization for enlarging the rice output under existing conditions of production in Monsoon Asia.