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AMA

AGRICULTURAL MECHANIZATION IN ASIA

VOL. VII, NO.4, AUTUMN 1976

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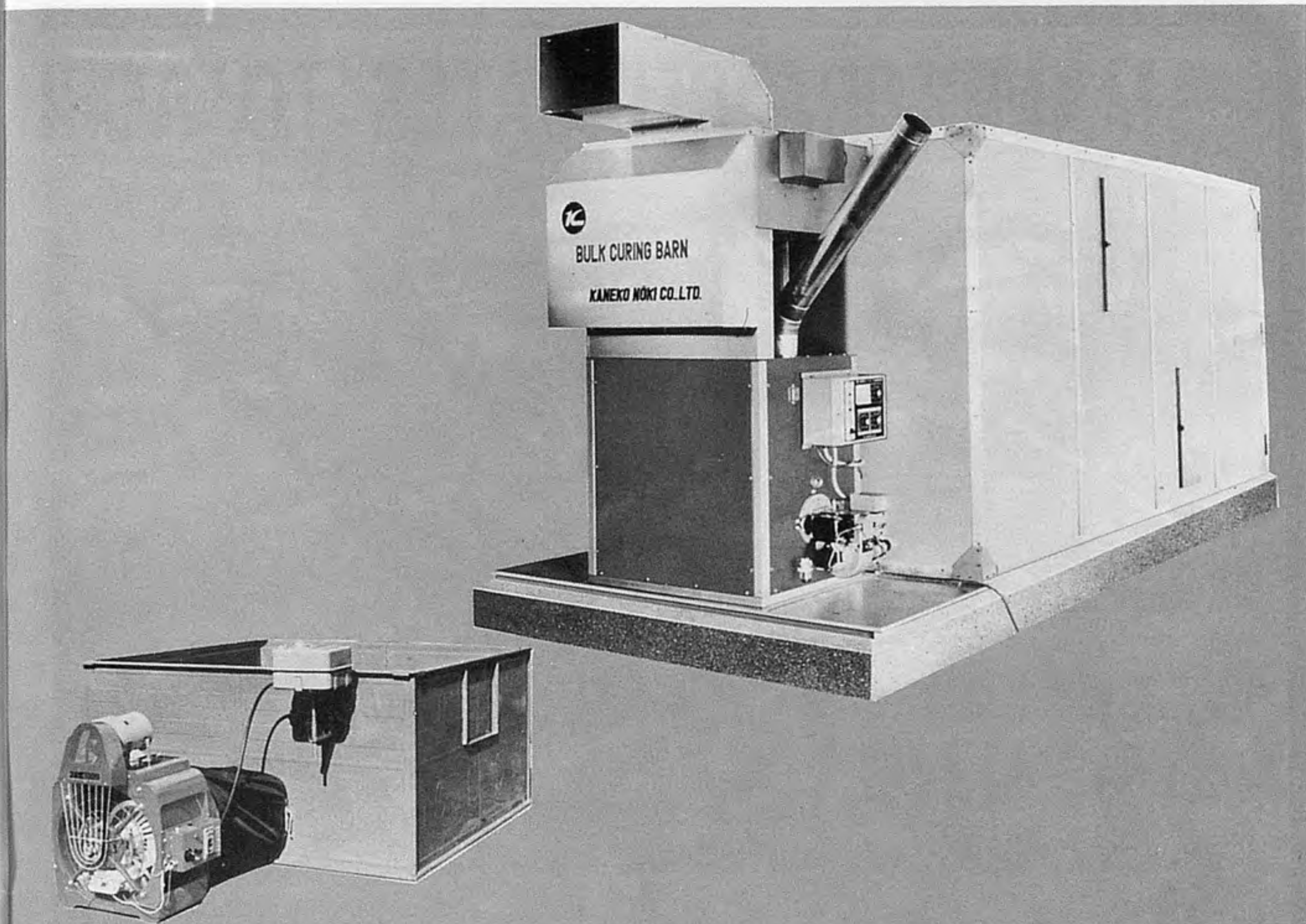

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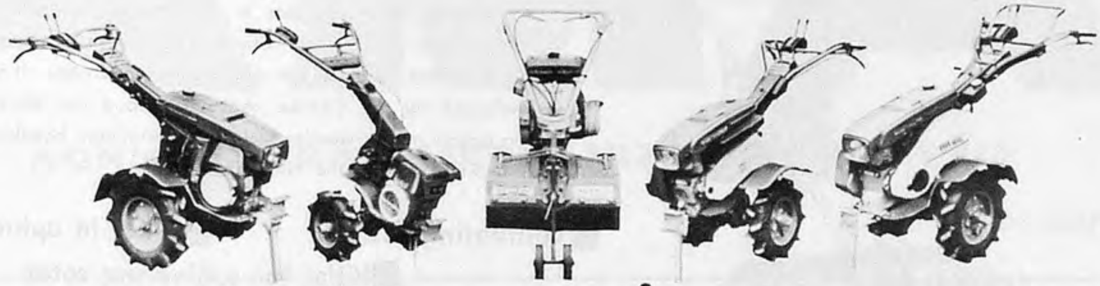

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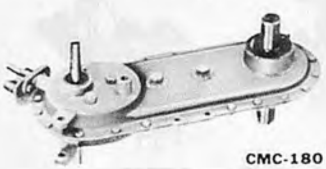

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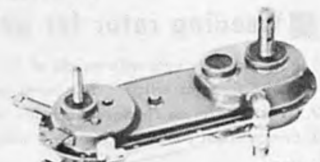
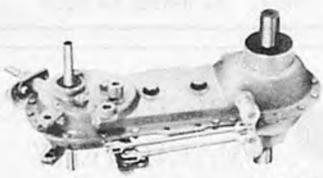
MRV3



SKD-II



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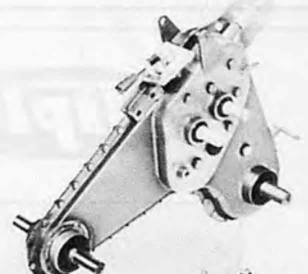

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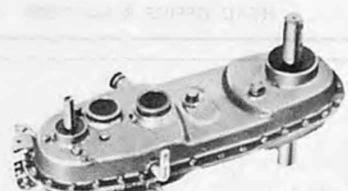

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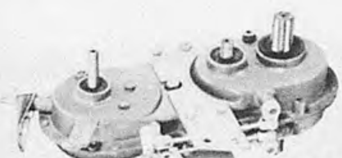

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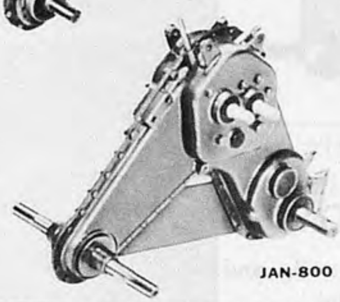

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Shifting Stages		F1	F1, R1	F2, R1	F2, R1	F3, R1	F2, R1	F2, R1	F3, R1	F4, R2	F6, R2	F2, R1	F1, R2	F1, R2
Sidecluch		—	—	—	—	○	○	○	○	○	○	○	○	○ with Lock
Gear Ratios		F_1=1:21·71	F_1=1:18·16	F_1=1:25·41	F_1=1:25·41	F_1=1:41·31	F_1=1:21·21	F_1=1:31·06	F_1=1:66·07	F_1=1:70·03	F_1=1:53·97	F_1=1:32·13	F_1=1:25·54	F_1=1:37·62
			R_1=1:27·24	F_2=1:15·38	F_2=1:15·38	F_2=1:19·40	F_2=1:10·28	F_2=1:11·34	F_2=1:18·96	F_2=1:38·73	F_2=1:37·41	F_2=1:16·92	R_2=1:29·37	R_1=1:32·83
				R_1=1:35·58	R_1=1:35·58	F_3=1: 9·35	R_1=1:21·33	F_1=1:44·52	F_3=1:11·43	F_3=1:15·81	F_3=1:18·50	R_1=1:32·77	R_1=1:20·22	R_2=1:10·69
						R_1=1:49·91			R_1=1:81·09	F_4=1: 8·74	F_4=1:19·42			
										R_1 1:105·04	F_5=1:13·47			
										R_2 1:23·71	F_6=1: 6·66			
										:	R_1=1:66·67			
											R_2=1:24·0			
Dimensions	A	170	170	170	170	202	192	192	224	234	243·5	192	192	192
	B	434	434	434	435·5	532	492	492	545	578·5	603 3	467	467	467
	C	289·5	289·5	289·5	289·5	344·7	336·75	336·75	336·75	319·7	402·5	409·9	287	287
	D	15	15	15	15	16	16	17	19	19	19	16	16	16
	E	31	31	31	31	31	31	31	31	34·5	34·5	31	31	31

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Preface

Looking back to the world agricultural production of this year, the most important thing that we have to take ~~into~~ account is the abnormal weather. Especially, the drought in Europe did great damage to the agricultural production. On the other hand, the unusual low temperature in northern part of Japan caused to the harvest the damage which, it is said, was as big as the one every 30 year.

Through the study I made, I found a very important fact, that is there exsist farmers who stopped the damage as small as possible in the very area which suffered from the big damage. One of the farmers harvested the 70% production of ordinary years, while in other fields, there were completely no production. The farmer succeeded in a good harvest, because of a careful and timely farm work. Without mechanization, he could not have transplanted rice in time and his feild would have suffered from the damage as the same as other farmers.

The abnormal weather of this year told us that timely farm work was most important not only in the rice-planting. It can be said that sometimes we do not notice how indispensable the timely treatment is, in farm work as well as others, such as marketing, production, research and etc., concerning the agricultural mechanization in developing countries.

I hope readers will discuss that matter.

Chief Editor
Yoshisuke Kishida

CONTENTS

AGRICULTURAL MECHANIZATION IN ASIA
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Institutional Obstacles to Expansion of World Food Production

by
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Washington, D.C. 20036, USA

Over the next several decades the most pressing problems in expanding world food production will be in the less developed countries (LDC's). It is in those that demand is likely to grow most rapidly, reflecting both relatively high population and income growth and a drive to improve nutrition, and where the mobilization and effective deployment of the needed resources will be most difficult. Consequently, this article deals with institutional obstacles to increasing food production in the LDC's. The institutional situation in the developed countries is treated only insofar as it might affect the flowof resources needed by the LDC's to stimulate their rates of increase in production.

It is generallyaccepted that over the next several decades a rising share of the growth of food production in the LDC's will come more from increasing yields and less from bringing new land under cultivation. The argument is that the amount of land economically suitable for cultivation is now much more limited relative to prospective demands than it was 20 years ago. The essential condition for increasing yields is that farmers increase their use of nonland inputs per unit of land, principally fertilizers, pesticides, improved seeds, water, and often machinery. The focus here, therefore, is on the conditions affecting the use of these inputs by farmers in the LDC's.

Conditions for Adopting New Technology

Three conditions must be satisfied if farmers are to increase their use of fertilizers and the other ingredients of modern agricultural technology: (i) the technology must be invented; (ii) the farmers must know how to use it efficiently; and (iii) they must have incentives to use it efficiently. Incentives are determined by the price and productivity of the technology relative to the prices of the goods it produces, by the ability of the farmer to acquire the ingredients of the technology when, where, and in the quantities he wants, and by the cost to the farmer of moving increased output to market.

The extent to which these three conditions are satisfied depends on the institutional structure within which the farmer lives and works. The more this structure encourages the flow of resources into development of and dissemination of knowledge about new technologies and strengthens farmers' incentives to adopt them, the faster will be the pace of agricultural development. Viewed in this way all obstacles to technological advance are institutional and all institutions may in principle be limiting. It is unlikely, however, that at any given time and place all institutions will be equally limiting. This suggests that a fruitful point of departure in assessing the ability of the LDC's to accelerate the growth of food production is to seek to identify the set of institutions most likely to limit the adoption of new technologies.

Search for Institutional Limits: The Problem of Theory

The search is greatly complicated by the lack of an adequate theory of the relation of institutions to technological change. All students of the subject agree that the relation is important, and probably most would agree that it is reciprocal, institutions serving to limit the pace of technological change at any given time and themselves undergoing modification over time under the impact of new technology. This view underlies all the work of Veblen and of his intellectual heirs among the institutional economists. A similar theory, and with specific reference to agriculture, has been developed more recently by Hayami and Ruttan (1) building on earlier work by T. W. Schultz (2). In this argument the development of new technology is the sine qua non of the breakout from agricultural underdevelopment. Without new technology, attempts to stimulate agriculture through reform of other institutions such as those relating to land tenure, extension, education, factor and product markets will avail little because the economic return to farmers of these reforms will be low. With respect to land tenure reform, for example, Hayami and Ruttan (1) assert that it had little impact in stimulating agricultural modernization in the 1950's and 1960's and attribute this to the fact that, in the absence of appropriate technologies, the economic returns to reform were insufficient to induce the political effort needed to make it effective (1, p. 263).

The Hayami-Ruttan theory that new technology creates a demand for institutional change by opening up productive opportunities unrealizable without such change is persuasive. The theory falters, however, in explaining the institutional supply response. The reference to political effort needed to achieve effective land reform suggests the surce of the problem. That some minimum political effort was needed to achieve the reforms required to exploit new technological opportunities implies that some social group, namely, those to be "reformed," saw the new technology not as an opportunity but as a threat. Hence they resisted, as indeed they continue to resist in many parts of the less developed world. It follows that a fully adequate theory of the relation of technological and institutional change must include an account of how the resistance of those who stand to lose from change is somehow overcome.

Since no such theory presently exists, the search for institutional limits to technological advance in the LDC's over the next several decades must be halting and the conclusions tentative. I believe, however, that available theoretical and empirical materials are sufficiently strong to support some useful speculation. The focus is on the near-to-medium term—say to 1985—because this is the period of most immediate present concern. However, the concluding remarks contain some comments about the longer term situation.

Categories of Institutional Limits: A Question of Priorities

In my judgment institutions affecting farmers' incentives to innovate will be more important than those affecting the supply of new technology or the technical abilities of farmers. There appears to still be considerable potential for expansion of production based on the technology underlying the Green Revolution. The key ingredient in this technology is the high yielding varieties (HYV's) of wheat and rice. There is reason to believe that, with the HYV's now in use or under development in the various national and international research centers, large additional increases in production can be obtained, both by planting more acres to these varieties and by increasing their yields on land where they already are used.

Dalrymple (3) indicates that in non-Communist Asia in 1972-1973 roughly 35 percent of the land in wheat and 20 percent of that in rice was in the HYV's. In Mexico almost all wheat land was in HYV's (rice being relatively unimportant), but in the rest of Latin America and in Africa the area sown to these varieties was relatively small. So far, the adoption of the HYV's, particularly in India and Pakistan, has been rather highly concentrated in certain areas. The reason, however, seems to be availability of irrigation rather than limits to the adaptability of the varieties which, according to one observer, have been "surprisingly wide" (4). The international research institutes continue to develop new varieties adapted to an increasing range of climatic and soil conditions, and they are giving high priority to support of the national research programs needed to produce even more location specific varieties (4). Some of these national programs already are strong, for example, almost all the HYV's of wheat and rice now grown in India were adapted by Indian research (4).

The potential from higher yields on lands already planted to the HYV's also looks promising. In the Philippines, even before the Green Revolution varieties became available, under fully irrigated conditions, average yields of rice often exceeded 3.0 metric tons in the wet season and 3.5 metric tons in the dry season (5). On farms participating in contests or under experimental conditions the figures for comparable yields for wet and dry seasons range from 4.0 to 4.5 metric tons to 5.0 to 6.0 metric tons. In recent years, the ceiling yields, under ideal conditions, have risen to about 8 to 10 tons. But at any given time yields on the average farm will never equal those achieved under experimental conditions. However, much of the difference is attributable to the average farmer's limited access to a controlled water supply and to the price and availability of fertilizers and pesticides. These conditions reflect institutional limitations affecting farmers' incentives rather than technological limitations. If incentives can be improved, the technology will permit average yields for the HYV's considerably above those now achieved.

The principal reason for believing that the technical ability of farmers will not be a major limiting factor over the next 5 to 10 years is the speed with which the Green Revolution spread and the demonstrated ability of small, poor farmers to use it effectively. Hertford's work on Mexico shows that, where irrigation was available and other conditions for adoption were favorable, the ejidatarios, beneficiaries under Mexico's land refrom program, shared substantially in the rapid spread of new technology among Mexican farmers over the last several decades. The ejidatarios achieved this despite the fact that their farms were on average small (about 15 acres in 1960), their soils were generally of poorer quality than on private farms, their formal education was scant (average of 3.4 years in 1965), and most of them lacked farm management experience before receiving land (6, pp. 7, 40, 41). A study sponsored by the International Rice Research Institute (IRRI) (7) indicates a similar capability of small farmers in Asia to adopt and profit from the new rice technology where irrigation was available and input and product market conditions were favorable. Other studies point to the same conclusion (8, 9).

The evidence on the ability of small farmers in Mexico and Asia to employ and profit from HYV technology should not be interpreted to mean that managerial capacity of these farmers is generally high. It does suggest, however, that lack of managerial capacity has not been a major factor so far in limiting the spread of the new technology. There still are millions of farmers in the LDC's as yet untouched by the Green Revolution. I suggest this has more to do with their lack of incentive to adopt the new technology than with their technical ability to use it productively.

Incentives

It sometimes is argued, although less frequently now than a decade ago, that because of the force of tradition, farmers in the LDC's will not respond to new technology, even when it is available on favorable terms and they know how to use it. In my judgment the evidence is overwhelmingly against this view. There is not space here to develop the counter argument. For some representative sources see (1, 6, 10).

Input-output price relations. Future food prices in the LDC's will depend on the growth of demand as well as on government policies. With population expected to grow at 2.7 percent annually, per capita income growth of 2.5 percent, if widely shared, could provide steady long-term annual growth in food demand of 3.5 to 4.0 percent, well above the historical growth of food production in the LDC's and enough to provide strong positive incentives to invest in new technology. Whether per capita income grows at the indicated rate will depend in part on the success of agriculture, but also very much on the entire development effort in the LDC's, a theme beyond the scope of this article. The point of interest here is that the growth in demand for food should be sufficient to support attractive prices for farmers if overall growth targets are achieved. In the past many governments in the LDC's have attempted to repress food prices to hold down the cost of living. Persistence of such policies could weaken the incentives farmers otherwise would receive from healthy growth in demand for food.

High prices of key modern inputs may be a more serious obstacle to continued expansion. About one-third of the fertilizers consumed by the LDC's (one-half excluding the Communist countries of Asia) are imported. These countries have been hard hit by the sharp increases in fertilizer prices in the last few years. A recent study (11, p.62) suggests that fertilizer prices may decline over the next decade as new capacity comes on line. This assumes, however, that the LDC's themselves will achieve sizable increases in fertilizer production, a matter treated below.

The LDC's clearly are not going to have much leverage on world fertilizer prices over the next decade, and except for those few included in OPEC (Organization of Petroleum Exporting Countris), they will have even less on energy prices, also significant because of the importance of petroleum in fueling tractors and driving irrigation pumps. The high price of fertilizer is primarily due to the uneven pace of capacity expansion in that industry rather than to institutional obstacles. The present price of energy, on the other hand, clearly reflects the power of OPEC as an institution. The significance of OPEC and its policies is not limited, howevre, to their effects on the costs to farmers of energy and fertilizer. Because of high prices, petroleum now absorbs a much greater proportion of foreign exahange than before, thereby limiting the capacity of the LDC's to import fetilizer and other modern farm inputs.

Availability of inputs. Increased domestic production of fertilizer and other inputs would be one response to the reduced ability to import, and many of the LDC's already are moving in this direction. In doing so, however, they face a number of obstacles, some of which appear to be institutional. Lead times for bringing new fertilizer capacity on stream have generally been longer in the LDC's than in developed countries, and capacity operating rates have been lower. As a consequence both capital and operating costs in the LDC's are higher (12). Fertilizer production is capital-intensive and complex, requiring high levels of technical and managerial skills to achieve efficient operation. Shortage of these skills may be one of the important reasons why the efforts of the LDC's to expand low cost fertilizer production have faltered.

Pesticide capacity in the LDC's is low relative to demand. Although plans to increase capacity are not known, it seems unlikely that domestic production of pesticide ingredients will satisfy more than a small, if rising, proportion of total demand over the next decade. Seed production capacity may also pose a problem. Few of the LDC's have a highly developed seed industry, leading the Food and Agriculture Organization to suggest that lack of a commercial supply of high quality HYV's has been an important factor limiting the spread of the Green Revolution.

Marketing. Institutions linking the farmer to suppliers of his inputs and final consumers of his products can also have important effects on his incentives. The operation of input and product market market institutions in the LDC's has been little investigated, in the case of inputs perhaps because their use in large volume is relatively recent. At a very general level, the rapid spread of the Green Revolution could be taken as evidence that, although we know little about the performance of these institutions, it appears to have been good. The fast increase in acreage planted to HYV's already has been noted. Fertilizer consumption in the LDC's grew at an average annual rate of almost 14 percent between 1961 and 1963 and 1972 to 1973. Less is known about the growth of pesticide consumption, but apparently it lagged not far behind the rate for fertilizers (13, p. 39). These are very fast rates of increase, comparing favorably with the experience of any of the developed countries at similar stages of agricultural development. They suggest that, however primitive input marketing institutions may have been, they worked.

With respect to institutions marketing farm products, a study by Hayami and Ruttan (1, p. 267) of rice and corn marketing systems in Southeast Asia showed that the system was very effective in transmitting information between producers, wholesalers, and retailers. Hayami and Ruttan cite other studies to the same effect, and conclude that the elasticity of supply of services in these markets was high (1, p. 267).

Other recent work supports this view. In Sonora, Mexico, urban based marketing of farm inputs and products expanded rapidly in response to the growth and modernization of agriculture there (14). Most of the expansion of the marketing activities was in private hands and was "spontaneous," that is, not planned or directly supported by government. The principal public role was to develop the technology on which agricultural development was based, to provide large supplies of irrigation water and a road-rail network linking the state with principal markets in Mexico and abroad, and through imports and domestic production to assure an adequate supply of attractively priced fertilizers, pesticides, and other modern inputs.

Gibb (9), in a study of central Luzon, Philippines, where the Green Revolution was widely adopted, found rapid expansion of both input and product marketing services provided to farmers. He concluded that the expansion was a response to the increased demand for these services following adoption by farmers of the new technology. Private initiative was the motive force for the growth of these services, the role of government apparently being similar to that in Mexico.

Analyzing the experience of the Pakistan Punjab in the second half of the 1960's, Child and Kaneda (15) found rapid growth of small-scale industry providing diesel engines, pumps, and other hardware to farmers in that region. The growth was a response by private initiative to the spread of the Green Revolution and the associated increase in demand for tube wells and equipment. Development was spontaneous, with no subsidies, no tax concessions, no special credit arrangements, and no technical assistance.

Credit. The failure of credit institutions to provide adequate financing to farmers, particularly small farmers, is frequenty cited as a major obstacle to the adoption of new technology. There is no question that adoption requires increased funds to purchase the needed inputs. It is also clear that formal credit institutions discriminate against small farmers in allocating loans. What is not clear is whether the elasticity of the supply of funds is as low as commonly thought. Hayami and Ruttan (1) cite evidence from the Philippines, Taiwan, and Korea which shows, in their judgment, that the elasticity of supply of rural savings has been grossly underestimated. They argue further that concern with formal credit institutions has led to underestimation of the importance of informal credit sources: suppliers of inputs or purchasers of outputs, friends, relatives, or local moneylenders. The IRRI study (7) also turned up evidence of the importance of informal credit sources despite increased government efforts in each of the six countries to strengthen formal credit institutions. The author of the study found that credit was a constraint in many places, but drew no conclusions concerning its importance relative to other constraints.

Land tenure. Probably no institution has been more written about as an obstacle to technical progress in agriculture in the LDC's than systems of land tenure. The argument takes a variety of forms, but the common core is that in largely rural societies control of land conveys political power and that this power is used to shape the whole structure of a nation's agricultural policies and institutions to favor the interests of large landowners (1, 16). Obviously these interests, as the large landowners perceive them, are not necessarily those of small farmers or of the nation as a whole. While the large farmers may have been innovative, they have tended to adopt capital intensive technologies, even though in the LDC's rural labor is abundant and capital scarce. Moreover, the structure of policies often has weakened the incentives of small farmers to innovate.

There is no question that these arguments about land tenure systems as obstacles to technical change in LDC agriculture have weight. The problem is that their weight varies from place to place and time to time in imperfectly understood patterns. A number of countries that have made significant progress in agriculture, for example, Taiwan in the postwar period, and Mexico, also have had significant land reforms. Howerer, Taiwan also enjoyed impressive technical progress from the early 1920's until about 1938, before the land reform (5). Hertford (6) credits the Mexican land reform as an important factor in Mexico's good showing, but he points out that irrigated ejidos have performed much better than those lacking irrigation. Then, of course, there are countries, or parts of countries, where substantial technical progress has occurred in the absence of significant land reform, for example, India, Pakistan, the Philippines, and Thailand.

We have too little understanding of the relationship between systems of land tenure and technological innovation to predict how important present tenure systems may be as obstacles to future technical progress in LDC agriculture. That they may impede progress seems certain, but it is equally certain that land tenure reform is not a generally necessary condition for innovation. This discussion of land tenure systems thus ends on a note of uncertainty. I will return to it briefly in some concluding comments below.

Irrigation institutions. It is a commonplace that irrigation is a key ingredient in the Green Revolution technology. The institutions determining the availability of irrigation water to farmers in the LDC's may increasingly impede the rate of technical innovation in those countries. The institutions are of two general sorts: (i) those concerned with mobilization of the resources needed to increase the supply of irrigation water, and (ii) those concerned with the allocation of water to farmers and their management of it. I will call these irrigation building and irrigation management institutions, respectively. By and large, irrigation building institutions have performed better than irrigation management institutions. Investment in irrigation projects in arid zones of Asia, Latin America, and Africa increased rapidly in the decades after World War II with corresponding increases in the amount of land at least nominally irrigated. The management of these projects, however, has frequently been inefficient in two senses: (i) the amount of land actually receiving water is a small proportion of the design amount (17), and (ii) the productivity of the water received bears little relationship to its social cost (18, 19).

The reasons for these inefficiencies are complex, but a major element is that the management of large irrigation projects is generally in the hands of public officials who are too far removed from the on-farm situation to know the conditions of efficient use, who lack economic incentives to achieve it even if they knew how, and who typically are bound by inflexible operating rules of water allocation impeding their response to economic incentives even if they had them. The inflexibility of operating rules is the most obvious of these limitations and in itself would be sufficient to explain inefficient use of water (18, 19). The institutionalized rigidities in irrigation management systems may become increasingly important obstacles to the spread of new agricultural technology. More land clearly will have to be brought under irrigation, but the real costs of doing so by building new projects is likely to be far higher than in the past. For example, existing irrigation works in Southeast Asia are inadequate to support the continued rapid spread of the Green Revolution; because the terrain in the principal rice-growing regions is characterized by broad river valleys and plains, particularly large investments in storade, transportation, and drainage works will be required (5).

There is much evidence that, because of the high and rising costs of building new irrigation projects, the payoff to improved management of existing ones will look increasingly attractive (13). It is difficult, however, not to be pessimistic about the likelihood that significant improvements in irrigation management institutions in the LDC's will be achieved. These institutions reflect a deep-seated view that patterns of water use hold more potential for social conflict than those of other agricultural resources; hence, water management requires a greater measure of social control. There is an important truth in this view. Unlike fertilizer or tractors, water is a moving, or "fugitive," resource. Consequently, it is difficult for any individual to establish an unambiguous property right in it, but many individuals may establish many ambiguous rights. This is the source of potential conflict.

There obviously is a case for a greater degree of social control in water management than in management of other agricultural resources. It seems apparent, however, that water managers have given far greater weight to avoidance of conflict than to capturing the full economic gains from efficient use of water. Unless there is a shift in the balance, more efficient use will not be achieved. There is no obvious mechanism by which to effect this shift since public managers would reap no direct economic benefits from improved efficiency.

Perhaps the best hope for achieving the needed institutional changes is the rising economic value of water and hence the increased payoff to improved management. This is the essence of the Hayami-Ruttan (1) theory of institutional change. Its weakness in this instance is the one noted above: Public water managers would not capture the economic gains from greater efficiency. Hence this powerful incentive to change is inoperative.

The persistence of inefficient management institutions may also be partly explained, however, by ignorance of the rising economic value of water. Since water markets are rare, there are no obvious measures of its economic value. The increasing importance of groundwater as a source of irrigation may help to heighten public awareness of the value of water, however. Private initiative, for example, in the Punjab region of Pakistan and India, has played a far greater role in development of groundwater than of surface water. So far as I know, studies have not been made of the cost to farmers of this source of water, but it must have been greatly above the charges for water from publicly managed surface systems. That the investments were nevertheless undertaken indicates that the value of the water obtained was well above the prices charged for surface water. If private development of groundwater continues perhaps the significance of this fact will eventually heighten public awareness of the high value of irrigation water and hence of the payoff to improved efficiency in water management.

Development of groundwater deserves more attention in its own right. A recent survey stressed the advantages of groundwater because its social costs generally are lower than those of surface systems (13). The much greater role possible for private initative also makes groundwater development look attractive because it avoids the institutional rigidities built into surface management systems. It is noteworthy that the tube well phenomenon in the Punjab penetrated even into areas with well-developed surface irrigation systems, quite possibly because the tube well gave the farmer command over a reliable supply of water when and in the quantities he wanted, something the publicly managed surface system did not provide (19).

A strategy giving increased emphasis to groundwater development thus may be the most promising way for reducing the now powerful institutional obstacles to more efficient irrigation management. Not only would it reduce the relative importance of rigidly managed surface irrigation systems but it culd also serve to heighten public awareness of the rising ecconomic value of water, thus generating pressure to move those systems toward greater efficiency.

Conclusions

It was argued that over the near-to-medium term—roughly to the mid-1980's—there is enough potential for growth existing Green Revolution technology and in technical capacity of farmers that institutions affecting these two sources of increased food production probably will not be seriously constraining. The principal bottlenecks likely will be found among those institutions affecting farmers' incentives to innovate. There is impressive evidence that when other conditions for innovation are favorable the supply of marketing services, for both inputs and outputs, is quite elastic. This seems to include the supply of funds from rural saving and informal credit sources, although the evidence is less clear in this respect.

The situation concerning price relations and availability of inputs appears mixed. If national income growth targets are achieved, then the growth in total demand for food in the LDC's should be fast enough to support incentive prices for farmers. This advantage could be lost, however, if governments adopt policies to suppress food prices to keep down the cost of living. The price of fertilizers is expected to fall from the high levels of 1974, the amount of the fall depending in good measure on the success of the LDC's in increasing fertilizer production. Historically, their efforts to expand capacity have been relatively inefficient. Moreover, many countries still lack adequate capacity to produce the HYV's and pesticides.

Even with good progress in expanding domestic production of inputs, imports will continue to be an important source of supply. Maintenance of present high prices of petroleum products could be a major obstacle to financing these imports on the necessary scale because of the drain it would place on available foreign exchange. I conclude, on balance, that prices and availability of fertilizers, pesticides, and seeds could have important negative effects on farmers' incentives to adopt Dreen Revolution technology.

Rigidities in water management institutions may be even more limiting, for reasons noted in the previous section. The role of existing land tenure institutions is not clear. The tentative conclusion, however, is that over the near-to-medium term the maintenance will not be a major obstacle to further spread of the Green Revolution. Over the longer term, it could become more seriously limiting. The reason is that continued expansion of food production will eventually require the invention and adoption of new technologies and a higher level of technical and managerial skill than most farmers in the LDC's now possess. To do this will require substantial investments in domestic research and extension institutions and in rural education. In countries where a small class of large landowners wield substantial political power, these investments may not occur on the necessary scale because the large farmers have their own means of acquiring the technology and little perceived interest in supporting the upgrading of the skills of small farmers.

This review of institutional obstacles to expansion of food production in the LDC's must end on a tentative note. The review does suggest some observations about the process of institutional change, however. There is impressive evidence of strong latent potential in the private sector of the LDC's for mobilizing the resources and effort needed for agricultural progress when the private economic rewards for doing so are high. Under these circumstances, needed changes in the institutions required to mobilize the resources and direct the effort seem relatively easy to achieve. Institutional resistance is stronger in situations where influential interests perceive change as a threat or where there is no direct personal economic reward to change, as in the typical public institution.

The latter point is particularly important because the performance of public institutions is critical. Development of new technology, the fundamental condition for continued long-term growth, is basically a public responsibility because the gains from adoption usually cannot be sufficiently captured by private institutions to justify their assuming the cost. Although private firms often have incentives to impart technical knowledge to farmers as a way of widening the market for their products, the broadening and strengthening of the institutional structures concerned with both the general and technical education of farmers is a public responsibility. This is true also of the development of large irrigation systems, both because of the scale of the needed investments and the potential for social conflict in water management. The lack of a well-defined mechanism that would link responses of public institutions to the large social payoffs to increased public investment in irrigation, new technology, and technical abilities of farmers may prove in the long run to be the most important single obstacle to adequate growth of food production in the LDC's.

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Tropical Agroecosystems

These habitats and misunderstood by the temperate zones, mismanaged by the tropics.

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Tropical countries (1) have one major problem: how to evolve a social system that is tailored to the carrying capacity of a small resource base and yet have any resources left once the experiments in setting up the system have run their course. This challenge must be met in a very harsh sociobiological evironment. Some of the outstanding environmental traits of most tropical countries are (i) past and present harvest of resources by temperate zone countries at prices unrelated to the worth of the resources at their place of origin; (ii) borders established directly or indirectly by temperate zone countries that were partitioning a resource for their own use; (iii) many nearly equal and opposing pressures acting on social structures, pressures generated not so much by the immediate environment as by the hybridization of two or more social structures with radically different goals in resource use; (iv) potential and realized resources per person already lower than in most temperate zone countries; (v) current social aspirations modeled after exploitative social systems that evolved in resource-rich habitats to deal with the harvest of highly pulsed, regionally homogeneous agricultural resources; and (vi) usable productivity per unit of human effort expended that is considerably lower than that in the temperate zones.

Scientists and policy-makers in the temperate zones often express high hopes for the future productivity of tropical agriculture (2-6), but constructive criticism of tropical agroecosystems (2-24) is in a primitive state. Nearly all research in tropical agriculture is highly reductionist, parochial, and discipline-oriented. This can be quickly observed by perusal of books such as Farming Systems in the Tropics (2) and Pests and Diseases of Tropical Crops and Their Control (25), as well as tropical agricultural journals (26). Articles with a holistic approach (21, 27, 28) are a conspicuous rarity in the trade journals, with the exception of those in recent volumes of Tropical Science.

It is widely believed in temperate zone countries that tropical countries disregard the rules of sustained-yield agroecosystems out of ignorance. This condescending evaluation is sometimes correct for certain aspects of the decision-making process. However, there are many more situations in which a key manager is deliberately maximizing short-term returns at the expense of long-term returns. It is not an acceptable defense to point out that technological knowledge, whether that of the culture or of the world at large, is not immediately available to the persons carrying out the act. If the cost of making technological knowledge available were to be charged against the project, even short-term exploitation would often be uneconomical.

Short-term exploitation is conspicuous at all levels of agricultural sophistication in the tropics, except perhaps in those rare "primitive" cultures whose traditions of resource harvest are still intact (29,30). What tropical countries so rarely grasp (22) is the fact that agriculture in the temperate zone countries evolved (and is still evolving) from short-term exploitation to sustained-yield agriculture while operating off a much larger natural capital than the tropical countries possess. Furthermore, this natural capital is in part obtained from the tropics (or other "undeveloped" areas) at a cost much less than its value (31).

Short-term exploitation is particularly easy in contemporary tropical societies. Government attitudes are generally "frontier exploitative" (32), and the "tragedy of the commons" (33) is promoted by undefined ownership of resources despite the fact that much of the land has been under stable subsistence agriculture for thousands of years. The temperate zone countries have said to the tropics, "Look at all the nice cash crops you can grow for us to buy," but have neglected to teach the tropics at the same time how to preserve the natural capital and harvest its natural interest.

By assuming that technological ignorance is the sole cause of agricultural problems in the tropics, we allow this ignorance to become the scapegoat for all ills of the agroecosystem (8, 10, 12). In fact, the scientific and folklore communities know quite enough to deal with most of the technological problems in tropical agroecosystems, or if not, how to get that information. As Talbot states in his analysis of deterioration of Masai rangeland. "These adverse ecological consequences of the developments were not intentional. They were, however, anticipated, predicted, and documented by some range managers, wildlife ecologists and other biologists who knew the area" (34, p. 695). There are many examples of a disastrous tropical agroecosystem existing side by side with a highly successful one—but under a different social system (35). This strongly suggests that the social rather than technological environment is at fault in problems of tropical agroecosystems.

It is common argument that technological advance in the tropics will buy time in the war against population increase and deterioration of natural capital (5). However, there is little evidence that anything is being done with the time bought. It is of no use to fund a soil or natural resource survey for a major development scheme (36, 37) when there is a preordained number of settlers (38). I feel that the plea for technological advance gives the scientific community a perfect excuse to continue their reductionist and esoteric approaches (12, 39) rather than to put their efforts into the far more frustrating task of generating sustained-yield tropical agroecosystems and ensuring that thchnological advances are integrated with them. Few basic studies in tropical biology genuinely seek to adapt their technology and findings to the agroecosystem (40), although many of them could. A few pious sentences in the introduction (41), or the use of economically important animals in experiments, does not remove a study from the category of "biological art form." Some argue that a crisis is needed to alter the situation (42). However, like other forms of tropical change, approaching tropical crises tend to be inconspicuous and cannot be recovered from as easily as can crises in the temperate zones.

When examining the problems that confront the development of a sustained-yield tropical agroecosystem (SYTA), it is impossible to separate the biological problems of practicing agriculture in the tropics from those of inadequate education, public facilities, administration, and social aspirations. The regions under discussion are both tropical and undeveloped, and it would be a major tactical error to attribute their overall difficulties to either of these traits.

I focus on some of the areas that seem to be generally unappreciated or ignored by those in the temperate zones who influence the development of SYTA's. In most cases, there is a conflict between optimization and maximization. Reductionism is the order of the day in the contemporary forces shaping SYTA's, and descriptions and analyses of SYTA's are influneced by this philosophy. Tropical agroecosystems are characterized by attempts to maximize outcomes of single processes and the glorification of the maximization. The major challenge in the tropics today is to determine which reductionist lines of research and development should be halted or deflected in deference to optimization processes within holistically designed SYTA's.

Productivity

Net annual primary productivity may be higher in the moist, lowland tropics than anywhere else in the world (43), but what really matters in the difference between the cost of turning that productivity into human desiderata and the value of the output (11, 17, 44, 45). This difference is very poorly understood as it applies to the tropics. There is a strong tendency for tropical administrators to evaluate labor as free input, to value land only for food and fiber production, and to value products in terms of the world market rather than national life-support systems. When people in the temperate zones say (46, p. 400):

> The need is universally recognized for drastic increases in production of food and fiber to feed and clothe a rapidly expanding [tropical] population, a large percentage of which is now undernourished and poorly clothed. It is also recognized that much of the increase required must come from the intensification of agricultural production in the developing nations.

and, "A continual guarantee of increasing agricultural productivity is absolutely essential for our tropics" (27, p. 1), they forget that tropical people are no more interested in spending all their waking hours picking beetles off bean bushes and transplanting rice by hand than they are. High-yield tropical agriculture requires immense amounts of very accurate hand care (2, 47-49) or tremendous amounts of fossil fuel (50), or both.

If agricultural production costs were determined equally and fully throughout the world, most of the lowland tropics would be classified as marginal farmland. Some researchers have come to this conclusion on the basis of weather data alone (9, 19). As Paddock puts it, "The hungry nations have been and are hungry because they have a poor piece of real estate" (15, p. 898). This is well illustrated by the very high cost and slow rate of development of tropical Australia as compared with temperate Australia. Tropical Australia lacks a large, free labor force and its products are in direct competition with those of temperate Australia (9). Oddly, the temperate zones accept of nonagricultural use of marginal farmland at the national level, but not at the international level.

In the tropics, "optimum population size and optimal political area are almost irreconcilable: for a state to reach a reasonable size of population it must overpstep the optimum-area limits; for it to remain within a reasonable area means more often than not a midget population. ..." (51, p. 435). There is no biological reason that the capacity to support human life should be evenly distributed over the earth's surface, nor why it should be correlated with the primary productivity of natural ecosystems or with the biomass (standing crop) of these ecosystems.

Temperate-tropical comparisons aside, as population density and cash cropping for export increase, the use of marginal land within the tropics increases. In addition to being fragile and having low productivity, marginal farmlands in the tropics have greatly fluctuating productivity. Colonization of such areas may appear justified for several years, and during this time the invading population severs its cultural-economic connection with its homeland (18). Then when drough (18, 34), hurricane (52), or resistance to pesticides (8, 53) occurs, it is termed a "natural disaster." Because one person can be sustained at a minimal standard of living more easily in the tropics than in the temperate zones, the population in the tropics is likely to have been greater before the catastrophe that it would have been in marginal farmland in the temperate zones.

Year-Round Warmth

The year-round warmth of the lowland tropics is a mixed blessing (11). High year-round soil temperatures lead to very rapid breakdown of litter, with subsequent leaching of soil nutrients before they can be taken up by plants (54). Plant diseases breed year round (27), and pests breed freely in stored food that is not chilled by winter cold (53). In addition, stored foods degenerate rapidly because of their own metabolic activity at high temperatures. Even in areas with a severe dry season, many insect species are present as active adults; they are concentrated at local moist sites or are breeding on alternate hosts (55, 56). Insect pests are therefore available for immediate colonization of newly planted fields, even during the harshest time of year; the same is probably true of plant diseases (27). Tropical herbivorous insects are highly adapted for making local migrations (55, 56); this makes it difficult to protect crops by introducing heterogeneity of fields in time and space.

One possible remedy is unpleasant for the conservationist. The agricultural potential of many parts of the seasonally dry tropics might well be improved by systematic destruction of the riparian and other vegetation that is often left for livestock shade, erosion control, and conservation. It might be well to replace the spreading banyan tree with a shed. The tremendous number of species of insects (56) and diseases (27) that characterizes the tropics might be severely reduced through habitat destruction. This conclusion might change the policy problem to a consideration of how much land should be set aside purely for conservation; the remaining land might not even approximate a natural ecosystem (57). Some studies even suggest that "overgrazed" pastures may have a higher overall yield than more carefully managed sites (58), especially if the real costs of management are charged against the system. If one wishes a high yield from a particular site, year-round warmth necessitates complex fallow systems to deal with the weeds and insects. However, it is possible that, over large areas, a much lower yield per acre in fields under continuous cultivation could produce the same average yield per acre as fallow systems. Social complications, rather than pests, are likely to be the major barrier to experimentation leading to SYTA's based on extensive, rather than intensive, agriculture; tropical countries are conspicuously hostile to schemes requiring tight administrative control over large areas by single sources of power.

It is not only superior nutrient dynamics of the soil that cause the seasonally dry tropics to be more productive agriculturally than the wet tropical lowlands. In the ever-warm tropics, irrigating between subtropical oases (36, 59) and between wet seasons is tempting, but it eliminates the only part of the physical environment that is on the farmer's side in his competition with animals and weeds. The less extreme the dry season (or the more thorough the irrigation), the less extreme are the seasonal dips in insect pest population, with which the farmer can synchronize his crop's growth. There are numerous parallel cases between the natural communities of the tropics and those of temperate zones (60, 61).

Ecosystem Fragility

Two very different concepts are involved in the "stability" so often attributed to tropical ecosystems. On the one hand, owing to the apparent lack of variation in the weather within each year (62) and the apparently small variations in the climate from year to year, temperate zone peoples often regard the trlpics as stable. However, much of this stability is illusory (63), as any farmer on a large scale will confirm after plowing under his third attempt to grow rice on a site in the seasonal tropics where rice can be grown only in wet years.

On the other hand, the conplex biological systems of the tropical lowlands are very easily perturbed and cannot be easily reconstituted from roadside and woodlot plants and animals (20), as could many North American habitats. For this reason, the complex processes in SYTA's are likely to be highly unstable. For example, a great variety of horticultural practices and strains of common tropical food plants have accumulated over the centuries (64). They are closely adjusted to local farming conditions and coevolved with the other dietary resources of the area. When high-yield hybrids are introduced, the local strains (65) and practices (66) are quickly abandoned. This later leads to (i) expensive and complex programs to reevolve these strains when adjusting hybrid monocultures to SYTA's (65), (ii) increased dependence on pesticides and complex breeding programs to keep abreast of the pest problem in single-strain monocultures, and (iii) increased imbalance in the distribution of wealth among farmers (6, 15, 16, 22). The same may be said for the replacement of indigenous floras by foreign grasses (67) and pure stands of foreign trees (14, 68), the generation of complex irrigation system susceptible to market perturbations (69), and the destruction of adaptive village structures by population pressure (70) or cash cropping (17, 30). As mentioned earlier with respect to the pest community, one way to remove fragility is to remove complexity. However, monocultures are clearly unstable in certain circumstances (23,57, 71), at least with respect to the demands made on them.

Crops and Spacing

Long distances in space and time between conspecific plants in the lowland tropics are a major element in their escape from their host-specific herbivores (11, 13, 60, 61, 72-74). The monocultures or moderately mixed stands that characterize modern agriculture are thus a much greater departure from normal in the tropics than they are in the temperate zones. In this sense, modern agriculture removes a much greater proportion of the plant's defense in the tropics than in the temperate zones. However, as has been correctly emphasized (45, 57, 71, 72, 75), crop heterogeneity is a mixed bag.

First, there is heterogeneity among monoculture fields in time and space. Here, the benefits of heterogeneity depend on whether the vegetation that is interspersed with the crop field sustains a pest community of less risk than the benefit of the entomophagus parasites and predators it also contains. The outcome has to be determined individually for each site, and in the tropics, it may well go either way (72, 76). The efficacy of letting a field lie fallow depends also on the proximity of seed sources for wild plants (30, 77) and the value of these wild plants for other uses (78). We cannot even infer that a reduction in yield after a shortened fallow period is the result of less effective pest control (79).

Second, there is heterogeneity within the field. Often viewed as the answer for the tropics, this practice has two major problems: harvesting a mixed crop requires greatly increased labor and skill, and different crops may well require mutually incompatible treatments (48, 68, 80). Furthermore, crop plants have had much of their chemical and mechanical defense system bred out of them. For many pests, a field of or five crops may be a monoculture (13, 74).

While some of the most complex mixed cropping is in the tropics (2), the tropics also have some very successful monoculture agriculture, if human labor is not included in the cost calculation (47). Finally, in some cases in the tropics, a monoculture may have a greater productivity than mixed crops (81).

Chemical Defenses against Pests

Secondary compounds are a tropical plants other major form of defense. However, tropical crops, perhaps even more than those in the temperate zones, have had many of their internal defenses bred out of them in man's quest for less toxic or offensive food. It is almost impossible to grow vegetables in pure stands in the lowland tropics without heavy use of pesticides (11, 82). Furthermore, when there is intense selection for higher yields and other energy—and nutrient-consuming traits, the plant probably reduces its defense outlay in order to balace its internal resoure budget. "Miracle grains" may be especially susceptible to insects and disease for internal reasons, as well as their genetic and horticultural uniformity.

In the tropics, as in the temperate zones, plants' internal defenses are often replaced with pesticides. However, tropical insects should develop resistance pesticides as fast as or faster than insects in the temperate zones. One of the classic stories of mismanagement of a tropical agroecosystem is the losing battle between largescale cotton production with the aid of pesticides and the evolution of insects' resistance (53, 82, 83). The modern tropics are dotted with doomed pesticide disclimaxes requiring ever-increasing amounts of chemicals for their maintenance. Only now are the side effects being monitored for a few major crops (84).

There are several reasons to expect a more rapid evolution of a pesticide-resistant pest community in tropical agroecosystems than in temperate agroecosystems: (i) the coevolution of herbivores and plant chemistry has always been a major aspect of tropical community structure—if there is a biochemical defense genome in insects, this is probably where it is most highly developed (11); (ii) the larger the proportion of the insect community that is hit by the pesticide, the more rapidly resistance may be expected to appear (85), and in tropical communities it is commonplace for an insect that is rare in nature to be very common in adjacent fields—even the use of systemic pesticides against vampire bats (86) has his problem; (iii) if tropical insects are as localized in their geographic distributions as they appear to be, there will be less chance for dilution of resistant genotypes by susceptible genotypes from unsprayed neighboring regions (82); and (iv) in species-rich tropical communities (27, 56, 87), the pool from which resistant species may be drawn is much larger than in a temperate zone community.

Tree crops, particularly prominent in discussions of tropical agroecosystem potential (73, 88, 89), deserve special mention here. In contrast to annual plants, it is impossible to breed resistant tree strains each year in order to keep ahead of pests that are resistant to natural and artificial pesticides. Not only are the breeding times of pest and host disproportionate, but farming tree crops is a long-term investment, and the loss of a tree crop to a newly resistant pest is a much greater loss to the agroecosystem than is the loss of an annual crop.

Soils

Soils in the tropical lowlands are often a nutrient reservoir of very low capacity (54, 90, 91). Plant ash from burning, ions from the very rapid litter breakdown, and chemical fertilizers are rapidly leached from the soil if not taken up by plants. There is generally a deep layer of nutrient-poor material over unweathered rock. Chemical fertilizers are a far more complex solution than they would appear to be. Because of the high rate of leaching from the soil, fertilizers must be added in far greater amounts than are actually taken up by the plant, and this creates a pollution problem. This overdose also raises the real cost of the crop. If fertilizers are added frequently, but in small amounts, the amount of work put into the crop is greatly increased. Even less appreciated is the fact that, since the soil nutrient pool is very small, a careful balance of chemical fertilizers must be added to avoid toxicity; sulfate of ammonia, the standard nitrogenous fertilizer in much of the tropics, may be doing more harm than good in that it acidifies an already acid soil (91).

In shifting agriculture, fields are commonly left fallow after 2 to 5 years of farming. The standard explanation for this is exhaustion of the nutrients in the soil. However, the real cause is lowered yield, and pest insects and competing weeds probably contribute as much as or more than soil depletion does to lowered yield (11, 30, 92). Magnificent stands of native weeds grow in the abandoned fields—and often in fields before they are abandoned. It is a very great mistake to analyze the adaptive significance of subsistence cultivation patterns in the tropics solely in terms of soil nutrient depletion. Ruthenberg's detailed description of tropical agriculture (2) contains not one sentence analyzing pest problems. The literature of tropical agriculture is replete with fertilizer trials, and there is almost no information on the dynamics of field colonization by insect and weed faunas (93).

Heterogeneity of Pest Distribution

There are at least five major kinds of pest communities that may be encountered as background to a tropical agroecosystem. As mentioned earlier, the insect community of the lowland seasonal tropics differs strikingly from that of the lowland seasonal tropics, primarily because of the difference in intensity of the dry season in the two habitats.

The third major pest community is that of upper elevations. Cooler soils and the lower humus decomposition rates associated with them are undoubtedly partly responsibe for the higher yields per acre of fixed-field agriculture at upper elevations in the tropics [and the focus of major societies on them (94)]. However, one can not ignore the effect of cool weather in slowing the growth rates of insect and weed populations. The elevation at which this effect is maximal is a complicated function of the decline of plant photosyntheses with increasing elevation, the amount of photosynthate metabolized at night, and the growth rates of insect and weed populations. I have recently found that there are more species and a greater biomass in natural insect communities at elevations of 500 to 1000 meters than in the lowland tropics (56). This suggests that man may be able to harvest more there if he is clever about it. Ironically, it is the intermediate to high elevations that are often ignored in overall investigations of tropical productivity (95, figure 1, p. 47).

The fourth major pest community is that of tropical islands. In addition to having very few species, native insect populations on tropical islands have an amazingly low biomass (56). Aside from the obvious potential effects on natural plant community structure and decomposition (60, 96), this means that crops on islands should have fewer challenges from native pests than those on the mainland. Further, when a pest is introduced, it is unlikely to be fed on by a native entomophage. These observations speak poorly for the extrapolation of results from tropical island agroecosystem studies (97) to mainland circumstances.

The fifth major type of pest community is that produced by plants growing on very poor soils. I have recently found that animal communities in Borneo are drastically reduced when supported by tropical rain forest growing on nutrient-poor white sand soils. The conspicuous success of lowland rice monoculture in Southeast Asia may be due, in part, to a generally depauperate insect community, as compared to that of other parts of the lowland tropics.

Finally, and to put it bluntly, next to nothing is known about the losses caused by insects and weeds in tropical agroecosystems. The evaluation systems so badly needed (98) are not only difficult to develop in areas with a poorly educated population, but they may cost more in cash and complexity than the value of the crop.

Cash Cropping

One of the largest stumbling blocks to the development of SYTA's is the philosophy that cash crops, usually for export, are the best use of the land, and that subsistence agriculture [including nomadism (99)] is a nuisance that must be tolerated to feed the farmer. For example (100, p. 569):

> The basic idea behind agricultural development in East Africa has been that it must increase the cash income from the land. Development has usually meant the introduction of a cash crop, such as cotton, pyrethrum, milk, coffee or tea into a subsistence economy, and the new system is expected to increase the farmer's incomes fivefold or more.

In his 1971 text Introduction to Tropical Agriculture, designed for junior high school students in the tropics, Sutherland states, "What is wrong with subsistence agriculture is that everything that is produced is used up by the people. The people only grow what thty need" (4, p. 5). Such reductionist economics leads easily into very distorted analyses. In his detailed description of tropical farming methods in 1971, Ruthenberg provides an example (2, pp. 108-109):

> Although [alternative] practices are traditionally known, they are rately employed in farming systems where cash cropping has been introduced and where land shortage is a recent phenomenon. In many of these situations particularly in the drier savanas, gullies increase rapidly in number and size, soil conservation usually being neglected as cash cropping and incomes per head increase, mainly because of the unfavorable short-term input-output relationship of the labor invested. The wav out of this undesirable situation probably does not lie in a return to traditional agricultural methods, but in additional cash cropping which, by changing the economic setting can make soil conservation economically worthwhile.

It is repeatedly stated that tropical staples are ignored in research programs (101), while export props are studied extensively. Some cash cropping is necessary for a country's SYTA, but when the crop is grown for export there is often a large social cost that is not charged against the product. When crops are grown in plantationsize stands, often to generate the crop uniformity desired by temperate zone markets, it disrupts the local agroecosystem. Farming peoples are lured from small holdings by wages and then are unable to return to their land when prices drop or disease eliminates the crop from the area. They cannot return because others have taken over their land, closely adapted seeds and stocks have been lost, sites have degenerated for lack of close care, details of farming the site have been forgotten, and the people are psychologically habituated to the things money can buy. Families on wages set the size of their families by the amount of cash coming in, rather than by the amount of land (homesteads) available and the multitude of other natural systems regulating population. This removes one of the main feedback loops in population control; large tropical families are often the result of planning rather than ignorance of birth control mechanisms.

Subsistence farming of steep slopes and other marginal farmlands is commonly the result when large commercial establishments own or control the best land (18). For example: "Whereas smallholders usually have to operate where they are settled, and adapt to the natural habitat, and are thus compelled to diversify production, the firm [engaged in cash farming] can select the most favorable economic and natural location, which is chiefly on land suitable for monoculture" (2, p. 194).

As cash cropping becomes a larger proportion of the total production of an area, there is generally a decrease in the variety of crops the farmer can grow and still mesh with the community's or world's plans for development (15, 102). The sensitivity of tropical crop monocultures to economic perturbations is well known (2, 23, 73). Demand for labor and machinery becomes highly pulsed, and production may be limited by the cost of manintaining people and draft animals between periods of maximum need (2). The more pulsed the labor demand, the less possible it is to execute the complex crop timing required to generate high yields. (Experiment stations can produce high yields by virtue of large labor, fossil fuel, and pesticide supplies for their small plots.) As the agroecosystem turns entirely to cash crop production, there is no upper limit to the security desired by the farmer, and the tendency to mine the soil and then move elsewhere becomes overpowering (103). Ultimately, the country may find itself in the position of having very little idea of the real value of its farmland in supporting its people on a sustained-yield basis, as their incomes are set by the taste and biochemical whims of the temperate zone countries. One of the major reasons that species-rich neotropical rain forests are not harvested for export as a mixed-species sustained yield, as is done by the African Timber and Plywood Company in Nigeria, is that the North American markets are not willing to accept the large variety of wood types that European markets will accept.

Political Expedience

Although seldom openly acknowledged, much of the motive for governmental manipulation of tropical agroecosystems is political. Occupancy implies ownership; an argument for development of the Australian tropics appears to be the irrational notion that occupancy will decrease the likelihood of its being invaded (9)— and this is not an uncommon sentiment with respect to the agricultural development of the Amazon basin. Farming is a job that many administrators assume can be done well by anybody (18); agrarian resettlement programs in the tropics commonly have as a driving force the need to quiet restive slum dwellers or starving farmers on marginal land during droughts (38). Fragmentation of large landholdings after revolutions need not be the best use of that land, even for a highly nationalized agroecosystem. Experiment stations tend to be political footballs, with the maximum life of an experiment limited to the amount of time between major elections (18, 104).

When farming populations are displaced even short distances, their age-old farming traditions often do not function well, and the reeducation programs generated by governments are notorious for technological and psychological insensitivity (18). The displaced smallholders are poor farmers, and it is often concluded that the smallholder is incapable of farming the tropics. For example, to make census-taking easier, the government of Sarawak forced the Iban upland rice farmers to live in village (longhouse) units of ten or more families, which increased rates of land degradation near the village and decreased crop protection at greater distances from the village (30). The people displaced by hydroelectric impoundments are usually relocated in areas where their age-old riparian farming traditions are of little use; the people downstream are of even less concern (8, 18). The following is a representative story (105, p. 597):

As part of an attempt to introduce cashcropping to the district, the Zande Scheme opened in the 1940's with the commissioner resettling five thousand homesteads in the Yambio area. The theory was that the cotton-producing scheme would be more successful if the supervision were easier. Ultimately 40 thousand families were resettled, almost the entire population. The cotton crop was a success for the first few years and the yields were high, but after three years of operation the production dropped off markedly. Force was then applied to attain the desired production levels and the Azande became plantation "peons" instead of the prime actors in a great drama of the advance of the stone age.

This would appear to be only quaint history today, but in fact it would probably be impossible to fit this population back into the tightly integrated local ecosystem they once occupied, and such settlement programs are currently in progress elsewhere (89).

Interference by the Temperate Zone

Can SYTA's really be developed if new traditions are constantly being bombarded by innovations from other social systems? Well-meaning persons are constantly injecting fragments of temperate zone agricultural technology into the tropics without realizing that much of the value of these fragments is intrinsic not to the technology, but rather to the society in which that technology evolved. Temperate zone countries tend to give "aid" in forms of which they have an excess, or in forms that will benefit their foreign trade (24). The Peace Crops, military bases, tractors, miracle grains, grain surpluses, hydroelectric dams, and antibiotics without birth control are a few examples. More often than not, these acts are simply modern versions of buying Manhattan for a few trinkets. That the tropical country "cannot resist" these gratuities is hardly justification for giving them. There appears to be no moral code for the injection of temperate zone technology into the tropics (106). Although DDT is banned in the United States, it is freely exported to the tropics. American cigaretts are sold in Central and South America without cancer warning labels. By eradicating tsetse flies, we encourage the raising of cattle in preference to wild game animals, the harvest of which may have been conducive to an SYTA. In the long run, modern drugs without concomitant birth control will take more lives than they save and will lead to a long-range lowering of health and standard of living.

A major force in tropical agro-eco-systems is "international development," as exported by the temperate zones. It is "a nebulous term, and its meaning seems to reflect the opinion, interest and profession of the beholder" (107). An important aspect of international development is illustrated by the following comments on irrigation, which apply equally to other areas (107):

Many development projects, whether in Australia, Massiland, Saudi Arabia, or Rhodesia, fail because they do not take this question of carrying capacity into consideration. Water is provided perhaps, and the land is thus enabled to support more animals and people. But seldom is provision made to hold populations at the new levels that land can support. *In consequence, the land deteriorates, deserts spread or become more barren, and a greater number of people end up worse off than they were before development of the area took place* [italics added]. One can question whether international development agencies should continue to play this losing game.

Conclusion

I have listed some of the ways in which the lowland tropics are not such a warn and wonderful place for the farmer, some of the reasons why it may be unreasonable to expect him to cope with the problems, and some of the ways in which the temperate zones make his task more difficult. The tropics are very close to being a tragedy of the commons on a global scale (69, 103), and it is the temperate zone's shepherds and sheep who are among the greatest offenders (31). Given that the temperate zones have some limited amount of resources with which they are willing to repay the tropics, how can these resources best be spent? The first answer, without doubt, is education, and the incorporation of what is already known about the tropics into that education. Second should be the generation of secure psychological and physical resources for governments that show they are enthusiatic about the the development of an SYTA. Third should be support of intensive research needed to generate the set of site-specific rules for specific, clearly identified SYTA's.

The subject matter of youths' cultural programming is presumably determined by what they will need during the rest of their lives. A major component of this programming should be the teaching of the socioeconomic rules of a sustained-yield, nonexpanding economy, tuned to the concept of living within the carrying capacity of the country's or region's resoures. In corporating such a process into tropical school systems will cause a major upheaval, if for no other reason than that it will involve an evaluation of the country's resources, what standard of living is to be accepted by those living on them, and who is presently harvesting them. Of even greater impact, it will have to evaluate resources in terms of their ability to raise the standard of living by

Y amount for X proportion of the people in the region, rather than in terms of their cash value on the world market.

For such a change to be technologically successful, it will require a great deal of pantropical information exchange. This information exchange will cost a great deal of resource, not only in travel funds and support of on-site study, but in insurance policies for the countries that are willing to take the risk of trying to change from an exploitative agroecosystem to an SYTA. For such an experiment to be sociologically successful, it will require a complete change in tropical educational systems, from emphasizing descriptions of events as they now stand, to emphasizing analysis of why things happen the way they do. This will also be very expensive. not only in retreading the technology and mind-sets of current teaching programs, but in gathering the facts on why the tropics have met their current fate.

There is a surfeit of biological and agricultural reports dealing with ecological experiments and generalities which suggest that such and such will be the outcome if such and such form of resource harvest is attempted. It is clear that human desiderata regarding a particular site are often radically different from the needs of the "average" wild animals and plants that formed the basis for such experiments and generalities. A finely tuned SYTA will come close to providing a unique solution for each region. The generalities that will rule it are highly stochatic. The more tropical the region, the more evenly weighted the suboutcomes will be, and thus the more likely each region will be to have a unique overall outcome. For example, it is easy to imagine four different parts of the tropics, each with the same kind of soil and the same climate, with four different, successful SYTA's, one based on paddy rice, one on shelterwood forestry, one on tourism, and one on shifting maize culture.

A regional experiment station working holistically toward an SYTA is potentially one of the best solutions available. As currently structured, however, almost all tropical experiment stations are inadequate for such a mission. Most commonly they are structured around a single export crop such as coffee, sugar, rubber, cotton, cacao, or tea. A major portion of their budgets comes directly or indirectly from the industry concerned. This industry can hardly be expected to wish to see its production integrated with a sustained-yield system that charges real costs for its materials. When an experiment station is centered around a major food crop, such as rice or maize, the goal becomes one of maximizing production per acre rather than per unit of resource spent; this goal may often be translated into one of generating more people. More general experiment stations tend to be established in the most productive regions of the country and, therefore, receive the most funding. Such regions (islands, intermediate elevations, areas with severe dry seasons) need experiment stations the least because they can often be successfully farmed with only slightly modified temperate zone technologies and philosophies. The administrators of tropical experiment stations often regard their jop as a hardship post and tend to orient their research toward the hand that feeds them, which is certainly not the farming communities in which they have been placed.

The tropics do not need more hard cash for tractors; they need a program that will show when, where, and how hand care should be replaced with draft animals, and draft animals with tractors. The tropics do not need more randomly gathered, esoteric or applied agricultural research: they need a means to integrate what is already known into the process of developing SYTA's. The tropics do not need more food as much as a means of evaluating the resources they have and generating social systems that will maximize the standard of living possible with those resources, whatever the size. The tropics need a realistic set of expectations.

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Sprinkler Irrigation for Water Conservation in India

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Agriculture is important to the economy of India. Irrigation plays an important role in India's agricultural production. Our method of irrigation should be such as to promote the fullest utilisation of limited water available in the coutry. Large quantities of water harvested from water sheds, pumped from ground water sources, etc., are lost by seepage and evaporation from tanks, canals, distributories and field channels. Inadequate or improperly dasigned field irrigation systems and uncontrolled water application methods are leading to huge losses of water by seepage and deep percolation below the crop root-zone. Seepage and deep percolation represents the loss of a valuable resource developed at a very high cost. In many cases not only is the loss of water of concern but the damage it creates by the accumulation of harmful salts and water logging is considerable.

Sprinkler Irrigation System

Sprinkler irrigation is a method of applying rain upon the land, when it is needed. A sprinkler irrigation system applies the right amount of water in the right place, at the right time, yet requires less water than surface irrigation methods. Water is conveyed under pressure through pipes to the area to be irrigated where it is discharged out through sprinklers. Based on portability, sprinkler system is classified in the following types: Portable system, semi-portable system, semi-parmanent system, solid-set system, and permanent system. Most of the systems working in India are portabls. Indian farmers prefer portable irrigation system it being more economical in initial investment. Moreover, it gives them opportunities of utilising available man-power on farm and flexibility in operation.

The cost of installing a portable sprinkler system works out to Rs. 1,400.00 to Rs. 1,800.00 per acre, depending upon the location of water supply and size of farm. The system comprises of four parts—(I) Power Generator, (II) Pump, (III) Pipe line and (IV) Sprinkler. The power generator may be electrical or mechanical. The pipe consists of two sections, the main line and laterals. The main line may be permanently buried underground or may be laid above the ground if it is to be used on a number of fields. The laterals are light weight aluminium pipes and are generally portable. The sprinklers are mounted on riser pipes attached to the laterals. Sprinklers are so spaced as to apply water in overlapping circular patterns. When one strip of land has been sufficiantly moistened, these portable aluminium lines are moved laterally to an adjoining strip until the entire area has been covered. Lateral lines may be moved from one location, or set, to another by farm labour.

Utilization of Sprinkler Irrigation System

Sprinkler irrigation can be used for almost all crops (except rice and jute) and on nearly all soils. Sprinkler irrigation is most desirable in areas having limited water supply and high cost of water. Sprinkier irrigation is particularly suited to coarse and sandy soils where percolation losses from surface irrigation are very high and also where frequent light irrigation is required because of the poor water holding capacity of the soil. This new technique is most economical where land is undulating or sloping and the cost of levelling is very high. Sprinkler irrigation can be used on extremely flat lands where drainage is difficult. Experience proves that sprinkler irrigation offers many advantages. As compared to conventional surface irrigation methods, sprinkler irrigation when properly applied has:

Photo.1. Application of Fertilizer Through Sprinkler Irrigation System

1. Increased land use efficiency.
2. Reduced harmful effects of soil crusts around the plant.
3. Reduced quantity of water applied to irrigate plants.

But a sprinkler system is more than a way to save water. It provides greater control on the crop's total growing environment. The single-use concept of sprinkler system for irrigation only has been replaced by the multiple use concept where fertilizers and other chemicals are being applied through the system with the irrigation water.

Saving of Water by Sprinklers

In order to determine the extant of water saving by sprinkler irrigation, several experiments were conducted in different parts of India. The extent of water saving attained by sprinkler irrigation as compared to conventional surface irrigation is given in the **table 1**:—

It is very clear from the experimental results that sprinkler irrigation is advantageous from the stand point of view of reduced water application, i.e. saving of water from 20% to 60% and consequently enlarges the command area of water source by 25% to 150%. It has been established that sprinkler irrigation system helps in improving the utilization of irrigation water from existing facilities to increase agricultural productivity.

Sprinkler Irrigation for Food Crops in India

Table 1

Sl. No.	Place of Experiment	Crop	Water saved	Consequential increase in command area.
1.	Chipima (Orissa)	Groundnut	25%	33%
2.	Coimbators (Tamil Nadu)	Cotton	20—30%	25—43%
3.	Delhi	Potato Tobacco	40%	67%
4.	Kharagpur (W. Bengal)	Potato	60%	150%
5.	Krishnarajasagar (Karnataka)	Wheat	35%	54%
6.	Kudimianiatar (Tamil Nadu)	Groundnut	36%	56%
7.	Ludhiana (Punjab)	Wheat	43%	75%
		Maize	47%	89%

Sprinkler irrigation was introduced in our country during early fifties. Initially, the sprinklers were used on high value plantation crops such as tea, coffee, chicory, cardemom and orchards. Today, more than 1000 plantations in various parts of the country are already using sprinkler irrigation system successfully. Use of sprinkler irrigation is gaining popularity on food crops, cotton, sugarcane, and vegetables in areas where sprinkler irrigation is economically justified and technically feasible.

Till 1970, there were only a few wheat fields under sprinkler irrigation. Today, you will not travel far in the wheat and gram producing areas of Jabalpur and Narsinghpur in Madhya Pradesh, without seeing a farm with sprinkler irrigation system installed. More than 40 sprinkler systems covering approximately 1500 acres are working extremely well at a farm near Haushangabad. This farm is under the Management of M.P. Agro-Industrial Development Corporation and according to the Farm Manager, they have achieved excellent results from the fields which are under sprinkler irrigation.

The growth of sprinkler irrigation in the Haryana State has been much more dramatic than the other States. More than 125 sprinkler irrigation units had already been installed in the sandy belt of Bhiwani, Jhajjar and Narainagar. The Haryana Government proposes to finance 1600 sprinkler irrigation units in the sandy and sub-mountain areas of the State at a cost of Rs. 3.38

Photo.2. Sprinkler Irrigation System Working in a Wheat Field Near Jabalpur (M.P.)

crores. Besides this, Haryana State Tube-wells Minor Irrigation Corporation has already installed 31 sprinkler units on shallow tubewells and they have undertaken a very ambitious project of raising a poultry of sprinkler systems on tube-wells.

Pongalur River Pumping Co-operative Society in Tamil Nadu has undertaken a big project to bring about 8000 acres of dry land under sprinkler irrigation, out of which, an area of 400 acres has already come under irrigation for raising groundnut crop. Various other Co-operative Sosieties in Tamil Nadu have been incorporating sprinkler irrigation systems in their lift irrigation schemes. The Minor Irrigation Department of Karnataka State is planning of incorporating installation of sprinkler irrigation systems in their various lift irrigation schemes.

Sprinkler irrigation in States like Kerala, Andhra Pradesh, Bihar, Uttar Pradesh, Himachal Pradesh is also gaining popularity.

Role of Industry and Various Agencies

Industry and Government departments have played a vital role in popularising sprinkler irrigation system in India. Voltas Limited, Bombay have done pioneering work of introducing new technology in the field of agriculture and industry in India. Voltas are the pioneers in sprinkler system and have been propagating the concept of water Management in India for the last 16 years. Recently, Voltas have exported to Muscat (OMAN), India's first comprehensive sprinkler irrigation system. With this order, a new avenue for Indian expertise in water management has been established in export markets. Premier Irrigation Equipment Pvt. Ltd., Calcutta; Oasis Irrigation Equipment Co., Calcutta and IAEC, Bangalore, have been offering sprinkler irrigation equipments to Indian farmers for quits some time.

Tea Board of India and Coffee Board of India have been helping planters in installing sprinkler irrigation system in tea and coffee estates respectively. Besides this, the Agricultural Refinance and Development Corporation have started playing a vital role in propagating the concept of sprinkler irrigation for conservation of water and more efficient use of our land and water resources. Some of the nationalised banks are also providing finance to farmers for the purchase of sprinkler irrigation equipment. The Haryana State Government have played a very important role in popularising irrigation by sprinklers in Haryana. The State Government have been giving a subsidy of 25% to farmers on the purchase of sprinkler irrigation equipment.

Agriculture Departments, Irrigation Departments, Agricultural Universities, Agro-Industries Development Corporation and other Departments related to water source development and water utilization can play a very important role in spreading new technology of irrigation by sprinklers in their State. Indian farmers should be made aware of the advantages of the sprinkler irrigation system. If this is done, farmers will be able to make judicious use of available water and will be in a position to bring more and more unirrigated land under irrigation.

Conclusion

The wise use of water and water conservation in connection with irrigation involves effective utilization of a total supply of fresh surface water and ground water. Central and State Governments should help all those who are willing to spread the techniques of conserving water by sprinkler irrigation and join the war against the national waste of water, developed at a very high cost. In the national interest every drop of water should be utilised as beneficially as is possible. Sprinkler irrigation is one of the best means of accomplishing this objective.

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■ ■

Strategy of Farm Mechanization in India

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Abstract

'Grey Revolution' (ust of machinery) is the only supplement to 'Green Revolution' for increasing the food-grain production in India. Estimated demand of tractors per year is expected to shoot up to 77,000 by 1978-79 from 39,100 of 1973-74. Such increase in power input to agriculture helps in increasing the net utility of land. Though there are number of machineries available for farming but the suitable match to specific region placed another limitation towards the efficient use of power input. Selective thoughts for the production of suitable range of power source have also to be given due importance. The papers emphasises the qualitative and quantitative need of mechanization in India.

Growth of Mechanization in India

India is the second most populous and seventh largest country in the world. Its population in mid-1974 was estimated at 58.15 crores. It has an area of 32,80,483 (provisional as on lst July, 1971) sq., km. Nearly 70% of the people are dependent for their living on agriculture and allied sectors which accounts for about 47% (on current prices) of the national income. The number of persons engaged in agriculture alone according to 1971 census was 12.55 crores-7.81 crores cultivators and 4.74 crores agricultural labourers.

Land Utilization

Refering to **Table 1** for the Land utilization in Asian countries India utilizes about 49% of total area while at the same time the potentially produced unused land remains around 173.621 mil. ha. It becomes obvious to point out that this potentially unused land comprises of the hilly area, forest land and barren land. **Table 2**, gives a statistics of land utilization for 3,060 crores hectare for 93.3 percent of the total area of 32.80 crores hectare. Basically it becomes evident from the above table that the net area sown more than once increases only by 0.11 crores hectare for single year which definitely shows a good scope for more intensive land utilization for meeting the target of food grains production.

Food Production

Through various movements like White (Milk) Revolution. Green Revolution, Grey Revolution i.c. farm machinery utilization movement, the farmers have become more alert for the increase in their farm production through the intensive utilization

Table 1. Land Utilization in Asian Countries

Sl. No.	Countries.	Total area (1000 Hac.)	Percentage of Area Arable.	Potentially prod. unused (1000 ha.)
1.	Afghanistan	64,750	12	48,906
2.	Burma	67,800	13	6,088
3.	Cambodia	18,100	17	1,168
4.	Ceylon	6,560	28	1,348
5.	Taiwan	3,590	25	—
6.	India	326,810	49	173,621
7.	Indonesia	190,440	12	10,258
8.	Iran	164,800	7	4,127
9.	Iraq	43,490	15	29,781
10.	Israel	2,070	20	736
11.	Japan	36,970	16	4,707
12.	Jordon	9,770	12	202
13.	Korea, Repub	9,850	23	—
14.	Laos	23,680	4	8,030
15.	Lebanon	1,040	29	358
16.	Malaysia	33,260	10	245
17.	Nepal	14,080	16	5,282
18.	Pakistan	94,650	30	—
19.	Philippines	30,000	20	4,079
20.	Ryukus	202	23	4
21.	Saudi Arabia	214,970	2	2,880
22.	Syria	18,520	33	6,499
23.	Thailand	51,400	22	—
24.	Turkey	78,060	34	13,095
25.	Vietnam S	17,090	16	4,000
	Total average	1,521,952	20	171,255

Source: Food & Agricultural Organization of the United Nations Production Year Book Vol. 22, 1968

* Unused but potentially productive waste land, grass land scrub rough grazing cultivable land requiring minor improvements, shifting cultivation, fallow, forest.

Table 2. Land Utilization

	(Crore hectares) 1969-70	1970-71
Total geographical area	32.80	32.80
Total reporting area for land utilization	30.60	30.60
1. Forests	6.60	6.59
2. Not available for cultivation		
(i) Area put to non-agricultural uses.	1.59	1.60
(ii) Barren and uncultivable lands	3.03	3.02
Total:	4.62	4.62
3. Other uncultivated land excluding fallow lands		
(i) Permanent pastures and grazing lands	1.30	1.30
(ii) Land under tree crops and groves	0.44	0.43
(iii) Cultivable waste	1.58	1.52
Total:	3.32	3.25
4. Fallow lands		
(i) Current fallows	1.23	1.11
(ii) Others	0.96	0.91
Total:	2.19	2.02
5. Net area sown	13.87	14.12
Area sown more than once	2.51	2.62
Total cropped area	16.38	16.74

1 Provisional
Ref. India 1975-Publication Divn. Ministry of Information and Broadcasting Govt. of India.

Table 3. Production of Principal Crops

('000 tonnes)

Crops	1950-51	1971-72	1972-73
Rice (cleaned)	22,068	43,068	38,633
jowar	6,250	7,722	6,442
Bajra	2,600	5,319	3,795
Maize	2,357	5,101	6,206
Tagi	1,353	2,208	1,913
Small Millets	1,776	1,669	1,474
Wheat	6,822	26,410	24,923
Barley	2,518	2,577	2,327
Total food grains	55,011	105,168	95,201
Potatoes	1,832	4,826	4,473
Sugarcane (cane)	70,490	113,570	123,968
Black pepper	20	26	26
Chillies (dry)	358	494	408
Ginger (dry)	14	35	33
Tobacco	257	419	364
Groundnut (in a nut shell)	3,319	6,181	3,924
Casterseed	107	154	136
Sesamum	422	449	356
Rapeseed and mustard	768	1,433	1,853
Linseed	364	529	439
Cotton (lint) ('000 bales)[4]	2,870	6,564	5,589
Jute (dry fibre) ('000 bales)[4]	3,497	5,684	4,978[5]
Mesta (dry fibre) ('000 bales)[3]	659	1,150	1,162
Tea	275	433	4,503
Coffee	25	69	90
Rubber	14	101	112
Coconut (crore nuts)	358	612	595

1. Adjusted: 2. Final estimates 3. Provisional
4. 180 kg. each 5. Revised estimates
Ref. India 75

Table 4. Import of Food Grains

('000 tonnes)

Cereals	1966	1967	1968	1969	1970	1971	1972	1973
Rice	787	453	446	487	206	240	131	—
Wheat and Wheat flour	7,832	6,400	4,766	3,090	3,425	1,814	314	2,414
Other Cerals	1,739	1,819	482	295	—	—	—	1,200
Total	10,358	8,672	5,694	3,972	3,631	2,054	445	3,614

Ref. India 1975, Government of India.

of proper inputs and its timely application through machineries. **Table** 2 to 4 reveal the fact of the year-wise increase in crop coverage area, total production of food grains and tis import through the foreign countries in order to meet the demands of the citizen of the country.

The government's policy has been to reduce the import of cereals as much as possible by increasing the food grain production. An exaustive study made by Dr. M.S. Swamynathan,* Director General, I. C. A. R. shows the projection of net and gross demand for food grains during 1975 to 2,000 year as shown in **Table** 5. The total gross demand as indicated through the above table comes to 173.62 million tonnes for the year 1985 while the present food grain production as shown in **Table** 5 around 121.86 million tonnes.

Present Status

The food grain production is effected by various factors as listed below:—

1) Proper inputs for a specific crop;
2) Effecient application and utilization of the inputs;
3) Irrigation facilities;
4) Total power available per hectare.

Referring to **Table** 6 the total horsepower available per hectare in India is approximated to 0.302 h.p. while in Japan it is 3.000 h.p. It is also interesting to point out that even the country like India being the second populous country in the world utilizes resourcefully the agricultural workers per hectare about 0.90 while Japan utilizes 2.16. It clearly shows that for the increase of food grain production the concept of total H.P. available per hectare along with other factors is to he con-

Source: * Swamynathan, M.S., Population and Food Supply Yojana, Vole. XVII, No.1 Jan., 26, 1973.

Table 5. Projection of Net and Gross Demand for Foodgrains 1975-2000 (Million tonnes)

Item	1975			1980			1985			2000*
	Rural	Urban	Total	Rural	Urban	Total	Rural	Urban	Total	
Rice	36.97	7.06	44.03	41.79	9.03	50.82	46.26	11.50	57.76	Net demand 172.80 (Assumption I)
Wheat	17.18	7.05	24.23	20.89	9.16	30.05	24.81	11.85	36.66	-do- 182.80 (Assumption II)
Other cereals	24.25	2.24	26.49	26.35	2.52	28.87	28.07	2.86	30.93	(Gross demand) 216.00 (Assumption I)
Pulses	9.30	2.58	11.88	11.18	3.47	14.65	13.21	4.68	17.89	(Gross Demand) 228.50 (Assumption II)
Total net demand	87.70	18.93	106.63	100.21	24.18	124.39	112.39	112.35	30.89	143.24
Total Gross demand**			121.86			146.34			173.62	

* The estimates under Assumption I are based on normative levels of per capita requirements for rural and urban areas, while those under assumption II based on normative levels of per capita for urban areas and the 1975 projected levels, of per capita demand for rural areas.

**Gross requirements are derived on the basis of the consumption that seed, feed and wastage ratio in '75,'80,'85 and in 2000 would be 12.50, 15.00, 17.50 and 20.00% respectively (of gross production).

Source: Swaminathan M. S. -Population & Food Supply, Yojana, Vol. IVII No. 1 Jan, 26, 1973.

Table 6. Arable Land & Land Holdings Power Available & Agricultural Workers per Hectare

Country	Arable land (1000 ha)	Land holdings (1000 ha).	Arable land per holding ha	Human power hp/ha	Animal Power hp/ha	Mech. power ha/ha	Total hp. available per ha	Agri. worker per ha
Ceylone	1,876	1,174	1.59	0.120	0.148	0.110	0.373	1.20
Taiwan	890	806	1.11	0.195	0.164	0.146	0.505	2.00
India	161,940	61,780	2.62	0.090	0.204	0.008	0.302	0.90
Indonesia	22,852	12,148	1.88	0.110	0.062	0.001*	0.173	1.10
Iran	11,593	1,877	6.17	0.037	0.048	0.154	0.239	0.37
Japan	6,004	5,665	1.06	0.216	0.120	2.664	3.000	2.16
Korea Rep.	2,265	2,507	0.90	0.196	0.236	0.003	0.435	1.96
Nepal	1,831	1,496	1.22	0.249	0.480	0.004	0.732	2.49
Pakistan	26,021	11,000	2.37	0.109	0.288	0.013	0.410	1.09
Philippines	7,924	2,166	3.66	0.071	0.104	0.023	0.198	0.77
Thailand	11,267	3,087	3.64	0.110	0.184	0.054	0.348	1.10
Vietnam E.	2,935	1,893	1.57	0.210	0.244	0.024	0.477	2.10
Total/Average	257,399	105,601	2.32	0.143	0.192	0.267	0.602	1.44

*Estimated (1968 fig)

Source: Esmay M.L. & Carl Hall, Agricultural Mechanization in Developing countries—Shin Norinsha Co. Ltd., Japan.

Table 7. Number of Tillers and Tractors, Horse-Power Available and Numbers of Draft Animals

Country	Tillers			Tillers			Total tractor and tiller H.P. available	Draft animal (1000)
	Type	No.	Available H.P.	Type	No.	Available H.P.		
Ceylon	Tiller	11	55	Tractors	589	20,615	20,670	694.0
Taiwan	Driving	12,436	97,448	Wheel	379	15,750	113,198	360.3
	Traction	2,531	12,665	Crawler	88	4,400	17,065	—
India	Walking	1,200	90,000	Riding	50,000	1,280,000	1,370,000	81,740.0
Indonesia	—	—	—	Wheel	1,007	31,575		
				Crawler	128			
Iran	Tillers	5,000	40,000	Wheel	50,000	1,750,000	1,790,000	1,354.8
Japan	Driving	629,920	5,039,360	Wheel	32,320	480,390	5,519,750	1,782.0
	Traction	2,095,510	10,477,555	Crawler	4,373	196,785	10,674,340	—
Korea	Tillers	949	4,745	Tractors	24	960	5,705	1,341.2
Napel	Tillers	11	55	Tractors	210	7,350	7,405	2,200.0
Pakistan	Tillers	750	3,750	Wheel	8,010	340,770	344,520	18,636.0
Philippines	Tillers*	523	2,876	Tractors	5,225	182,875	182,875	2,052.0
Thailand	Driving	600	3,600	Wheel	12,000	500,000	503,600	5,174.0
	Traction	400	1,600	Crawler	2,000	1,000,000	101,600	—
Vietnam	Driving	904	5,424	Wheel	846	21,150	26,574	1,783.0
				Crawler	255	15,300	15,300	—
Total		2,770,745	15,779,128		167,454	4,948,920	20,724,172	117,117

*Estimated

Source: Ozaki & Mc. Colly 1968 Agri. Mechanization in South East Asia, Japan.

sidered most important than others. The **Table 7** indicates the comparative number of tillers, tractors, their H.P. available and no. of draft animals in respect to the agricultural inputs.

These tables as numbered 6 & 7 give a comparable statement for the due consideration of making more H.P. available for the farming enterprize. The present trend of the farm machinery, production and utilization has been quite interesting meeting the target as for as possible (the population figures of tractor, combines, power tillers, I.C. engines are given ahead).

The facts indicating the irrigation facilities for the farming enterprize has been also quite considerable as shown in **Table 8** which reveals that the increase in area under irrigation has been 1.03 crores hectares in 1970-71 taking the base year 1950-51. This increase in area under irrigation has in all the way produced the favourable conditions for growing the hybrid varieties of the crops. Thus by the virtue of increasing the cropping intensity the net crop area could be increased by 200 and 300%. The existing set up evolves some initiative characteristics of mechanization on the farming. This includes establishment of Agro Service Centers, providing

Table 8. Area Under Irrigation (Crore hectares)

Source of irrigation	1950-51	1970-71	Increase(+) or decrease(−)
Canals	0.83	1.25	
Tanks	0.26	0.45	+0.09
Wells	0.60	1.18	+1.59
Other sources	0.30	0.24	−0.06
Total	2.09	3.12	+1.62

Ref. India 75
Govt. of India

loans to the desired educated personals through banks for opening workshops and custom-hiring of machineries.

It is believed that this initiative has awakened the poor and help-less farmers. There have been instances in previous decade that the farmer even owning 100 acres of land, used to cultivate a portion say 50 acre or so, due to lack of resources. This problem is to be solved in the coming years through mechanization.

Farm Machinery Population

The realization of farm machinery utilization for the farming enterprize has been felt as early as in the 3rd decade of the 20 centure in India. The tractor as a foremost means of prime-mover is being used for the various purposes as below:

1) Land development;
2) Forest reclaimation;
3) Farm cultivation;
4) For haulage work; and
5) Used as stationary prime mover.

The areawise total production of the tractors and its import for meeting the demand is shown in **Table 9** and clearly indicates that the existing population of the tractor at the end of the Fourth Five Year Plan was approximately 2 lakhs while as per a report* these figures should have been adequate only for Punjab Region if other things remain favourable. But because of many limiting factors the figure has been quite low. Some of the reasons are mentioned ahead.

*Source: Tractors, Implements & Pump sets for Punjab Farmers. —Agricultural Information Service, Dept. of Agriculture Punjab, Chandigarh.

Table 9. Population of Power Tillers

Year	Indigenous	Imported (not available)
1865	237	
1966	562	
1967	274	
1968	217	
1969	290	
1970	695	
1971	1,279	
1972	1,010	
1973	1,391	

Source: Machinery & Planning Division, Ministry of Agriculture & Irrigation (Department of Agriculture) Government of India.

Table 10, 11 and 12 indicate the figure of the power tiller, self-propelled combine and I.C. engine. These figures have been quite inefficient to meet the then demand raised by the farmer. This has been pointed out because of the obvious reasons that sufficient field is still left which could be called as tractor cropped area. However, the effect of meeting the demand of the power unit by the consumers is not so far covered as it should have been.

Tractor Effecting the Demand of Power Units

The farmer's demand for the particular power unit is based on the following para meters: —

1) Availability;
2) Computability over each other;
3) Easy after-sale-service;
4) Multi-pharious use;
5) Inter changeable parts;
6) Maximum utility;
7) Less operating cost.

It has been quite oftenly reviewed that in view of the above facts the demand of farmers centers to a particular/specific type and make of the machinery which finds scarcity in the market and thus creates economic imbalance in the market for the type of implement. This phenomena is to be avoided and to the same some of the fundamentals/basic points are to be considered by the Government as:

1) Standardization of the parts and equipment;
2) Time to time random sampling and its testing by the authorized organizations;
3) No equipment/machinery should come in the market without being properly tested and registered since it confuses the farmers illegally;
4) As shown in **Table 13.** the ceiling on holdings imposes another fact for the consideration of farm machinery utilization.

It is reported, that, in general, the demand of tractor for any specific land holding is decided approximately on the rate of 1 H.P. per 1.25 acre and thus it

Table 10. Tractor Population

Year	Indigenous	Imported	Total
1961-62	880	2,997	2,877
1962-63	1,414	2,616	4,030
1963-64	1,983	2,349	4,332
1964-65	4,323	2,323	6,646
1965-66	5,796	1,939	7,735
1966-67	8,816	2,991	11,407
1967-68	11,394	4,033	15,427
1968-69	15,466	4,279	19,745
1969-70	18,120	10,473	28,593
1970-71	20,099	13,300	33,399
1971-72	18,100	11,519	29,619
1972-73	20,802	5,639	26,441
1973-74	24,216	5,666	29,882

Machinery & Planning Division, Ministry of Agri. & Irrigation. (Dept. of Agriculture) Govt. of India.

Table 11. Import of Self Propelled Combines

Year prior to 1970	66
1970	157
1971	60
1972	165
1973	35
1974	39

Source: Machinery & Planning Division Ministry of Agriculture & Irrigation (Department of Agriculture) Krishi Bhawan, Govt. of India.

Table 12. I.C. Engine Population

States/Union Territories	Year 1960-61	1965-66	1968-69
Andhra Pradesh	33,940	46,741	60,000
Assam	76	362	4,220
Bihar	3,187	3,698	38,000
Gujarat	—	112,428	20,000
Haryana	1,175	3,656	6,140
Jammu & Kashmir	20	18	18
Kerala	3,372	6,824	8,800
Madhya Pradesh	9,681	16,511	32,000
Maharastra	63,747	40,786	215,000
Mysore	10,087	24,575	48,000
Orissa	1,203	710	10,000
Punjab	6,983	25,670	43,860
Rajasthan	2,468	7,252	18,000
Tamil Nadu	36,832	42,882	118,000
U.P.	8,408	28,146	85,000
West Bengal	3,637	4,126	30,000
Union Territories	168	577	—
		Total=	650,000

Machinery Planning Division Ministry of Agriculture & Irrigation (Department of Agriculture) Government of India.

Table 13. Ceiling on Holdings

State	Level of ceiling (hectares)
Andhra Pradesh	4.05 to 21.85
Assam	6.74[1]
Bihar	6.07 to 18.21
Gujarat	4.05 to 21.85
Haryana	7.25 to 21.85
Himachal Pradesh	4.05 to 12.14[2]
Jammu & Kashmir	3.68 to 7.77[3]
Karnataka	4.86 to 21.85
Kerala	4.86 to 6.07
Madhya Pradesh	4.05 to 21.85
Maharashtra	7.25 to 21.85
Manipur	10.12[4]
Orissa	4.05 to 18.21
Punjab	7.00 to 21.80
Rajasthan	7.25 to 21.85[5]
Tamil Nadu	4.86 to 24.28
Tripura	2.00 to 7.20[6]
Uttar Pradesh	7.25 to 18.21
West Bengal	5.00 to 7.00

1. Actual area of the orchard, subject to a maximum of 2.02 hectares in excess of the ceiling, can be retained.
2. In certain specified areas up to 28.33 hectares.
3. Orchards in excess of the ceiling can be retained subject to an annual tax.
4. To be revised.
5. In certain specified areas up to 70.82 hectares.
6. Standard.

Ref.: India '75, Government of India.

may be pointed out that the demand of tractors in the coming year would be of two types i.e. one for around 30 H.P. while another for above 50 H.P.

The tractors of above 50 H.P. would be recommended for use on the big farms to be managed/or being managed by the Central organizations/State Governments etc. They are also preferably to be used for the custom hiring which is finding a quite locatable prospect in the country of ours, where the extreme conditions of some regions do not find good reasons for tractors being purchased by every farmer.

There is a great emphasis of unemployment or replacement of labour by the use of machinery on farm which needs proper justification. During various surveys made by the team of workers it has been established that the replacement of labour do not occur in the region where the machinery is being recommended because i) there remains already shortage of labour supply by the increase of cropping in tensity ii) high yielding production, iii) establishing more small scale industries; and iv) establishing more post harvest processing units. Statement as given below clarifies the above fact. *Gill reported that the labour utilization for Distr. Ludhiana was found to be 1.7 ha/labour while the cultivated land per labour is 2.0 ha. The report favours the fact of increasing employment potenial through mechanisation in the intensive cropping system of farming.

New Programmes

Through the various tables of food grain production demand for the next decade as stated previously it has been obviously felt that some new programmes are to be chalked out for meeting the target and they should be implemented with its full huge and enthusiasm. It is improper to say that the increase of tractor population requirement and rate of annual supplies would meet the target. The training and refreshing courses on tractor, use and maintenance is to be strengthened as per requirement.

*Ref. Gill, G. W., A guide to planning and managing Agricultural operations for national demonstration I.C.A.R. 1970.

(A statement showing the tractor requirement and rate of annual supply is given in **Table 14** & **Table 15**). In order to revive the whole programme in short it may be pointed out that the follow up action programme is to be framed for strengthening the actions of the programmes already implemented since there remains always a lacuna while implementing the same.

In vew of the above fact it is felt that a small field unit should be prepared for pursueing the matter of mechainzed farming having the aim as follows:

1) To contact with the actual consumer and find out their short comings, comment, troubles etc;
2) To contact with the manufacturer, suppliers, agents of the farm machinery for meeting the demand of the farmers in specifc field having the specific considerations;
3) To suggest remedial measures considering the consumers and producers side to the Government and for its strict implementation;
4) To develop suitable attachment to the power units and equipment for specific regions in order to increase the efficiency of the farm equipment in the regions economically;
5) To collect data and formulate new programmes for the efficient land utilization with respect to farm machinery utilization and increasing the food grain production as a whole.

These points would also high-

Table 14. Tractor Requirement and Rate of Supply

Country	Tractor Park			Harvested Ha per 40 H.P. Tractor Unit			Rate of Annual supplies of Tractor								
							1965			1975			1985		
	1965	1975	1985	1965	1975	1985	As replacement	For growth	Total	As replacement	For growth	Total	As replacement	For growth	Total
India															
2wheel	2,000		500,000	3,652	2,056	267	50	450	500	2,000	13,000	15,000	20,000	130,000	150,000
4wheel	40,000	160,000	650,000	—	—	—	2,500	6,000	8,500	9,000	24,000	33,000	35,000	95,000	130,000

Note: 1. Due to lack of reliable statistics, many of the 1965 figures for Tractor park have been estimated.
2. On the basis that five 2-wheel of 20 H.P.-One-4-wheel tractor of 40 H.P.

Ref: A proposal for Agricultural mechanization in Developing Countries of South East Asia, Agril. Mechanization in South Asia, Spring '71, Tokyo-Japan.

Table 15.

Model 1 Tractor Stock as a Function of Lagged Agricultural Production Relatively Price and Irrigated Area (Figures in '000 Nos.)

Year	Estimated stock	Investment demand	Replacement demand	Annual demand
1972—73	212.7	—	—	—
1973—74	243.5	30.8	8.3	39.1
1974—75	278.9	35.4	9.5	44.9
1975—76	319.2	40.3	10.9	51.2
1976—77	365.5	46.3	12.4	58.7
1977—78	418.5	53.0	14.2	67.2
1978—79	479.2	60.7	16.3	77.0

Assumptions for forecasting:
1. Relative price constant at 1971-72 level.
2. Irrigated area increases at 1.5 percent per annum.
3. Agricultural production increases by 5 percent per annum.
4. Replacement demand during the period 1971-72to1978-79 is assumed to form 3.5 percent of the previous year's stock.

Model 2 Tractor Stock Relatively Price, Total Cropped Area and Lagged Agricultural Production (Figures in '000 Nos.)

Year	Estimated stock	Investment demand	Replacement demand	Annual demand
1972—73	211.1	—	—	—
1973—74	241.6	29.8	8.2	38.0
1974—75	275.6	34.0	9.4	43.4
1975—76	314.3	38.7	10.7	49.4
1976—77	358.4	44.1	12.2	56.3
1977—78	408.8	50.4	13.9	64.3
1978—79	466.2	57.4	15.9	73.3

Assumptions for forecasting:
1. Relative price constant at 1971-72 level.
2. Agricultural production increaed by 5 percent per annum.
3. Total cropped area increases by 0.7 percent per annum.
4. Replacement demand during the period 1971-72 to 1978-79 is assumed to form 3.4 percent of the previous year's stock.

Model 3 Tractor Stock Relative Price Lagged Agricultural Production (Figures in '000 Nos.)

Year	Estimated stock	Investment demand	Replacement demand	Annual demand
1972—73	213.1	—	—	—
1973—74	244.4	31.3	8.3	39.6
1974—75	280.5	36.1	9.5	45.6
1975—76	321.8	41.3	10.9	52.2
1976—77	369.2	47.4	12.6	60.0
1977—78	423.6	54.4	14.4	68.8
1978—79	486.0	62.4	16.5	78.9

Assumptions for forecasting:
1. Relative price constant at 1971-72 level.
2. Agricultural production increases by 5 percent per annum.
3. Replacement demand forms 3.4 percent of previous year's stock.

light the scope of mechnization without any further consideration for the country like India where the status of population is second but the production of food grains remainds much below the target.

Conclusion

It is observed that the import trend of food grain has been reducing satisfactorily by the increase in the production. The increasing rate of production is to be shoot up much higher than the existing conditions since population and other factors are effecting the requirement vigorously.

As a matter of fact mechanization in India calls for the following steps to the considered on priority:

1) Increase in cropped area by increasing the intensity of cropping in more percentage of arable area.

2) Increase in area arable by developing the potentially producable land.

Table 16. Mechanization at a Glance: in India

1.	Total area	328.81 mil. he—1968
2.	Percentage of area arable	49 1968
3.	Potentially producible unused area	173.621 mil. he. 1968
4.	Area sown more than once	26.2 mil he 1970—71
5.	Total cropped area	1967.4 mil. he 1970—71
6.	Total food grains production	95.201 mil. tonnes 1972—73
7.	Total Import of cereals	3.614 mil. tonnes 1973
8.	Total net demand of food grains for 75	106.63 mil. tonnes.
9.	Total import of cereals	mil. tonnes
10.	Power available: (1968 figures)	
	i) Human power hp/ha	0.090
	ii) Animal power hp/ha	0.204
	iii) Mech. power hp/ha	0.008
	iv) Total HP available per ha	0.302
	v) Agric. work per ha	0.90
11.	Existing estimation of power unit and its population:	
	a) i) Tractor population at the end of IV Plan.	200,000
	ii) Power Tiller at the end of IV Plan.	10,000
	iii) Self propelled combine harvesters.	512 up to 6/73/
	b) Estimated annual demand of tractor with (as per NCAER Report) V Plan.	

1973—74	39,100	1976—77	58,700
1974—75	44,900	1977—78	67,200
1975—76	51,200	1978—79	77,000

3) Increase in production and utilization of crop inputs viz-a-viz;

i) Hybrid seed;
ii) Improved fertilizers;
iii) Use of manures, and other organic matter;
iv) Increase in irrigation facilities.

4) Increase in power available per ha.—as

i) Increase in general purpose tractors population;
ii) Increase in other source of power units;
i) Effective design, production and utilization of farm machinery;
iv) Effective use of existing resources.

5) Enhacing the motivation of evolving proper improved techniques in farming enterprize.

6) Proper research and development facilities for—

i) Finding out the root cause to increase production through less use of inputs;
ii) Developing proper attachment and devices to be used for specific reasons for increasing the efficiency of the power machinery;
iii) To find out systematised farm operations to be followed for the same or more production with less power consumption.

and likewise the increase in Annual demand of other power units have been estimated. ■ ■

Mechanization and Increased Efficiency in Sugarcane Production : An Industry Goal

by
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The sugar industry is considered the most mechanized sector of Philippine agriculture. By and large, however, mechanization of sugarcane production is limited to tillage, specifically plowing and harrowing. The sugar industry still has to go a long way to full mechanization and increased efficiency which have been achieved in other countries, notably Australia. It is a known fact that the Philippine sugar production cost is one of the highest in the world in spite of our so-called low labor costs. Of course, this is partly due to our low yields but it can also be attributed to inefficiencies in most aspects of production. Having enjoyed a premium market in the United States for so long has bred complacency in our sugar farmers. Now that we have to compete in the open market, the sugar industry has to start modernizing its production methods to increase yields and lower costs. Otherwise, we may be faced with the same predicament which Puerto Rico did a few years back and which resulted in the closing of a number of mills.

There are several aspects of the field production cycle which can stand further improvement through mechanization, namely, tillage, crop care, land forming and drainage, irrigation, harvesting and loading, transport, as well as handling crop residue. In this parer, I shall only highlight certain aspects of these operations which can immediately be modernized. I do not advocate complete mechanization at the outset but rather a gradual but sensible change in our methods so that, as labor is absorbed by industry and its rates increase substantially, the industry can survive.

As we have learned from experience, there are constraints to adopting systems and equipment used in other countries such as Australia. One of these is row spacing. Australia equipment are designed to straddle one row spaced 1.4 to 1.5 meters apart. Victorias Sugarmill studies indicate that with the present varieties, yields drop at row spacings more than 1.3 meters. This was experienced when a tractor distributor introduced high clearance tractors and Cuban tools in the early 50's. The main reason Australia and other countries use wide row spacing is for efficient mechanization—the tractor can go faster without damaging the plants. To adopt this system, varieties which yield higher with wide rows have to be developed.

Another constraint is the higher rainfall and typhoons we experience which cause bogging down of equipment and lodging of the cane plants. This can be partly overcome by proper surface and sub-surface drainage, land smoothing and deep tillage.

When modernizing farm operations, especially when introducing new machines, there have to be compromises made by various agricultural disciplines for the sake of efficiency and the ultimate goal of profit. Plant breeders and agronomists may have to change the plant and/or farming practices so machines can handle them better and at less cost than present methods. Agricultural engineers and equipment suppliers need also endeavor to adopt their machines to suit the conditions or promote improvements in crop and field conditions as long as immediate and/or long term economic benefits can be achieved.

It is heartening to note that some equipment suppliers and a growing number of progressive sugar farmers, especially in Negros, are testing and obtaining benefits from new equipment. I shall endeavor to cover the various phases of cane production where mechanization has been tested and can offer improvements over the present system:

Land Forming

The main objective of land forming is to ensure efficient and uniform drainage of fields so that crops do not suffer from waterlogging and to facilitate use of farm machinery and transport equipment. It may be desirable also where furrow or flood irrigation is to be employed but it may be too expensive for this purpose for a crop like sugarcane where sprinkler irrigation has been generally accepted.

It is ironic that most of the investments on sugarcane farms have been channeled to irrigation in spite of our annual rainfall of 200 to 300 cm. (80 to 100 inches). Except for main farm and field ditches, little attention has been given land forming, drainage, as well as moisture conservation.

Land forming basically involves smoothening the surface of the field and the elimination of water basins (depressions where water accumulates). Where large amounts of soil have to be moved, a carry-all scraper is used. This may be done by a contractor or the equipment can be supplied by the mill. There are small 3 to 5 cubic yard farm scrapers which can be towed by an ordinary farm tractor. Ideally, the top soil should first be scraped and put aside to be spread back on top after the infertile subsoil has leveled. This may, however, be an expensive proposition. When the soil fertility is disturbed through leveling, it is recommended that organic matter, such as filter press mud, be spread over the field and higher levels of inorganic fertilizer be applied if the field is to be planted. If the field can be laid fallow for some time, a legume should be seeded and plowed in when in flower. This practice will also allow soil in filled areas to stabilize.

To eliminate small depressions, a land plane can be passed over the field as the final operation in tillage. This is basically a 12 to 14 foot grader blade with a long wheelbase.

The digging of drainage ditches bordering the fields may also be considered a part of land forming. This operation has become fast and economical with the use of a tractor driven rotary ditcher which can dig a one kilometer long, one meter deep trapezoidal ditch in one day.

To increase internal drainage, mole drains can be made perpendicular to ditches with a subsoiler equipped with a "bullet."

The ultimate and most ideal drainage scheme is to lay clay or cement tiles or corrugated plastic pipes at a depth of one to two meters. This permanent land improvement not only eliminates waterlogging but it encourages a deeper root zone which results in greatly increased yields.

Tillage

There are some improvements in tillage which can be promoted. The most promising and economical is Chisel Plowing. The chisel plow is a tined implement which, in construction, is something between a subsoiler and an inter-row cultivator. The tines could either be rigid or spring loaded. It can penetrate from 12 to 18 inches deep in one or two passes at field capacities higher than disc plowing.

The chisel plow can be used prior to disc plowing or harrowing. By taking off a few tines, it can be used between ratoon cane rows to cut old roots and improve internal drainage.

The chisel plow is ideal for hill farms where they presently plow downhill thus causing erosion. The chisel plow can easily be pulled across the slope to minimize erosion and encourage internal seepage of water.

The chisel plow is fairly well accepted in Negros. It was recently introduced at Hacienda Luisita in Tarlac where the stand of cane has improved because the hard pan was broken and water now infiltrates instead of "drowning" the plants. In dry periods, the cane can benefit from the greater amount of moistre stored in the soil.

Another tillage implement which deserves more attention is the Rotavator. This is a versatile tool which can be used for chopping and incorporating cane trash, for primary and secondary tillage (breaking up plow clods), cultivating between ratoon or plant cane rows (by taking of blades and flanges over the rows) and for making furrows. A front mounted toolbar with two subsoiler tines is now available so that the soil can be broken before the Rotavator blades pass thus saving on blade wear and increasing working depths.The fine tilth which can be obtained with a Rotavator improves the germination of seed pieces and minimizes the evaporation of soil moisture.

Conserving Crop Residue

The average sugar farmer usually burns the cane trash because he cannot plow it in. In the last three years, a flail type trash chopper was introduced in Negros. With an ordinary farm tractor, the trash is chopped finely so it can easily be plowed under to increase the organic matter of the soil. On ratoon crops, chopped cane trash can be left as a mulch between the rows to minimize soil erosion, weeds, and evaporation of moisture. The chopper also shaves the old cane stubble. Farmers who have been plowing in their cane trash find that their soil is more friable and easy to work on, it retains more moisture, and their yields are generally higher.

Spreading of filter press mud can be more uniform when a manure spreader is used. Our company has sold a number of tank-type spreaders which distributes solid or slurry material to the side. When the field is too wet to enter, material can still be spread from the road.

Crop Care

Many cane tools are made locally and cheaply in Negros. There are, however, a few new tools which can help the cane farmer improve his operations, namely:

a) Subsoiler with furrowing wings which cut a slit at the bottom of the furrow for easier insertion of the cane point and for better drainage right under it. This has been used by the Canlubang Sugar Estate for several years.

b) The Australian Weeder Rake. This is a wide rake with closely spaced, light spring tines which can uproot young weeds and do not damage the young cane plants. It is passed over the row and between rows when weeds have just germinated.

c) Disc and PTO-driven rotary cultivators for more effecting inter-row cultivation.

d) Inter-row Sprayer. There is now available a tractor mounted sprayer with a conventional boom as well as an inter-row attachment. In the latter, the spray nozzles are attached to a rod pivoted at the boom and trailed on skids between the rows. Nozzle height remains almost constant irregarless of movements of the tractor or main sprayer boom. Herbicides or other chemicals can be accurately sprayed between cane rows. When the cane has its first leaf sheet off the ground, a contact herbicide like Gramoxone can be sprayed without harming the cane plant.

e) Compact tractors for inter-row applications. While most farmers still use carabaos for inter-row cultivation and some are now using hand tractors, small 14 to 25 HP four-wheel tractors are now getting accepted in rice tillage. They can also be used to work between cane rows for cultivation and spraying.

Harvesting, Loading, and Transport

This phase of sugar production has been the most neglected; it is also the most inefficient link in the chain. Oftentimes, the cane is milled 36 hours after it is cut. Thus, much of the sugar produced by the plant for 12 months is lost. By contrast, the average lead time from cutting to milling in Australia is less than 14 hours. Almost 100 percent of Australia's cane crop is mechanically harvested and loaded. They also have one of the most efficient transport systems in the sugarcane world.

There are, however, technical and social constraints to fully adopting the Australian harvesting system. These technical constraints are:

a) Narrow rows and small fields

b) Lodging cane

c) Wet, boggy fields

d) Mills resist receiving burned, chopped cane

e) Inefficient transport and unsuitable mill unloading systems

One progressive mill in Negros has been testing a German harvester developed in Cuba which can cut lodged green cane planted in one meter rows. While it can enter wet fields, soil compaction and transport limitations pose problems. The mill district is now preparing their fields for mechanization by removing rocks with a mechanical picker so they do not damage the havester's base cutter and by installing tile drains in boggy fields to enable the harvester and transport equipment to enter them without destroying the soil structure.

The mill does not intend to fully mechanize their harvesting immediately because of social implications. The experience they will have gathered from their initial usage of the harvester, however, will be invaluable when the time comes that it will be too expensive to cut and load cane by hand as has happened in many cane growing areas.

Cane loading is an arduous task which limits the productivity of manual harvesters. Over ten years ago when most of the Australian cane crop was still cut by hand, a cane cutter could cut four to five tons a day. The cane was then all loaded mechanically. In the Philippines, cane cutters can cut and load only one ton a day. The wider use of mechanical loaders in the sugar industry can be an intermediate step in improving harvesting efficiency.

Cane transport and mill unloading can definitely stand much improvement. Trucks act as storage bins for 8 to 24 hours in many mills. Industry has to do some long range planning exercises before further investments are made in this area. It should seriously consider the harvesting system which will be employed in the next five to ten years as this will have a bearing on the transport and unloading systems.

Farm Tractors

The basic power unit on cane farms, the tractor, has heretofore not been touched upon and deliberately so since the selection of the right tractor size is dependent on the work to be done. The most popular tractor model in sugar is the 70 to 80 horsepower general purpose unit. It can handle most of the chores on a 50 to 100 hectare farm. There are some applications for lighter tractors on small farms and for cultivation and light jobs on bigger farms. Tractor hire for tillage of small cane farms is being practiced in new districts.

Four-wheel drive tractors of 80 to 120 HP have become popular in the sugar industry for deep tillage, cane transport, and for hilly areas. They have the tractive and flotation characteristics of a crawler tractor and the advantages of mobility, low initial and maintenance costs of wheel tractors.

There is likewise a growing interest in higher horsepower tractors (90 to 150 HP) for handling tougher jobs, such as trash chopping, heavy discing, subsoiling, etc.

Mechanization and the Small Cane Farmer

The average size sugarcane farm in the Philippines is only 15.6 hectares. Ninety-four percent of the planters own less than 50 hectares and their farm comprise 52 percent of the total sugarcane acreage of the Country.

Studies show that the small sugar farms have significantly lower yields than large ones. This is attributed to the lower level of management, capital, and mechanization available to small farmer.

Long term credit for the acquisition of better farm equipment has been made available to farmers with less than 50 hectares from rural banks through the CB-IBRD Rural Credit Program. These loans, however, are being questioned because the small sugar farmer is still much more affluent than the average rice and corn farmer. It is hoped that this credit facility shall continue being available to the small sugar farmer because he has no other source of long term credit. (DBP requires that the farmer have at least 50 hectares for a tractor loan.)

Another way by which small cane farmers can benefit from mechanization is for government or private farm equipment pools to perform the jobs which require expensive equipment, such as subsoiling, digging drainage, ditches, etc. For greater mobility to service small fields which are not contiguous, four-wheel drive tractors would be ideal.

Sugar is an important sector of the Country's balance of trade and the national economy. A rational program for mechanizing field operations to increase yields and lower costs is one of the several factors that will determine the future growth or survival of the sugar industry. ■■

Co-Operating Editors

New Co-Operating Editors

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1) Conversion of an old inverter into an electric dynamometer.

2) Agricultural Mechanization in Bangladesh (Problems and possible solutions).

Chairman, Sub-committee for Testing of Tractors, Power Tillers and Agricultural Machines.

Member of the standing Committee for Agricultural Engineering, Irrigation and Water Management, Bangladesh Agricultural Research Council.

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1966-1967, Manager, Test Section, Honda R & D Co., Ltd.

1967-1968, Planning Manager, Head Office, Honda Motor Co., Ltd.

1968-1969, Associate Professor, Department of Agricultural Machinery, Mie University, Japan

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International Experience:

Thailand, 1965 (5 months), investigation into tropical farming, farm mechanization, marketing and service engineer training.

U.S.A., 1967 (6 months), investigation into farm mechinery and engine industries, dealer network marketing and service engineer training.

Okinawa and Philippines, 1967 (2 months), marketing and study on tropical farming.

Philippines and Europe, 1969-1971 (22 months and 2 months), as Unesco Expart, participating in the Unesco project of "Strengthening Agricultural Education" in Central Luzon State University, Philippines.

Netherland and other several European countries, September 1974, attending VIIIth International Congress of Agricultural Engineering C.I.G.R.

Sweden, June 1976, as Japanese Delegate to the 7th Conference of the International Soil Tillage Research Organization.

Awards and Recognitions:

Society Award, 1964, The Society of Agricultural Machinery, Japan, for the achievements of hand tractor and rotary tillage engineering research.

Honorary Membership Award, 1969, Philippine Society of Agricultural Engineers, CLSU Chapter, for teaching and research activities.

Certificate of Appreciation, 1971, Central Luzon State University for contribution to the strengthening of agricultural training.

Certificate of Appreciation, 1971, The College of Engineering, Central Luzon State University, for services to the college.

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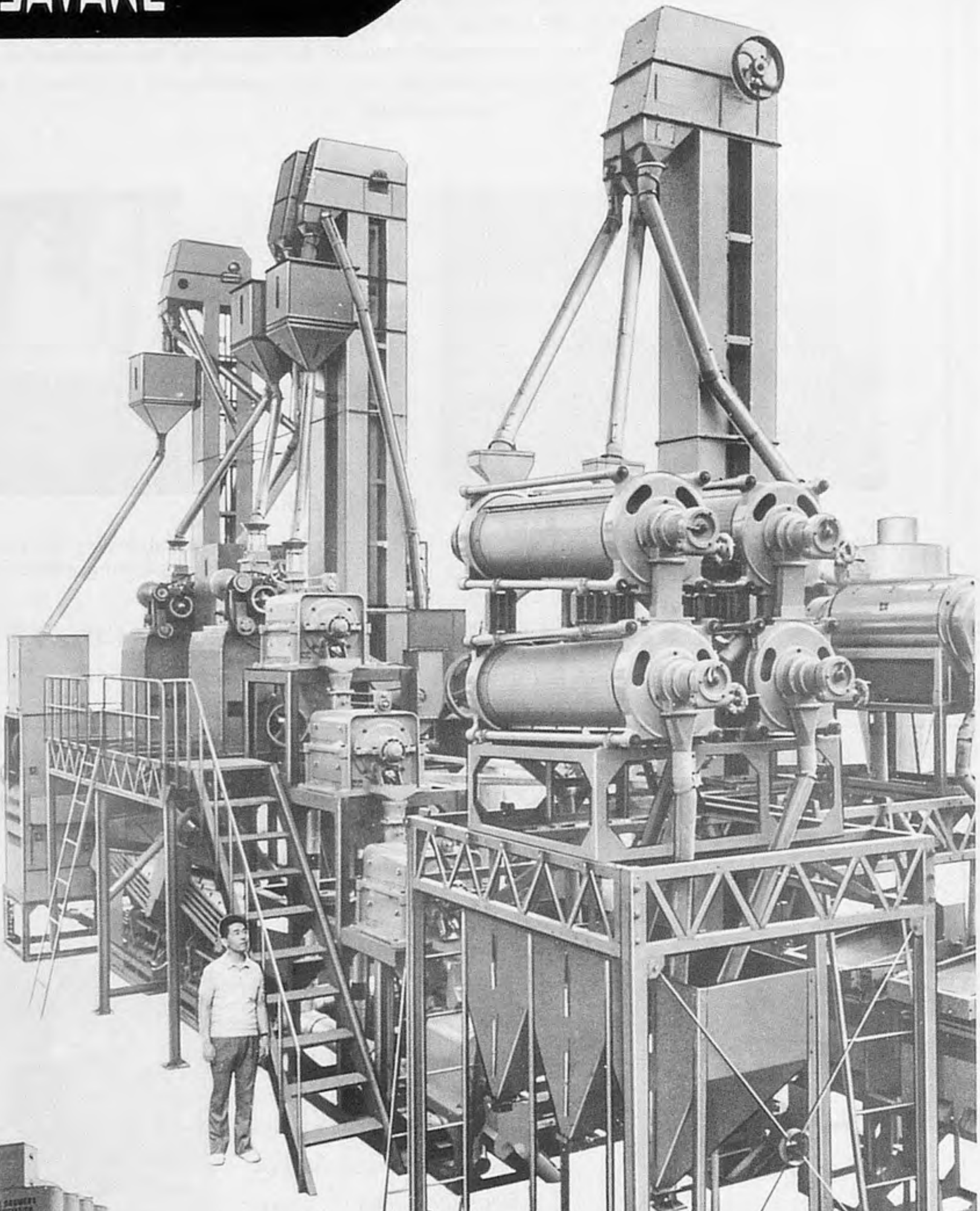

4-TON TYPE RICE MILLING PLANT

RICE MILL IN U.S.A.

Economies of Size in Sugarcane Farming

by
Liboro S. Cabanilla
Instructor,
Department of Agricultural Economics, U.P.
Los Baños, Philippines

The productivity of sugarcane farms in the Philippines is glaringly low when compared with that of other sugar producing countries. For a while, this problem seems to have been forgotten because of the tremendous increase in the price of sugar in the world market over the last year. However, we should not be remiss and side-step the problem completely. Worldwide shortage of sugar supply which has primarily caused the general increase in sugar prices may just be for a while. Moreover, net sugarcane farm incomes may not have actually increased because of an almost simultaneous increase in cost of all agricultural inputs. Hence, renewed efforts to increase efficiency of sugarcane farming should be exerted.

It is generally contended that large, highly mechanized sugarcane farms tend to be more efficient than small farm of higher efficiency of production or are there other factors associated with size and efficiency by looking into the returns to the factors of production among small and large farms and by identifying factors associated with size which may explain the higher efficiency among large sugarcane farms.

※This paper forms part of the research undertaken by the author on his MS thesis, Economies of Sugarcane Farming, Victorias Milling District, Philippines, 1971-72. UP at Los Baños, 1974.

Methodology

Study area

The study was conducted in the Victorias Milling District on Negros Island. The choice of the area was primarily because of the existence of a wide variety of sugarcane farms in the said District-from a small familytype farm to a large highly mechanized one. In addition, a study grant of 1,500 was awarded the author by the Victorias Milling Company.

The Victorias Milling District has earned for itself distinction in several ways. Aside from planting roughly 10 percent of the total land area planted to sugarcane in the Philippines, it also produces 12% of the total sugar output of the country despite the proliferation of new sugar centrals. It has also an enviably high productivity compared with other districts.

Sampling and data gathering

Sample farms in the study were selected from the list of all sugarcane farms within the Victorias Milling District. The list included statistics on the total area planted to sugarcane per farm, total output (in piculs sugar and tons cane) and also production rate per hectare (PS/Ha. and TC/Ha.)

The farme were grouped by size into large and small farms. The average size in the District of 28 hectares was used as boundary line between large and small farms so that small farms are those that are 28hectares and below while large farms are those that are above 28 hectares.

Farms grouped under these categories were further classified into low, medium and high-yielding farms. Low yielding farms are those producing 75 PS/ha. and below; medium yiolding farms are those producing 76-100 PS/ha. and high yiolding farms are those producing 101 PS/ha. and above. An equal sample size of 15 from these sub-classification was randomly selected, giving a total sample of 90 farms from which data were gathered through personal interviews.

Method of analysis

The farm business analysis was used in determining the returns to the three major factors of production among small and large farms. In an attempt to consider other factors associated with size, which might explain differences in productivity, some farm practices and resource endowments were examined.

Resources and Farm Practices of Study Farms

The importance of comparing farm resources and farm practices rests primarily in knowing why, if indeed, large farms are more efficient producing units than small farms. The capacity of a farm to increase output, for example, depends largely on the resources at its disposal. The more favorable its resource, the better are its chances of increasing production.

Human resources

One of the striking differences between small and large sugarcane farms is the management factor. Among the study farms 28 percent of the large farms and about 15 percent of the small farms employed administrators. Among these farms employing administrators, large farms have higher productivity than small farms (**Table 1**). The difference in productivity is statistically significant at 5 per cent. This seems to indicate that large farms are better managed than small farms as borne out by the data. More among large farms perform yield-increasing practices than the small farms (**Table 2**). Moreover, it is interesting to note that only 71 per cent among the small farms employing administrators selected planting materials (a practice found to increase yield significantly by regression analysis) whereas 100 per cent among large farms employing administrators did the same (**Table 3**).

Table 1. Productivity of small and large farms employing administrators, Victorias Milling District, Philippines, 1971-72.

Size/ Productivity	Area (has.)	Number	Per cent	Production (PS/ha.)
Small				
Low	12.50	3	7	69
Medium	16.00	2	4	85
High	11.10	2	4	103
All Small	13.10	7	15	83
Large				
Low	32.40	2	4	69
Medium	45.79	5	11	87
High	70.79	6	13	119
All Large	55.27	13	28	99

Table 2. Number of farms performing some selected farm practices, Victorias Milling District, Philippines, 1971-72.

Farm Practices	Small Farms			Large Farms		
	No.	%	Prod'n	No.	%	Prod'n
Seedpiece treatment**	6	13	85.5	15	33	93.80
Selection of planting materials**	42	93	88.76	45	100	92.27
Subsoiling*	8	18	101.75	12	27	103.54

** Difference in productivity not significant.
* Difference in productivity significant at 20%.

Farm resources

The farm resources on sugarcane farms consist primarily of land, buildings, farm machinery, tools and equipment, and livestock. The quantity and also quality of farm resources affect the productivity of farms. Farms with tractors, for example, are in a better position to perform deeper plowing than farms without tractors; hence, sugar-cane plants have better root growth.

Large farms had a total investment value of 714,726 per

Table 3. Productivity of farms with administrators performing selection of planting materials, Victorias Milling District, Philippines, 1971-72.

Size/ Productivity	Number of Farms Reporting	Production (PS/Ha.)
Small		
Low	1	75
Medium	2	85
High	2	103
All small	5	90
Large		
Low	2	69
Medium	5	87
High	6	119
All large	13	99

Table 4. Summary of average investment among small and large sugarcane farms in Victorias Milling District, Philippines, 1971-72.[a]

Items[b]	Small Farms Value in pesos		Per cent	Large Farms Value in pesos		Per cent
	Per farm	Per hectare		Per farm	Per hectare	
Cane land	128,292.35	9,654.46	58.14	508,896.44	10,312.02	71.20
Building	10,410.81	419.48	4.72	32,758.09	641.48	4.58
Machinery	56,098.23	1,881.84	25.42	89,431.69	1,753.18	12.51
Transportation facilities	21,525.51	943.32	9.75	34,944.32	685.38	4.89
Office equipment	973.97	17.32	0.44	43,416.13	16.77	6.07
Tools and animal drawn equipment	1,084.14	30.57	0.49	1,925.21	37.94	0.27
Livestock	2,276.04	142.24	1.03	3,354.54	120.40	0.47
Total investment	220,661.05	13,089.23	100.00	714,726.42	13,567.17	100.00

a Irrigation facilities was eliminated because there was only one respondent among the small farms and seven among the large farms. This tended to bias the estimate on investments.
b Values here represent only the farm reporting investments on the different items.

farm (**Table 4**). On a per hectare basis, large farms had a total investment of 13,567 per hectare while the small farms had 13,089 per hectare.

Degree of mechanization

The extent to which the potential yield of the soil can be fully exploited depends heavily on the depth, quality of tillage, and adherence to optimum timing of the tillage operation.* Deeper tillage encourages deeper root growth of sugarcane plants for better resistance during drought periods and optimum timing of tillage reduces the chances of weeds to thrive. All these are made possible through the use of mechanical power. Thus, higher yields are made possible through increased use of machine on the farm.

On a per hectare basis, large farms employed 26 machine days while small farms employed 19 machine days. It should be noted that while the small farms had a higher average investment in machinery per hectare, they had lesser machine use per hectare. However, it must also be noted that small farms, on the average, have one tractor per farm while large farms have two. This means a tractor-land ratio of 1 : 12 among small farms as compared to 1 : 25 among large farms. This explains why small farms have higher investment in machinery per hectare. Furthermore, this indicates that possibilities of fuller tractor use is better among large farms than among small farms.

Land utilization

On a per hectare basis, large farms employed lesser labor compared to the small farms.

*Walth Schnefer kchnort, Farm Mechanization in the Developing Countries, Economics, Vol. I (Biannual contribution of Recent German contributions to the Field of Economic Science), p. 88.

Table 5. Partial budget, better land preparation by employing more machine days versus more man-days on weeding per hectare, large farms, Victorias Milling District, Philippines, 1971-72.

a. Increase in cost per hectare (3 tractor days)		a. Decrease in cost per hectare
1. Depreciation per day of use	₱4.49	1. Labor saved in weeding = 13man-days/ha. ₱7.00/man-day = ₱91.00
2. Interest on capital per day (6% per annum)	₱4.04	
3. Repairs and maintenance	₱4.12	
4. Fuel consumption/day	₱6.32	
5. Wage of operator/day	₱7.50	
(Total per day)	₱26.47	
Total increase: ₱26.47 × 3	= ₱79.41	
b. Decrease in return per hectare-Nil		b. Increase in returns per hectare-Nil
A. Total of a and b = ₱79.41		B. Total of a and b = ₱91.00
Net gain (B − A) = ₱11.59/hectares		

Large farms employed 142 man days per hectare, while small farms employed 162 man days.

Among the sugarcane farm operations, weeding is the most labor intensive, about 35 man days per hectare, or 22 per cent of total labor input among the small farms, and 22 man days among large farms, or 15 per cent of total labor input. Lesser weed population on the farm will decrease labor for weeding substantially, hence, labor expenses. The weed population can however be effectively decreased by proper land preparation.* Large farms employing more machine days on land preparation prepared land more thoroughly than small farms; therefore, the former needed lesser labor input on weed control. A simple budget analysis showed that large farms incurred lower cost by preparing land more thoroughly, thus employing lesser labor on weeding (**Table 5**).

Land, Labor and Capital Use Efficiency

Size and productivity per hectare

Land being a limiting factor in sugarcane farming should be used as efficiently as possible. For comparison, the amount of output

*N.R. Deomampo, An Economic Analysis of the Effect of Tillage, Weeding, Nitrogen Interaction on Yield of Rice M.S. Thesis, UPCA, 1963 (Unpublished).

Table 6. Relationship between size and productivity in some sugarcane farms in Victorias Milling District, Philippines, 1971-72.

Size/ Productivity	Area (ha.)	Production ※ (piculs/ha.)
Small		
Low	10.32	67.46
Medium	10.71	87.51
High	16.63	103.44
All small	12.55	87.82
Large		
Low	41.65	71.26
Medium	52.37	91.85
High	58.22	113.64
All large	50.74	92.27
All farms	32.15	90.00

※ Arithmetic mean was used because: (a) values among productivity groups are quite normal, i.e., without extremely low and high values; (b) for computational feasibility; and (c) computation of t values involved independent average productivity per hectare.

derived from an area of land is good indicator of how efficiently land is utilized among small and large farms.

Large farms were found to be relatively more productive than the small farms (**Table 6**). Low, medium, and highyielding farms on the large farm group are consistently more productive in terms of piculs sugar per hectare than the low, medium, and high yielding farms among the small farms respectively. A t-test showed that the difference in productivity between small and large farms is significant at 15 per cent.

Labor productivity

Labor may not be as limiting as the other resources in sugarcane farming in the sense that it can easily be had in any desired

Table 7. Returns per man-day of labor among and small farms, Victorias Milling District, Philippines, 1971-72.

Item	Small farms	Large farms	All farms
Number of farms	45	45	90
Receipts		(per hectare)	
Piculs sugar	87.82	92.37	90.04
Value in pesos	6,000.74	6,304.81	6,152.43
Expenses:			
Cash			
Fuel and oil	219.75	164.37	174.10
Fertilizer and chemicals	559.36	519.41	527.28
Repairs and maintenance	256.37	107.16	150.21
Rents and taxes	272.01	233.45	250.23
Supplies	13.19	6.78	7.92
Irrigation fee	—	65.38	65.38
Interesting on operating capital (12%)	158.48	131.58	141.01
Total Cash Cost	1,479.16	1,228.13	1,316.13
Milling			
Value of share for milling	2,160.27	2,269.73	2,211.87
Non-Cash Depreciation	390.13	245.62	274.05
Total Non-Cash Cost	390.13	245.62	274.05
Total Cost (Excluding labor exp.)	4,029.56	3,373.56	3,802.05
Farm Income	1,971.18	2,561.33	2,350.38
Interest on Capital Investment (6%)	785.35	814.04	799.69
Return to Man-Labor	1,185.83	1,747.29	1,550.69
Total Labor Input (Man-days)	162.24	142.18	144.35
Returns per man day of labor	7.31	12.29	10.74

quantity for farm operations. Its cost however has been continuously rising over the years. This necessitates the increase in efficiency of labor employed on the farms, i.e., to increase the output per unit of labor input to compensate for the increase in its cost.

Return per man day of labor was 12.29 among large farms as compared to 7.31 per man day among small farms (**Table 7**). Three factors account for the difference in labor productivity. Firstly, large farms used more machine days, making labor more efficient. Secondly, division of labor was more evident among large farms than on small farms. Among large farms, rarely did an "encargado" devote all his time in supervision. He also did bookkeeping and accounting. A tractor operator did not likewise devote his time primarily in driving a tractor. He also worked as a mechanic. Among large farms, each personnel was assigned to a specific job so that each developed a unique skill on his job and thus, higher efficiency was attained. Thirdly, laborers among large farms were provided with relativoly better facilities and benefits than those among the small farms. These include the house, light and water facilities, hospitalization and recreation.

Percent return to capital investment.

Capital has become more limiting because of its increasing cost. One way of measuring the financial success of a sugarcane farm, being capital intensive, is by looking into how much is earned by capital invested on the farm during a year of operation. The per cent return to capital indicates how efficient the farm is in recovering the capital invested on the farm. It also provides a basis in determining whether capital has been wisely invested. If the market rate of interest is greater than the per cent return to capital, it would have been better in the short-run if the capital invested on the farm were placed in the capital market.

The difference between the total receipts and total cost, excluding the cost of the use of capital investment, is what capital earned on the farm. Capital invested on large farms earned 1,387 per hectare while capital invested on small farms earned 64 (**Table** 8). Thus large farms got a rate of return of 10 per cent compared to 0.5 per cent on the small farms.

Summary and Conclusions

It is apparent from the study that the three major factors of production-land, labor, and capital-earned higher returns on the large farms than on the small farms; this indicates that large farms are more efficient producing units. Notably, there is a big difference in the per cent return

Table 8. Comparative returns to capital investment among large and small farms, Victorias Milling District, Philippines, 1971-72*

Item	Small farms	Large farms	All farms
		per hectare	
Receipts:			
Picul sugar	87.82	92.27	90.04
Value in pesos	6,000.74	6,304.81	6,152.43
Expenses (pesos)			
Cash			
Salary to permanent labor	490.97	338.79	367.82
Hired labor (contractual)	821.86	709.91	732.11
Fuel and oil	219.75	164.37	174.10
Fertilizer and chemicals	559.36	519.41	527.28
Repairs and maintenance	256.37	107.16	150.21
Rents and taxes	272.01	233.45	250.23
Supplies	13.19	6.78	7.92
Irrigation expenses	—	65.38	65.38
Interest on operating capital	315.96	257.43	273.00
Total Cash Cost	2,948.97	2,402.68	2,548.05
Milling			
Value of share of millings	2,160.67	2,269.73	2,211.87
Unpaid family labor[b]	436.94	—	436.94
Depreciation	390.13	245.62	436.94
Total Non-Cash Cost	827.07	245.62	710.99
Total Cost	5,936.71	4,918.03	5,470.91
Return above all cost			
(Return to capital)	64.03	1,386.78	681.52
Total capital investment	13,089.23	13,567.17	13,328.20
Per cent return to capital investment	0.49	10.22	5.11

to capital.

Labor had higher returns per man-day on large farms because of three reasons. First, large farms used more machine days, making labor more efficient; secondly, division of labor was more evident among large farms than on small farms; and thirdly, laborers among large farms were provided with better facilities and benefits than laborers among the small farms.

The big difference in the return to capital, on the other hand, seems to be explained by : (a) the low productivity of small farms resulting to lower receipts as compared with the large farms; (b) the higher costs incurred by the small farms, which result from higher labor employment, and higher investment on less fully utilized machinery; and (c) the unwise use of capital investments. When the tractor, for example, is not needed in vital farm operations, it is used to transport laborers to nearby towns. This might explain high expenses on fuel and oil, and repairs and maintenance on small farms.

Finally, the difference in productivity per unit of land seem to be explained by the difference in management capabilities among farm administrators. The productivity of large farms employing administrators is significantly higher than the productivity of small farms employing administrators. Moreover, a greater number of the large farms employ yield-increasing practices like seed-piece treatment, selection of planting materials, and sub-soiling.

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NewsLetter

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Yoshikuni Kishida
Head of Directors

Evaluation of Small 4-Wheel Riding Tractors for Developing Countries



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Introduction

During the past few years there has been a growing concern throughout the world regarding the adequacy of food supplies to meet the demand of an ever increasing population. In view of this situation, efforts are being forcused on means for increasing production through more effective use of small farmers.

One way to increase production is through proper mechanization. Mechanization in the broadest sense includes the use of hand operated tools, animal drawn equipment and mechanical powered equipment. All three levels of mechanization may exist side by side depending on the situation. It is estimated that more than half of the cultivated area of the world is still tilled by hand tools and animal drawn equipment. Some individuals believe that animal power will continue to remain for years as an important level of mechanization for agricultural production. However, in certain areas of the developing world where land is scarce, some concern and consideration are being given to utilizing land for human food production that is now required for providing food for work animals. Thus, either human or mechanical power would replace animal power under these circumstances. Previous studies have shown that mechanical power and further mechanization can contribute to intensified farming systems such as making operations more timely and effifient which leads to increased yields. Also, double cropping can be practiced through improved mechanization.

The work reported in this paper is the result of encouragement and support created by an agency known as the INTERLINK. It is supported by Christian businessmen in the U.S. who have an interest and desire to support programs in developing countries and which are oriented toward a business venture such as farming. One of their approachs is to organize an association for farm assistance in the country which provides management training and on-the-farm advisory assistance through a demonstration/training center where mechanized equipment is introduced. To begin with a simple small tractor with associated equipment is introduced trough the training ceter. Once the trainee has been through the center with various farming operations and completed the requirements then he is given assistance to operate similar equipment on his own farm.

Self Help and Agro-Util are two small companies in the U.S. who have been interested and involved in the work by Interlink. Since very little data exists on what can be expected in the way of performance output from a simple small 4-wheel tractor, a few preliminary tests were conducted at Kansas State for the purpose of providing some information that could be utilized in planning a system of farming with this size class of tractors.

At the outset it should be pointed out that the intent of the original design of these tractors was to meet the following criteria:

1. Simple in construction, safe and easy to operate.
2. Reasonably rugged.
3. Clearance and wheel tread sufficient to meet most cropping system requirements.
4. Maneuverable.
5. Los initial cost.
6. Most of its parts could be assembled or even fabricated in the country.

7. Engine would be gasoline, diesel or kerosene and easily replaced.
8. It can be operated by people with very little mechanical background.
9. Repair parts available through a local dealer in the country.

A wide selection of small field equipment can be adapted to either tractor. A trailer is available so that the tractor can be used for hauling products to market and equipment to the field. The power unit can be used for stationary operations such as driving a thueshing unit, pumping irrigation water and for operating spraying equipment.

Equipment and Procedure

The tractors used in the study were equipped with the following engines:

1. Agri-Util had an air-cooled Wisconsin Model S-12D which develops a maximum horsepower of 12.5 at 3600 R.P.M.
2. Self Help had an air-cooled Wisconsin Model EY44W which develops 10.5 horsepower at 3600 R.P.M.

The tractors are equipped with 7.50 × 16 tires on the rear and 4.00 × 12 on the front. They both utilize the V-belt as first speed reduction from the power unit to the transmission and utilize a hand operated mechanical lift for raising and lowering the hitch. The Self Help uses a special hitch which needs to be adapted to the implement being drawn. The Agro-Util utilizes a 3-point hitch which is adaptable to a variety of 3-point hitch type tools and is equipped with individual disc type brakes to facilitate turning in loose soil.

The promary tillage tools used for the test were the 12" moldboard plow, 48" single disk harrow and a ridger (lister). The tests were conducted on a silty clay loam to clay loam soil in field areas ranging in size from 0.13 acres up to 0.86 acres and the lengh of plots ranged from 185 feet to 365 feet.

Fuel consumption was determined by filling the fuel tank to a predetermined level at the beginning of the operation and measuring the amount of fuel required to refill tank at end of field operation performed, noting the time required and area covered.

The total time recorded for each operation includes the time for turning, adjustments and stoppages due to clogging.

All operations were conducted in second gear for each tractor. The travel speed in this gear is near 2.5 miles per hour. The governed engine speed was near 2800 R.P.M.

Drawbard pull tests were conducted with the Agro-Util by means of direct reading hydraulic type pullmeter connected between the drawbar and the sled used for loading purposes. One of the problems that is frequently encountered with the small tractor is the high degree of slippage due to the tractor's light overall weght. Therefore, dratbar pull tests were conducted to determine what can be expected without excessive slip for different levels of weight on the rear wheels and each gear available.

The tests were conducted on a rather firm soil which was actually an old road bed and not been cultivated for many years.

Results of Performance Tests

The results of field operations for plowing, ridging and disking are shown in **Tables 1 and 2** for the Self Help and Agri-Util, respectively.

It is of interest to note that a wide range of values were obtained because of such factors as soil and mosture conditions, different operators, and degree of wheel slippage at the time the operation was performed.

Based on the data in **Tables 1** and **2**, fuel consumption for plowing could vary from a high of 4.5 gallons per acre to a low of 2.3 grllons per acre depending on the operating conditions. For a single disking operation, a high of 0.69 gallons per acre to a low of 0.52 gallons per acre were obtained. Whereas. double disking required a high of 1.28 gallons per acre to a low of 0.82 gallons per acre.

Ridging, which may be known as listing in the U.S. and practiced in some parts of the world for planting on the ridge, required a high of 0.90 to a low of 0.82 gallons per acre.

With regard to area covered, it may be noted in **Tables 1** and **2** that the time required for plowing arce varied from 5.90 hours to a low of 4.35 hours. This value is affected greatly by the slze and shape of filed, and stops made to adjust or clean out equipment. In other words, this equipment could be expected on the average to plow about 2 acres per 10-hour day.

The disking operation (single) varied from a high of 1.02 to a low of 0.96 hours per acre, or approximately 10 acres per 10 hour day, whereas double disking operation resulted in a high of 1.24 and a low of 0.94 hours which is approximately 9 acres per 10 hour day.

Ridging was done at a rate as high as 2.50 hours per acre and as low as 1.79 hours per acre or approximately 5 acres per 10 hour day.

If one considers the fuel consumption based on the rated maximum horsepower of the engine for operations performed in this study, the average is near 0.21 of a liter of gasoline for each maximum rated horse power.

Table 3 shows the results of the drawbar pull tests for the Agro-Util tractor. It is interesting to note that there is a remarkable increase in drawbar pull

Table 1. Performance Data for the Self Help.

Date	Operation	Time Required		Fuel Consumption				Soil Conditions and Remarks
		Hrs/Acre	Hrs/Ha	Gal/Hr	L/Ha	Gal/Ac	L/Ha	
10/2/74	Plowing	4.71	(11.63)	0.74	(2.80)	3.49	(32.63)	6" depth. Soil dry. Disked wheat stubble.
10/4/74	Plowing	5.44	(13.44)	0.43	(1.63)	2.31	(21.60)	4" to 6" depth. Disked wheat stubble and very dry-trouble with plow getting clogged.
4/29/75	Plowing	5.07	(12.52)	0.48	(1.82)	2.43	(22.72)	Ground had gone through winter unplowed. Ideal soil conditions. 6" to 7" depth.
11/20/74	Disking (double)	1.24	(3.06)	1.03	(3.90)	1.28	(11.97)	Double disking plowed grounds.
5/6/75	Disking (single)	0.96	(2.37)	0.62	(2.35)	0.60	(5.61)	Single disking plowed ground after raind but on dry side.
12/5/74	Ridging	2.50	(6.18)	0.36	(1.36)	0.90	(8.41)	Area had been plowed and disked. Wheat stubble caused some clogging.
4/30/75	Ridging	1.79	(4.42)	0.49	(1.85)	0.87	(8.13)	Ridged after single disking unplowed ground.
5/1/75	Ridging	1.79	(4.42)	0.46	(1.74)	0.82	(7.61)	Splitting ridges previously formed.

Table 2. Performance Data for the Agro-Util.

Date	Operation	Time Required		Fuel Consumption				Soil Conditions and Remarks
		Hrs/Acre	Hrs/Ha	Gal/Hr	L/Ha	Gal/Ac	L/Ha	
11/22/74	Plowing	5.70	(14.08)	0.79	(2.99)	4.50	(42.07)	4" to 6" depth. High moisture in disked wheat stubble. Excessive wheel slippage-No water in tires-concrete wheel weights only.
4/30/75	Plowing	5.90	(14.57)	0.49	(1.85)	2.91	(27.20)	Ideal soil conditions 7" to 8" depth. Water in tires and wheel weights.
10/8/75	Plowing	4.35	(10.74)	0.92	(3.48)	3.99	(37.30)	6" to 8" depth. Moisture content satisfactory. Wheat stubble previously disked but quite firm.
5/21/75	Disking (single)	1.02	(2.52)	0.61	(2.31)	0.62	(5.80)	Disk set at maximum angle-soil dry on top and ground plowed and disked once previously.
5/21/75	Disking (single)	0.99	(2.44)	0.69	(2.61)	0.69	(6.45)	Disking followed operation above. Soil very loose on top.
10/8/75	Disking (double)	0.94	(2.32)	0.91	(3.44)	0.85	(7.95)	Disking previously disked wheat stubble.

Table 3. Drawbar Pull and Horsepower Versus Wheel Slip for Different Weights on Rear Wheel in Second Gear.

Drawbar Pull		Static Weight Rear Wheels		Wheel Slip %	H.P.	Kw
Lbs.	Kg.	Lbs.	Kg.			
440	200	992	451	4.35	3.29	2.45
740	336	1,122	510	17.22	4.61	3.44
945	430	1,261	573	19.52	5.54	4.13
*990	450	1,408	640	16.74	5.56	4.15

NOTE: Moisture content of soil 6.1% on dry basis. Basic rear weight of tractor is 992 which includes weight of operator, water in tires and 105 lbs. of concrete wheel weight.

* Engine was overloaded and not up to full governed speed of 3,600 R.P.M. for maximum horsepower.

with an increase in weight on the rear wheels. Approximately one pound of weight on the rear wheels produced approximately one pound increase in drawbar pull for the conditions encountered. In all cases, the maximum slip was less than 20 percent.

No attempt has been made in this paper to evaluate the tractor's expected life and repair costs bacause of the limited amount of time the tractors were acturally used in this study. Generally, it is belived that 2000 hours is a reasonable life for this class of equipment particularly when it is to be used in a developing country by less experienced personnel who have very little mechanical background.

In order to possible exted the life of the power unit, it has been proposed that these engines be operated at a governed speed between 2500 and 2800 R.P.M. which is still above the maximum torque R.P.M. for the engine.

In general it can be said that this class of tractors, 10-14 H.P., has ample power for the tillage tools used but the limiting factor is wheel slippage when not enough weight is on the traction members.

In Nigeria, particularly the northern part, where general farming is practiced and primarilly row crops are grown such as millet, corn (maize), guinea corn, cotton, groundnuts and cowpeas, it was observed that one man and his familly, an average size of six, can handle approximately 3 acres per year. A man and his family with a team of oxen and good management could handle up to 15 acres. With the small tractor it is believed a man and his family could handle 25 to 30 acres with good management. For smaller areas the possibility exists that the owner could do custom work for his neighbors or a group of small farmers could jointly own the equipment on a cooperative basis.

Thus where there is need to increase food production the small farmer could possibly expand his operation by means of the small tractor provided some means or scheme can be worked out to handle the high initial investment of equipment. Another factor which is beginning to show up in developing countries is the migration of the young rural people to more lucrative jobs in the urban areas as the country becomes more industrialized. This is creating peak labor shortages in rural areas particularly at weeding and harvest time. *(Continued on page 64)*

Traction Assist for a Two Wheeled Paddy Tractor

by
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Introduction

Traction problems in saturated rice soils have been a major limitation to the adaptation of Mechanization in rice producing Asian countries. Sinkage of agricultural machinery has been a topic of intensive research in the past and will continue to be in the future. The main problem in mechanizing paddy cultivation is the development of a suitable traction device for operation in saturated soils. Soft soils with low trafficability have resulted in excessive sinkage of tillage machinery. Considerable time and energy are lost in attempting to cultivate in soft soils, because of the extra time necessary to remove sunken machinery from the fields. The drudgery involved, as well as the infeasibility of using tillage machinery in soft boggy fields have led farmers to eigher under utilize or completely abandon the cultivation of some land.

The objective of this saturated soil mobility study was to find a suitable traction device that would provide effective movement of tillage machinery in soft saturated rice soils. Good traction would permit tillage operations to be performed at the optimum time with greater effectiveness and maximize labor, time and energy inputs.

An anchored cable and winch principle was used as a traction aid to move a 5 hp walking tractor through saturated soil. The tractor winched itself through the saturated soil on a cable anchored outside the field. This winching principle was used to move the tractor in a simulated rice field on a research plot at Michigan State University. The traction device proved successful and the tractor moved through the field at a speed equal to its movement on concrete. Without the winch the tractor often mired itself helplessly in to the mud.

Construction of the Traction Winching Device

The basic principle of the mechanism was to drive the winch from the PTO shaft of the tractor. This required reducing the speed of the PTO shaft so that the cable takeup speed on the winch matched the ground wheel speed of the tractor. This was necessary for proper operation of the winch with continued tension on the cable. A half inch Manila rope was used instead of a steel cable. The rope provided more friction between the surface of the winch drum and was less expensive than a steel cable of similar strength.

The speed of the rope moving onto the winch had to be designed to be equal to the wheel travel speed of the tractor at all times. If the rope take up was too fast, the tractor would be dragged through the mud without allowing for any wheel assistance. If the rope ran too slowly, too much energy was lost through unnecessary wheel slippage and occasionally a slack rope. To achieve proper take up speeds for the rope, travel speeds on a concrete

※This paper was prepared for and presented at the anual national meeting of ASAE at Lincoln, Nebraska, June 28, 1976 at a technical session sponsored jointly by the ASAE International Relations Commitee and the Division of Power and Machinery.

Table 1. Travel speeds in relation to Engine and PTO rpm. for Different Gears.

Engine	Gear	PTO rpm.	Time to travel 24 ft. in sec.	Travel Speed ft/mi.
950	1 low	45	63	22
	2 low	160	15	96
	1 high	71	40	36
	2 high	259	10	144
1200	1 low	55	50	28
	2 low	205	12	120
	1 high	85	30	48
	2 high	330	8	180
1500	1 low	70	40	30
	2 low	—	—	—
	1 high	110	25	57
	2 high	—	—	—

Table 2. Winch speed and PTO/winch Ratio in Relation to rope speed and engine rpm.

Engine	Gear	Rope travel speed ft/m.	Winch speed rpm	PTO rpm	PTO/winch rpm ratio
950	1 low	22	18	43	2.24
	2 low	96	77	170	2.33
	1 high	36	28	70	2.42
1200	1 low	28	22	55	2.40
	2 low	120	96	205	2.12
	1 high	48	38	85	2.20
	2 high	180	140	330	2.28
1500	1 low	36	28	71	2.41
	2 low	—	—	—	—
	1 high	57	46	100	2.59
				Mean Ratio	2.31

floor for different gear ratios and engine speeds were measured. **Table 1** shows the travel speed in ft/min, and the PTO rpm for different engine speeds and gear ratios.

Travel speeds obtained from the above table, were used as the rope take up speeds for the different gear ratios used. The rope speeds depended on the revolutions per minute of the winch as calculated from formula (1), normally used to calculate the velocity of belt speeds on a pulley; $V = \frac{D\pi N}{12}$ (1) where V = velocity of the belt in ft/min, D = diameter of the pulley in inches, N = rpm of pulley.

A capstan winch was used for this construction. The diameter of the winch was 4.75 inches in accordance with the manufacturers specifications. The pulley rpm (the winch rpm in this study) was then calculated and tabulated, **Table 2.** Since this study was to test the principle of the traction device, components for the device were taken from available parts in the Agricultural Engineering Department and so designing for exact specification were made. An average reduction of 2.30 : 1 was used in order to match the available sprocket wheels to facilitate reductions in speed between the PTO and winch.

The diameter of the driving pulley was calculated keeping the diameter of the driven pulley at a maximum of 8″ for ease of construction. The closest available size for the driven sprocket wheel was 3.5 inches.

To transmit power the PTO to the winch, a 90° drive gear box with a ratio of 1 : 1 between the horizontal and verticle gear arrangements was used. the reduction in speed was only between the PTO and the input shaft of the gear box. The reduction was made by a 3.5 inch sprocket wheel at the PTO and an 8 inch sprocket wheel at the input of the gear box.

Braces and frames to support the extended PTO and gear box were constructed with 1/8 inch angle iron. Heavy gage metal was used for areas where higher forces were expected, so that the gear box had enugh support for the forces generated by the winch, **Fig.1.**

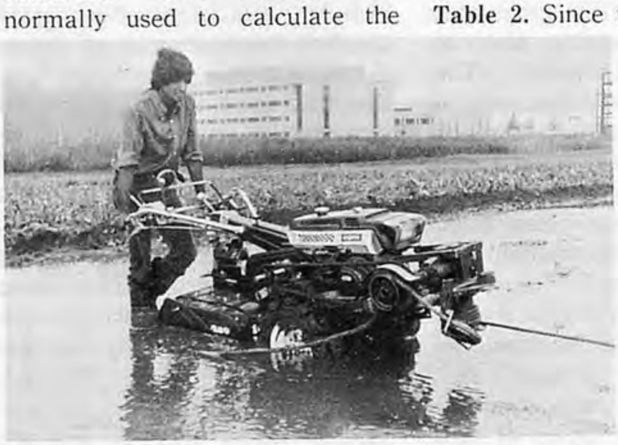

Fig.1. A view of the braces and frames used to support the gear box, extended PTO shaft and all other accessories.

Fig.2. A closer look at the winch assembly showing the change in direction of the rope by useing the pulley arrangement.

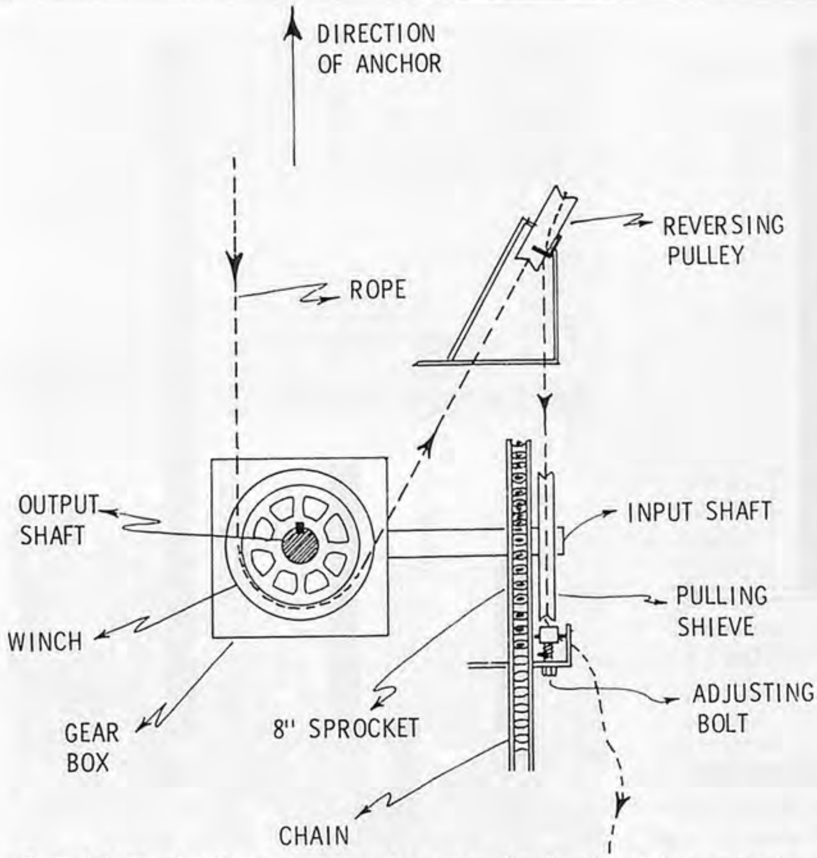

Fig.3. A sketch showing the method used to reverse the direction of the rope leaving the winch assembly.

To keep the rope tight on the back side of the winch a take up mechanism was designed and driven by the input shaft of the gear box. A 4.5 inch pulley was attached to the shaft and the direction of the rope was reversed by making use of a pulley arrangement shown in **Fig. 2** and **Fig. 3**. An idler roller was used to keep the pulley rope tight at all times, which made the slieve pull the rope at the same rate at which it came into the winch. The rope was then laid down on the ground without any tension.

Field Testing and Results

Traction tests were made with water standing at a level of 3 inches or more. The main test criteria was to determine the travel speed of the tractor in the saturated soil, with and without the winch. To determine the differences between soil conditions, travel speeds for different gear ratios and engine speeds were made on firm soil, saturated soil with the winch, saturated soil without the winch as well as on concrete. The results of the field tests are shown in **Table 3** and **Fig. 4. 5, 6.**

The tractor made little or no forward movement in the saturated soil. Excessive slip of the wheels in the mud caused the tractor to bog down. Adhesion of the mud and filling in between the wheel lugs caused the lugs of the wheels to be ineffective. Traction was therefore limited and the wheels did not provide the necessary power transmittal to the soil to bring about forward propulsion. An increase in engine speed did not affect further movement but caused the tractor to sink deeper, **Fig. 7.** Also the rotovator of the tractor did not provide enogh propulsion to move the tractor forwards.

With the use of the winch system the tractor was able to pull itself through the saturated soil, although at lower engine speeds (950 rpm) the power generated by the enine was not sufficient to prevent engine stalling. At higher engine speeds the movement of the tractor demonstrated a positive action by the winch in pulling the tractor through the saturated soil and thereby increasing its mobility. **Fig. 8** illustrates the lifting of the front end of the tractor when the winch was used which provided better rotovator blade-to-soil contact and improved its ability to provide extra propulsion. The use of the winch also provided a "cleaning" effect on the wheel lugs, thereby providing a better traction for the wheels.

Table 3. Average Travel Speeds on Different Surface Conditions for Varying Engine Speeds and Gear Ratios.

Engine Speed	Gears	Travel on Concrete ft/min	Travel on firm soil without Rotovator ft/min	Travel on firm soil with roto. ft/min	Saturated soil without winch	Saturated soil with winch
950	1 low	24	22	21	no movement	Stalled Eng.
	1 high	37	36	34	no movement	Stalled Eng.
	2 low	98	95	84	no movement	Stalled Eng.
	2 high	148	—	—	no movement	Stalled Eng.
1200	1 low	29	28	27	no movement	29
	1 high	48	47	45	no movement	47
	2 low	123	105	96	no movement	Stalled Eng.
	2 high	177	—	—	no movement	Stalled Eng.
1500	1 low	36	35	33	no movement	35
	1 high	58	56	54	no movement	56
	2 low	Speeds Too Fast				
	2 high	Speeds Too Fast				

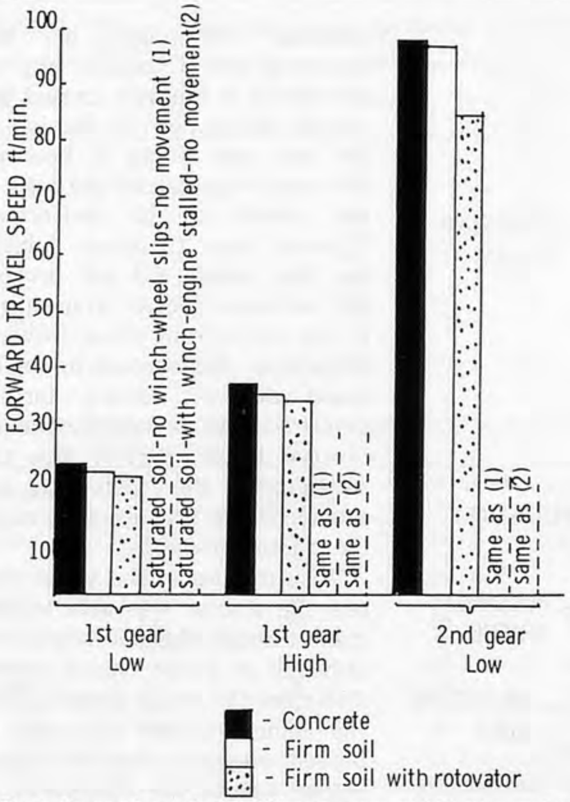

Fig.4. Forward speeds for different gears at 950 rpm engine speed, under varying surface conditions.

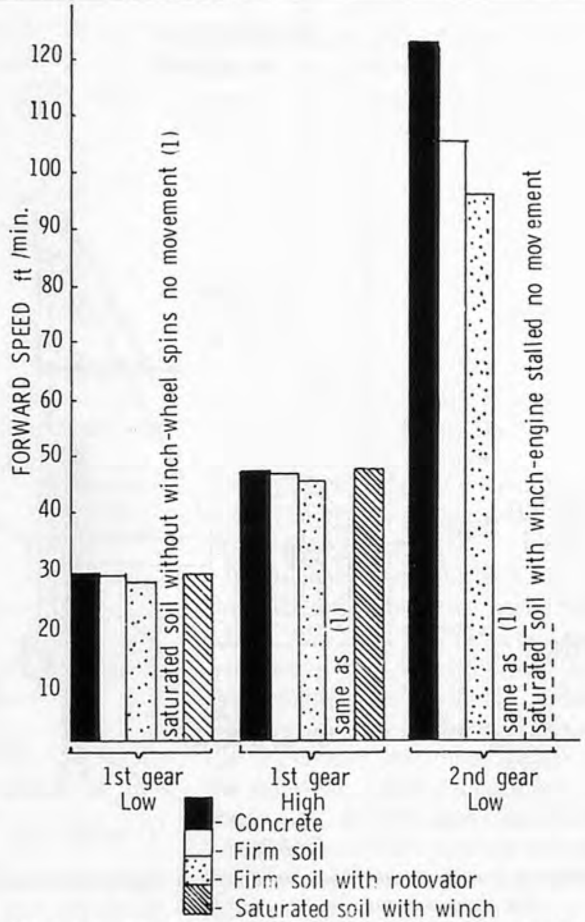

Fig.5. Forward speeds for different gears at 1200 rpm engine speed, under varying surface conditions.

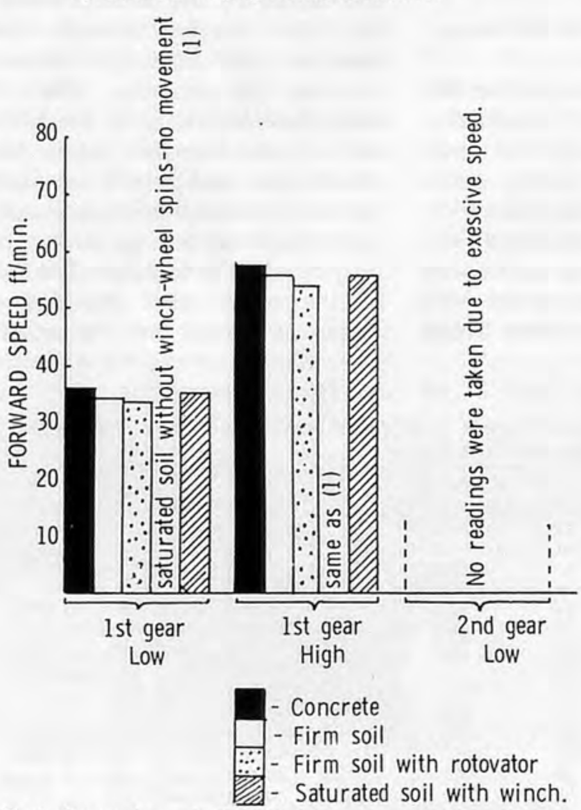

Fig.6. Forward speeds for different gears at 1500 rpm engine speed, under varying surface conditions.

The efficiencies in travel speeds were obtained for the different soil conditions, engine speeds and gear ratios, by taking the speeds on concrete as the condition of minimum slip or 100% efficiency, **Fig. 9.** The efficiency of tractor with the winch system is shown and compared to that of the tractor without the winch.

The most significant advantage of the winch system when compared to the conventional traction aids, is that the winch traction aid is entirely independent of the soil conditions. The conventional traction aids such as cage wheels, extendable lugs crawlers, half tracts, etc., all depend on surface texture, soil shear strength and the condition of the soil for satisfactory performance. The winch system however does

Fig.7. The tractor bogged down in the saturated soil without any further movement.

Fig.8. The front end of the tractor was lifted when the winch system was used.

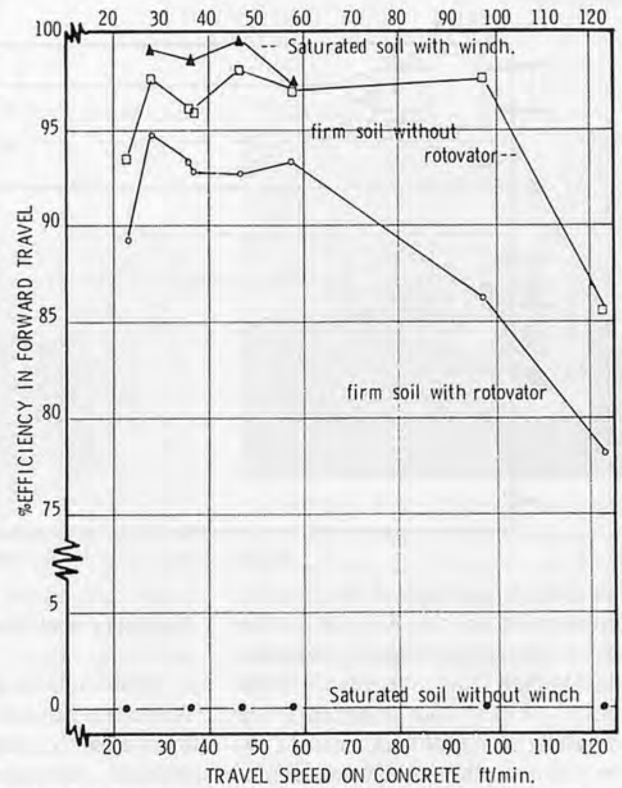

Fig.9. Efficiency in forward travel varying forward speeds. The speed on concrete is taken as 100% efficient.

not depend on the soil and is applicable in any soil type. Since little slip is experienced by this traction aid the only work it has to perform is to pull the tractor forwards aided by the minimal propulsion of the rotovator blades and the wheels.

Application of the System

Field sizes for rice cultivation in saturated soil are small. A one acre rice field would normally be divided into quarter acre blocks or smaller. Therefore anchoring of the rope to a point outside the field could easily be done by the operator. In most Asian countries labor is abundant. It is very common to see numerous people waching a tractor working in the field. Making use or labor to attach a rope to an anchor point would not be a problem, especially in family farms where extra help is available.

Fig. 10 represents a proposed method of application for the designed winching system, on a land area 40 ft wide and 100 ft long, using a tractor having a working of 3 feet. This system would make use of the operator to anchor the rope on to the edge of the field. The stakes are represented by a on the field in **Fig. 10.** These would be the anchor points. They could be either temporary fixtures or be permanent, in which case they may be used for future cultuvation seasons. The latter is preferred. The proposed plan is for permanent stakes, this reduces the time needed for driving the stakes into the ground. If permanent stakes on the land will permit the land to remain in cultivation rather than be abandoned for lack of tillage, it is a strong argument for this system. Considering the maximum utilization of land and the increased productivity, the additional expenditure of permanent stakes for inaccessible land seems to be a worth while expenditure. The stakes could be either made of strong wood with a ring attached to it, or made or steel. The construction of the stake would depend on the maximum pull exerted by the winch. A hook attached to either end of the rope would help in attaching the rope to the ring on the stake.

The tractor in this design could start on either side of the field and puddle the soil progressively toward the end of the field. The rope coming out of the take-up pulley is slack and does not need any tension. **Fig. 10** shows the

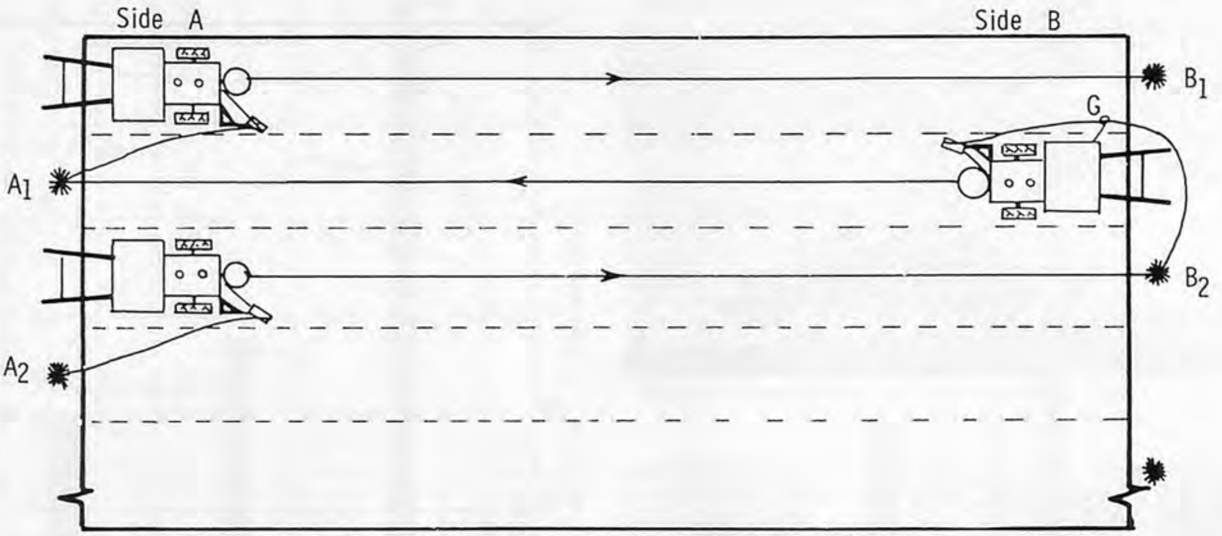

Fig.10. Schematic for the proposed application of the winch system.

tractor unit attached for its first movement to the side B of the field. The rope from the take-up is attached to A_1 on side A of the field. When the operator has moved B by pulling on stake B_1, he removes the rope from B_1 and then from the winch, by unwrapping it from the bottom of the winch and pulling it out from the take-up pulleys. The tractor is then turked and ready to move towards A by winching on the rope attached to A_1 at the far side of the field. The rope removed from B_1 is wrapped around the winch system, and sent through a rope guide (G) on the tractor and fixed onto the anchor B_2. The guide prevents the rope getting entangled with the tractor and the rotovator at any time during the operation. There will be plenty of slack on the rope leaving the take-up pulleys. When the operator moves to A_1, he removes the rope on A_1 and unwinds the rope on the winch system. The tractor is then turned to face B. The operator winds the rope around the winch system and attaches to end to A_2. The tractor is then moved across the field by pulling on anchor B_2. The process is repeated till the end of the field is reached.

Summary and Conclusions

Timeliness of tillage operations is a most important consideration in the mechanization of rice production. Efficient movement of tillage machinery in highly sturated rice soils would permit tillage operations to be performed at the optimum time with greater efficiency, while at the same time utilizing labor, time and energy inputs to a maximum.

The principle of the cable and winch, as a traction aid proved to be workable mechanism for efficiently moving a two wheeled tractor through soft soils with low trafficability. Adaptation of this mechanism in soft unproductive and abandon lands would help utilize limited land resources to a maximum, so as to contribute to the increase in total rice output of a nation. The extra expenditure incurred in adapting this system seems justifiable. ■■

Evaluation of Small...
(*From page* 58)

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Tractor

Kubota M4000···This tractor has 16 speeds forward and 4 speeds backward in a transmission so that you can choose a right speed in accordance with working. It is adapted the independence system which travelling and PTO system are divided. You can use a wide range of farm working implements because the two speeds PTO allows to use tractor at the high-speed of 1,000 r.p.m. besides the average speed of 540 r.p.m. The engine is a quite and less-vibrating 6-cylindered engine. It has wet disk brake built-in and exceeds in water-proof and mud-proof. The brake works smoothly even by stepping on the pedal softly. The seat is the parallel ring bucket type which is adjustable up and down, forward and backward. Every turning parts has a safety cover. It is applied a saftey-starter.

Specifications

Dimension: 3,330 × 1,620 × 2,290mm (L × W × H)

Axle : 1,975mm

Mim. ground clearance : 425mm

Weight : 1,780kg

Engine : cubic water-cooled 4 cycle diesel engine

Cylinder : 6

Exhaust : 2,231cc

Output(max.) : 45/2600ps/rpm

Clutch : dry independent system

Speed : forward 16 speeds, backward 4 speeds

Brake : wet disk brake

(Kubota Ltd. : 2-22, Funade-cho, Naniwaku, Osaka City, Japan)

Tractor

Mitsubishi D2500 II···Mitsubishi Tractor D2500 II has 15 speeds forward and 3 speeds backward, can efficiently manage various kinds of farm working implements and drive only 180m an hour with the low speed. Even a cold morning, the engine will start with one starting. Besides that, it is quiet and does not let out black smoke. You can operate in safe because a safty cver guards the engine. The cell-starter works after the clutch cuts.

Specifications

Dimension : 2,570 × 1,355 × 1,395 mm (L × W × H)

Mim. ground clearance : 410mm

Weight : 1,030kg

Engine : 2 cylindbr, water-cooled 4 diesel engine

Exahust : 1,302cc

Output : 25ps/2,500rpm

Speed : Forward 15 speeds, Backward 3 Speeds

PTO shaft speed : Independence 4 speeds

Width of rotary tiller : 1,500mm

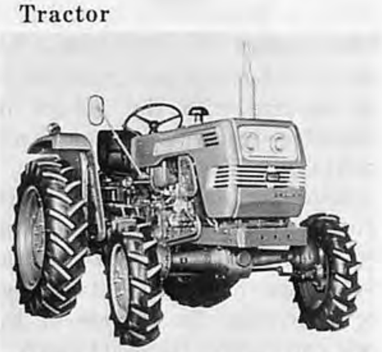
(Mitsubish-Kiki Hanbai Co., Ltd. : 2-2-3, Uchisaiwai-cho, Chiyoda-ku, Tokyo, Japan)

Tractor

Schlüter 3500 TVL···This tractor with 320hp was displayed at the exhibition of Munich in 1976. This tractor has SuperSilent cab and this cab which adopts hydraulic ram, is designed to incline backward. So, the adjustment is very easy.

(Motorenfabrik Anton Schlüter Munchen, 8050 Freising)

Tractor



Shibaura Tractor SD4000··· This tractor is installed a Strong IHI-Shibaura diesel engines, which combine power, durability and economy. Futher, this model has so many exclusive features as follow;

Transmission and PTO to fit your farming.

Provide a dual clutch system. This provides better and more convenient control of PTO-driven implements.

Easy-reach controls and easy-to-read instruments are grouped closely in front of a driver.

NEW PRODUCTS

Specification

Dimensions: Length 3,290mm Width 1,520mm, Height 1,925 mm&1,550mm

Minimum ground clearance: 385 mm

Weight: 1,565kg

Travelling Speeds: Forward 12 speeds, Reverse 4 speeds

Minimum turning radius 3,600mm

(Ishikawajima-Shibaura Machinery Co., Ltd.: Seiwa Bldg., Nishishinjuku 1-6-8, Shinjuku-ku, Tokyo, Japan)

Power Tiller

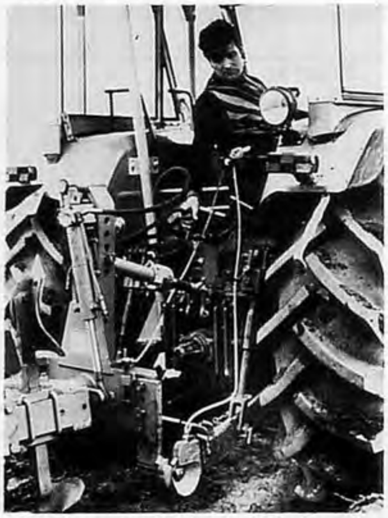
Mametora HMD-25···This machine has become much easier to operate with the aid of its patented overdrive and main and auxiliary pulleys.

With its overdrive and main and auxiliary mission, its eight-stage system for forward and four-stage for reverse two-stage respective by the change of the belt can control its speed easily.

Further, it is full of epoch-making mechanism such as a solid all-gear transmission and side clutch which can continue smooth movement in any kind of hard works without applying excessive pressure on its body and engine. Thus it is superior both in economy and durability.

(Mametora Agric. Machinery Co., Ltd.: 9-37, Nishi-2chome, Okegawa-shi, Saitama Japan)

Automatic Hitch



Walterscheid-Dreipunktkuppler ···This hitch which connects a tractor automatically with a working implement, was developped because both tractors and working implements are showing a tendency to grow larger. One can hitch, while driving a tractor on a sheet.

(Jean Walterscheid GmbH, 5200 Siegburg)

Power Sprayer

Asian HST-100A···This sprayer, adopting high pressure pump is efficient and economical. This is designed to be used with various purposes. So, in the case of fitting this sprayer on a hand-tractor, two hose reels can be attached to it.

Specifications

Length width height (mm) : 435 × 285 × 360

Weight (kg) : 26.8～27.2

Required power (Ps) : 3.5～4.5

Pressure (kg/cm²) : 21～35

Speed (rpm) : 700～1,200

Suction Capacity (l/min) : 47～93

Pulley outside dia (m/m) 240 (B—2)

(Asia Industrial Co.: 220, 3-Ka, Nowon-dong, Buk-Ku, Daegu, Korea)

Bush Cutter

Kaaz HB-KT18R···The Kaaz Reaper is so light as to perform swift and easy reaping. Its application ranges from weeding in a forest to rice harvesting. It has been developed through the advanced technology of the specialist reaper manufacturer.

Specifications

Driving system : Automatic centrifugal clutch spiral bevel gear

Reduction ratio : 16:19

Rotating speed of blade : 5050 rpm

Rotating direction : Anti-clockwise

Weight (main body) : 7.0kg

Dimension : 1655mm × 565mm × 460mm

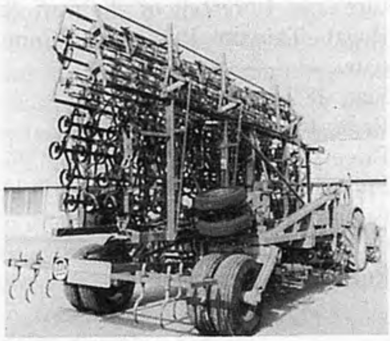
(Kaaz Machinery Co., Ltd.: 1-15, 5-chome, Higashi furumatsu, Okayama, Japan)

Combine Harvester

Sampo Rosenlew 410···This combine is made in Finland. The size of the combine is rather small (cutting width: 3m), com-

paring with others which are showing the trend to grow larger in order countries.
Working width : 300 cm
Cutting height : − 7 ··· + 8.5cm
Length:
—transport : 740cm
—threshing : 880cm
Height : 288cm
Engine-Valmet 411 BL : 2500 rpm 82 hp DIN
Driving speeds
—forward gearless 1.5—23km/h
—reverse gearless : 2.7— 7 km/h
Volume of fuel tank : 140 liters
Volume of grain tank : 2250 liters
Emptying height of the grain tank (from the ground)
Total Weight : 4200 Kg

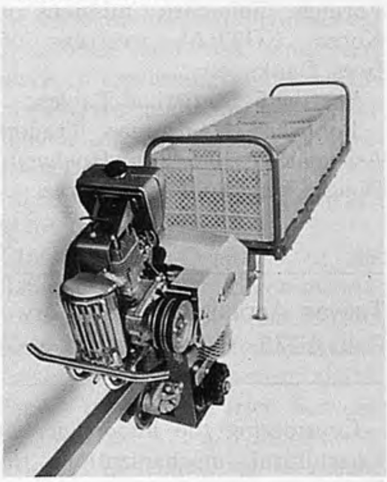
Springtine Harrow



Rau-Kombimat Super···This is a springtine harrow, 45 feet width, and is applied to tractors with 200-300hp. The utilization of hydraulic ram made it possible to fold up the harrow, as the picture shows. So, one can easily transport the harrow outside fields.

Specifications
Working width : 11.20m-14.00m
Equipment : 3FZ+SW, 3S+3W
Power : 200hp-300hp
Capacity : 8-10(hp/h)
Weight : 5626-6650kg
(Maschinenfabrik RAU HG: D7315 Weilheim/Teck)

Auto Wagon



Seiko Monorail MR-7···This Auto Wagon is a new type transport of orchard. It saves labor and improves the harvesting efficiency at the same time. It is safe. Besides, the handling is easy enough for anyone to move it.
(Body)
Dimention; 750 × 750 × 390mm
Weight; 85kg (including engine)
Carrying capability: 200 kg on 45 degree slope
Speed : forward 43m/sec backward 43.5m/sec
transmission : forward 1 step backward 1 step
(Wagon)
Dimention; 1884 × 685 × 550mm
Weight : 70 kg
(Rail)
Length; 6 m
Weight; 26 kg/6m
Pole Interval : 1.5 m
(Kyodo Seiko Co. Ltd.: 2059, Miyoshi, Okayama City, Okayama Pref., 700 Japan) ■■

NEW PUBLICATIONS

The Green Book

The 1976 edition of the Green Book of Tractors, Farm and Forestry Equipment has now been published and it has been found necessary to add an extra 64 pages to those in the previous volume, in order to cover the wide range of items available.

Complete revision has been carried out by Harry Catling, Head of the Mechanization Department of the Royal Agricultural College, Cirencester, a revision that has reflected tremendous changes in the tractor range and the many other machines of varying types illustrated and escribed throughout the book.

Whether used as a catalogue, reference book or directory, readers find the Green Book's unique presentation of invaluable help in keeping before them the whole range of essential equipment. Its use over the years has widened from the farmer or estate manager, to the plant hirer and local council authorities who intend buying machinery to assist them in their varied activites.

When capital outlay is being considered, the Green Book is the shop window for every type of agricultural product, a catalogue that is always ready-to-hand on one's desk in the office, or used in the workshop for its technical data and instruction.

The cost is £ 10.50., plus a small order charge of 62 pence for a single copy. Illustrated brochure and order form available from:—

Thomas Reed Industrial Press Ltd.,
36-37 Cock Lane,
London ECIA 9BY
or from booksellers.

1976 Korean Trade Directory

This book is the 18th annual edition of The Korean Trade Directory and the main contents of this directory are as follows.

Section 1. Korean Economy Today.

Section 2. List of Exports with Index.

Section 3. List of Imports with Index.

Section 4. List of Addresses: Registered foreign traders, Government office, Missions abroad of the Republic of Korea, Foreign diplomatic missions in Korea, KOTRA's overseas offices, Banks, etc.....

Section 5. Statistical Tables.

Published by Korean Traders Association, 10-1, 2ka, Hoehyon-Dong, Chung-ku, Seoul, Korea.

Taiwan Agricultural Machinery Gide 1976

Considering the importance of agricultural mechanization, the Taiwn government put a four-year program on the agricultural machinery promotion into practice from 1970 and appealed the promotion to the organizations concerned, academic groups, farmers groups and so on. The fruitful results came oue of the program. Through carrying the promotion program, we recoginized the necessity of the systematic and detailed materials concerned with comprehensive agricultural mechnization. This is the book which is collected and arranged the materials from that point of view. The main contents of Taiwan Agricultural Machinery Gide are followings.

* The retrospection and prospect of agricultural mechnization in Taiwan
* The kind of agricultural machinery which are widely spreading out.
* The introduction of manufacturers and dealers of agricultural machinery
* The address list of agricultural machinery manufacturers and staff concerned with agricultural machinery
* The outline of the loan for promotiong agricultural mechanization
* The management and dealing of agricultural machinery in Taiwan
* The examination rules for drivers of an agricultural tractor in Taiwan

Editor: The Ministry of Agriculture and Forestry of Taiwan & Rural Taiwan Publishing Company.
Size: 18.7 × 26.0cm
Page: 166 page
Price: NT $72
Published by Rural Taiwan Publishing Company
Cantact: Joint commission on Rural Reconstruction.

Energy for Agriculture
A Computerized Information Retrieval System

Much has been written about the explosion technical information being produced in most scientific fields. Researchers and other users of technical information are hard-pressed to keep up with current literature in their fields. A number of information retrieval systems have evolved to facilitate locating information as it is needed. One of these is the Basic Information Retrieval

System (BIRS).

BIRS is a set of fundamental programs designed to allow researchers to use their own locally based computers to construct and maintain a variety of information retrieval systems.

For the purposes of this particular project, each information element of bibliographic entry to be retrieved is placed into the computer's memory by means of a terminal outlet or punched cards. Each entry contains basic information about its source, the author, etc., plus a set of keywords or terms that are used to describe the content of the article or element. BIRS is then used to generate a book of all information contained in the entries plus author and keyword indices.

The present edition is little more than a draft. It was assembled hurriedly. The keywords are in many cases incomplete and possibly inaccurate. The project will continue, both in terms of adding new bibliographic entries and also by improving the keywords and possibly including brief summaries of some of the most relevant references. Errors in the present edition should be pointed out.

Compiled by B.A. Stout, Professor, Agricultural Engineering Dept., Michigan State University, East Lansing, Michigan 48824, USA.

Copies may be obtained by writing Dr. Stout. The price …$5.00. Make checks payable to Michigan State University.

Post-Harvest Crop Protection
Proceedings of the Planning Meeting, September 15-19, 1975

This program was initiated by the Planning Meeting held September 15-19, 1975, at the East-West Center in Honolulu.

The report of the proceedings presents an overview of the planning meeting and the recommendations formulated by the participants, with a discussion of the Food Institute's program plans for Post-Production Crop Protection, a compilation of the contributed papers, and the list of participants.

For those institutions and individuals who share a common interest in the problems of post-production crop protection, this report provides an indication of the opportunities for involvement in project activities, and may serve to encourage inputs to the cooperative planning and development of this important program.

The contents of this report are as foolows.

Introduction, Overview of the planning meeting, Recommendations (cereal grains, oilseeds, and legumes), Recommendations (fresh fruit and vegetables), Papers contributed (rice harvesting method, crop distribution, progress in technology to reduce losses in rice, research and information needs for post-harvest crop protection, the role of the sandy trout food preservation research laboratory in post-harvest crop protection, reducing post-harvest loss through food preservation, soybean drying, Ford Foundation-IRRI post-production projects in India, loss of food quality of grains during storage and milling), List of Participants.

Edited by Allan L. Phillips, Research Associate, East-West Food Institute, East-West Center, 1777 East-West Road, Honolulu, Hawaii 96822.

Solar Energy Applications in Agricultur Potential, Research Needs and Adoption Strategies

This report presents the results of a research project carried out by the Agricultural Experiment Station of the University of Maryland into the potential application of solar energy to specific agricultural operations. The project was performed under an agreement with the Agricultural Research Service of the United States Department of Agriculture with grant funds received from the National Science Foundation.

The main contents are as follow:

Application of Solar Energy to Grain Drying.
Application of Solar Energy to Tobacco Curing.
Application of Solar Energy to Peanut Drying.
Application of Solar Energy to Boiler Housing.
Application of Solar Energy to Swine Production.
Application of Solar Energy to Farm Housing.
Application of Solar Energy to Greenhouses.
Application of Solar Engrgy to Irrigation.
Types and Prices Fuel by Region.
Economic Implications of Achieving a Successful Conversion to Solar Energy in Agriculture.
Resource Allocation and Methodology Study.

Prepared for Agricultural Research Service, U.S. Department of Agriculture.

Agricultural Experiment Station, University of Maryland, College Park, Mary land, USA

NEW PUBLICATIONS

Mushroon Science IX (Part I)

The Mushroom Science IX (Part I) contains the papers presented at the IXth International Congress on the Cultivation of Edible Fungi, held in Japan in November 1974; most of them were read at the Congress and others were received from the authors who were not able to attend.

This publication includes 36 papers of Agaricus spp., 17 papers of Lentinus edodes, 10 papers of Pleurotus spp., 4 papers of Volvariella volvacea, and 14 papers of miscellaneous subjects, amounting approximately to 890 art pages with 380 photographs and figures.

This publication is wide in its coverage, ranging from the highly scientific papers which are of interest for researchers to the general papers on techniques of cultivation which are useful to growers, and it has also a wide range of special scientific fields, including biology, biochemistry, genetics, breeding and cytology, fruit-body formation, spawn, compost, casing, nutrient, pests and diseases, post-harvest treatments, production, etc. And new knowledges concerning the cultivation of so-called mycorrhiza-forming fungi, for instance, truffles, Tricholoma matsutake, etc., and also those concerning medical effects of Shii-ta-ke on human body are introduced.

There is much of interest, therefore, not only for pure mycologists but also for all concerned with any aspect of commercial edible fungi growing and industry.

There are 67 English papers, 9 French papers and 5 German papers, totaling 81 papers, with summaries in English, French and German. A complete list of papers, subject and author indexes, and a list of participants are appended. It is the largest and most comprehensive volume ever published (size: 22.5 × 14.5 cm).

The Mushroom Science IX (Part I) is available at the price of US$ 67 (plus US$ 4 postage for surface mail) from the Mushroom Research Institute in Japan, 8, Hirai-cho, Kiryu, 367, Japan.

Expected Date of Issue: September 30, 1976

Edited by K. Mori

The Mushroom Research Institute in Japan, 8, Hiraicho, Kiryushi, Gunma, Japan.

Nutrition and Agricultural Development Significance and Potential for the Tropics
(Volume 7 in Basic Life Sciences)

From a definition of the problem of nutrition to viable solutions to production, this book develops a feasible approach to the threat of severe food shortage. Dealing with the immediate problems of Latin America, international authorities evaluate the relationship between people, food, and environment and then redefine priorities in food and nutrition planning. Postharvest conservation, processing, and the distribution of foods are an integral part of this analysis, along with an assessment of the technological, ecological, social, and economic problems currently limiting the production of food and food supplies.

This volume also examines the agricultural, envionmental, and political factors that would play a crucial role in a worldwide commitment to nutrition and describes both immediate and long-range solutions that include

New ways of improving nutritional quality, including the use of protein concentrates

Prospects for stepping up production

Methods of changing patterns of consumption

Multiple-crop potentials

Genetics of food improvement

A Continuation Order Pan is available for this series. A continuation order will bring delivery of each new volume immediately upon publication. Volumes are billed only upon actual shipment. For further information please contact the publisher.

Edited by Nevin S. Scrimshaw and Moisés Béhar.

Associated Universities, Inc., 1717 Massachusetts Avenue, N.W. Washington, D.C. 20036, USA. ■■

Historical Review of the College/University Education in Agricultural Machinery & Mechanization in Japan

by
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Associate professor
Department of Agricultural Machinery
Faculty of Agriculture
Mie University
Kamihama-cho, Tsu City, Japan 514

Preface

The modern college/university education in Japan, surrounded by the sea, has shown a unique development system, compared with other countries.

Because of her policy of national isolation from 1633 to 1857, Japan was scarcely influenced by foreign countries, and she had to build a modern nation rapidly within several decades after 1859.

In the first part of the report, Japanese general development process of the whole education system will be described, including the historically important national background at that time.

Next, the historical development process of college/university education and research system in the fields of agricultural machinery and mechanization as a part of agricultural engineering field, will be explained.

In this report, the emphasis of description was put rather on the original development before World War II than on the progress of the post war reconstruction process.

This is the report added more details to the author's reply data to Mr. H. J. von Hülst, Chief, Agricultural Engineering Service, Agricultural Service Division, F.A.O. in 1975.

General Background of the College/University Education Development in Japan

Principle and Preparation of Establishment

In 1868, Japan had the Meiji Imperial Government after Tokugawa Shogunate of 224 years' national isolation policy.

The governmentary policy of the Meiji era consisted of two important bases of "Increase of Production and Establishment of Industries" and "Wealth and Armament of the Country". The government started to reform the old education system to westernized one.

In 1871, the Ministry of Education was established in Japan. Many schools under Tokugawa system were reorganized into the new system and were classified into Primary school and higher education institutions, under the "Promulgation of School System" enforced in 1872. This law was recorrected several times afterward, though.

In 1885, Mr. Arinori Mori took office of the first Education Minister. The government enforced four important imperial ordinances in 1886 as follows:

Primary School Ordinance; The compulsory education became a national duty. Its term was four years at the beginning but became six years later.

Middle School Ordinance; for standard high education different from vocational education.

Imperial University Ordinance; In general, Western-type university education in Japan began to be established with this ordinance, and the original institution of Tokyo University was founded in 1886.

Normal School Ordinance; for special education system of teachers' courses.

These four ordinances became the base of Japanese school system before World War II.

While these laws were being carried out, it was being discussed that the decision of the basic principle of moral education is important as well as intellectual one. When the conference of prefectural governers was held in 1890, they made a proposal that the basic principle of moral education should be established. At the end of 1890, "The Imperial Rescript on Education" was promulgated to all the schools through the Ministry of Education. This rescript was also the important principle of the prewar moral education in Japan.

From 1894 to 1903, additional important imperial ordinances were enforced as follows:

Higher School Ordinance (1894); for specialized education to the students who should enter the Imperial University

Girls' High School Ordinance (1895); Official education to girl students started, since "Middle School" was only for boy students.

Vocational School Ordinance (1899); for vocational education of high school level in engineering, agriculture, commerce, mercantile marine, and others

College Ordinance (1903); for higher education of engineering, agriculture, commerce, medical science, pharmaceutics, law, literature and so forth

These four ordinances also became the base of Japanese school systems and had influence on the determination of the prewar education system.

Actual Procedure of Development in Old Education System

The thirty-two years from 1886 to 1918 was the period of setting up the whole education system from primary school to college/university. This education system expanded and continued till the end of the Second World War. It is called "The Old Education System" in Japan.

After several trials of setting college/university education system, two basic systems were settled, as (a) and (b) of Table 1 and Fig. 1. Course (a) was to give the highest learning to students, while (b) was to bring up higher class professionals in the society and teachers in higher education fields.

These systems of college/university level had, as a rule, rather specific education for students. Each school, except primary school of compulsory education, had a strict entrance examination system. This system was for admitting only the students with intellectual and physical powers enough to accept as high education as possible, by

Table 1. Main schooling system of "Old Education System"

	School/University		
(a)	Primary School	6 years	14 years Basic Education
	Middle School	5 years	
	Girls' High School		
	Higher School	3 years	
	University	3 to 4 years	
(b)	Primary School	6 years	11 years Basic Education
	Middle School	5 years	
	Girls' High school		
	College	3 to 4 years	

Source: Ninety Years' History of School System, the Ministry of Education, Japan, 1964

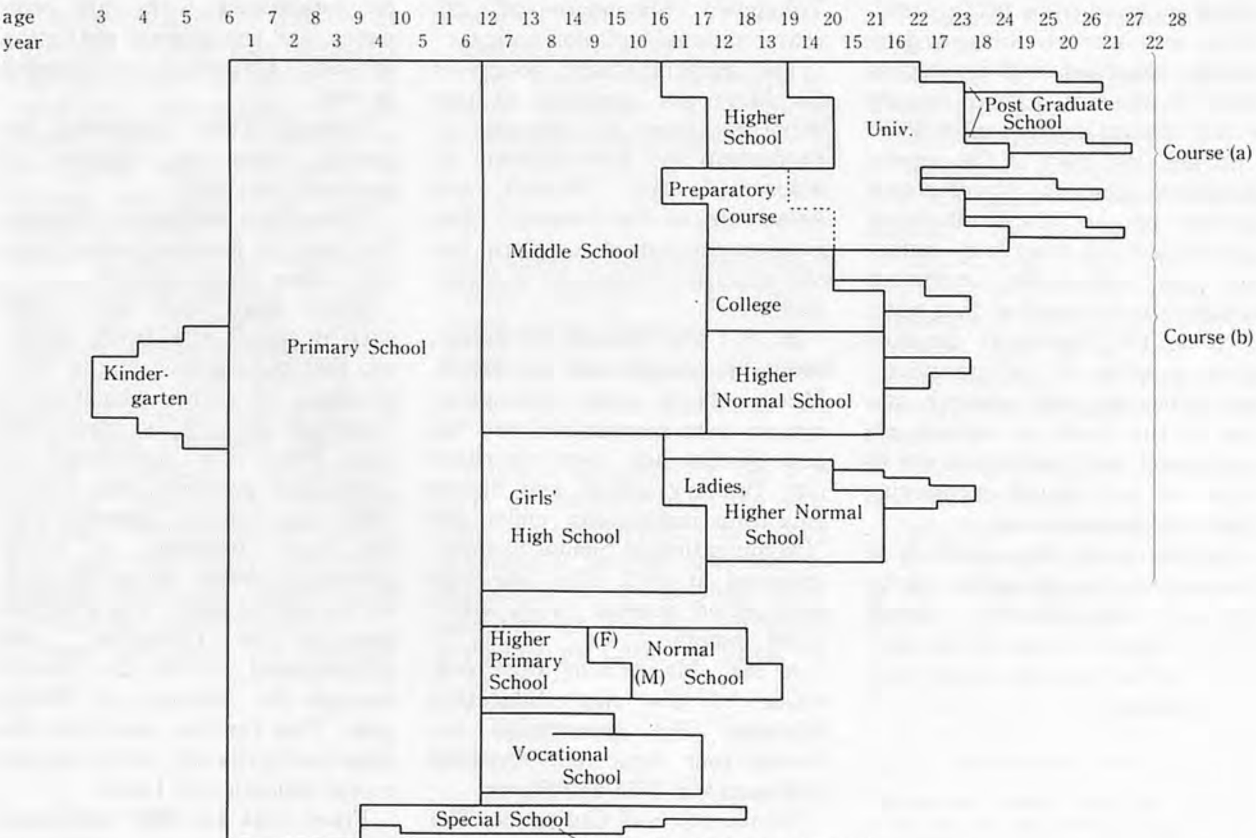

Fig.1. School system in 1919 to around 1942. (Source: Ninety Years' History of School System, Japan Ministry of Education, 1964.

spending the national budget efficiently. Because Japan was not so rich country at that time.

The fourth year students of middle schools and girls' high schools were permitted to take the entrance examination of upper schools with their seniors, if they were excellent.

The imperial university group is expressed in course (a) of **Table 1** and **Fig. 1.** From 1886, when the Imperial University Ordinance was enforced, to 1918, five imperial universities thoroughly equipped with the European-type institution of education and research were established all over the country as follows:

Imperial Univ.	Year
Tokyo	1886
Kyoto	1897
Tohoku	1907
Kyushu	1910
Hokkaido	1918

and afterwards;

Osaka	1931
Nagoya	1939

Table 2, 3 and 4 show the development of national schools. **Table 5 and 6** show that of public and private schools.

In 1920, the total number of students in the national colleges/universities including higher schools was about 34,000 among about 56,000,000 population of Japan. In 1940, it became about 88,000 among about 72,000,000 population.

The total number of students in all the higher education systems was about 47,000 students in 1920, and 150,000 students in 1940. As shown in the tebles, the education system at that time was not coeducational, as a rule.

Table 2. Increase of University (national)

Year	Schools	Students		Teachers	
		Male	Female	Male	Female
1890	1	1,312	—	169	—
1900	2	3,240	—	291	—
1910	3	7,239	—	625	—
1920	6	11,123	2	1,177	—
1930	17	16,239	29	2,854	—
1940	19	30,072	97	3,540	—

Source: Ninety Years' History of School System, the Ministry of Education, Japan, 1964

Table 3. Increase of Higher School (national)

Year	Schools	Students		Teachers	
		Male	Female	Male	Female
1890	7	4,356	—	300	—
1900	7	5,684	—	345	—
1910	8	6,341	—	351	—
1920	15	8,839	—	561	—
1930	25	16,395	—	1,094	—
1940	25	15,670	—	1,089	—

Source: Ninety Years' History of School System, the Ministry of Education, Japan, 1964

Table 4. Increase of Collage (national)

Year	Technical (Agriculture, Engineering, Commerce, etc.)					Education					Other Specialties				
	Schools	Students		Teachers		Schools	Students		Teachers		Schools	Students		Teachers	
		Male	Female	Male	Female		Male	Female	Male	Female		Male	Female	Male	Female
1890	3	813	—	54	—	2	94	105	32	11	2	117	42	30	2
1900	4	1,472	—	169	—	2	76	86	28	2	3	800	168	114	14
1910	13	5,899	—	482	—	2	480	323	110	—	9	3,988	354	268	15
1920	20	7,153	48	715	—	4	1,293	766	259	37	8	4,242	635	327	15
1930	42	17,759	66	1,769	—	4	1,875	897	271	28	8	3,530	559	352	23
1940	51	32,865	52	2,863	—	4	2,088	977	300	38	8	5,068	1,204	519	58

Note: These colleges did not belong to any university.
Source: Ninety years' history of school system, Japan Ministry of Education, 1964

Table 5. Increase of University (public and private)

Year	Public					Private				
	Schools	Students		Teachers		Schools	Students		Teachers	
		Male	Female	Male	Female		Male	Female	Male	Female
1890	—	—	—	—	—	—	—	—	—	—
1900	—	—	—	—	—	—	—	—	—	—
1910	—	—	—	—	—	—	—	—	—	—
1920	2	899	—	76	—	8	9,891	—	629	—
1930	5	2,560	—	211	—	24	40,725	52	2,874	2
1940	2	1,552	—	115	—	26	50,164	114	3,364	—

Source: Ninety Years' History of School System, the Ministry of Education, Japan, 1964

Table 6. Increase of College (public and private)

Year	Public					private				
	Schools	Students		Teachers		Schools	Students		Teachers	
		Male	Female	Male	Female		Male	Female	Male	Female
1890	—	—	—	—	—	—	—	—	—	—
1900	—	—	—	—	—	—	—	—	—	—
1910	2	443	—	55	—	2	383	—	52	—
1920	2	699	—	66	—	5	1,272	—	182	—
1930	2	568	—	38	—	7	1,613	27	158	1
1940	3	1,202	—	55	—	18	8,180	212	575	3

Source: Ninety Years' History of School System, the Ministry of Education, Japan, 1964

Development to New Education System

In 1947, two years after the war, new "School Education Law" and "National School Establishment Law" were enforced. The reformation was based on American type of 6-3-3-(4) education system, what is called "New Education System" in Japan as follows:

6 years: primary school
3 years: junior high school
3 years: senior high school

First 9 years of primary and junior high schools are for compulsory education. In colleges and universities, the new system started in 1949. As a result, the old imperial universities changed into national universities by name, and the colleges were put together by regional groups to establish at least one national university in every prefecture. The schooling term of college-/uniyersity is as follows:

junior college: 2 years
standard university: 4 years
medical course in university: 6 years

The diagram of the whole new education system is shown in **Fig. 2.**

As a rule the "New Education System" is a coeducational one, but it doesn't have a free admission system. The system of entrance examination is still being continued since the time of the Old Education System.

The difference of the new system from the old one is the wide spread of the education of high school and college/university level all over the country. In 1974, there were nine hundred and fifteen colleges/universities in all in Japan as shown in **Table 7.** Four hundred and ten of them were four-year universities and the others were two-year junior colleges. There were seventy-eight national universities in fourty-seven prefectures. About 2,000,000 students were in college/university level of education, while the total population of Japan was about 110,000,000.

Table 7. Status of schools in Japan (May, 1974)

		Schools	Teachers (thou.)	Students (mil.)
University	national	73	40.9	342.3
	public	33	5.5	49.9
	private	299	40.2	1,267.1
	total	410	86.6	1,659.3
Junior College	national	26	0.5	11.9
	public	47	1.5	17.6
	private	432	13.1	300.9
	total	505	15.2	330.4
National Nurse-teacher School		9	0.09	1.1
Higher Professional School	national	52	2.9	37.3
	public	4	0.3	3.9
	private	7	0.4	7.1
	total	63	3.7	48.4
Senior High School	national	3,687	168.0	2,966.1
	private	1,229	50.2	1,304.8
	total	4,916	218.2	4,271.0
Junior High School	national	10,241	226.3	4,585.0
	private	561	6.5	150.7
	total	10,802	232.8	4,735.7
Primary School	national	24,444	401.6	10,031.4
	private	162	2.5	57.4
	total	24,606	404.1	10,088.8
Kinder-garten	national	5,071	21.0	542.6
	private	7,614	60.9	1,690.5
	total	12,685	82.0	2,233.1
Special School	national	539	18.1	60.6
	private	13	0.2	0.8
	total	552	18.3	61.4
Grand Total		54,548	1,060.8	23,429.2

Source: Basic Report of School, Japan Ministry of Education, 1974

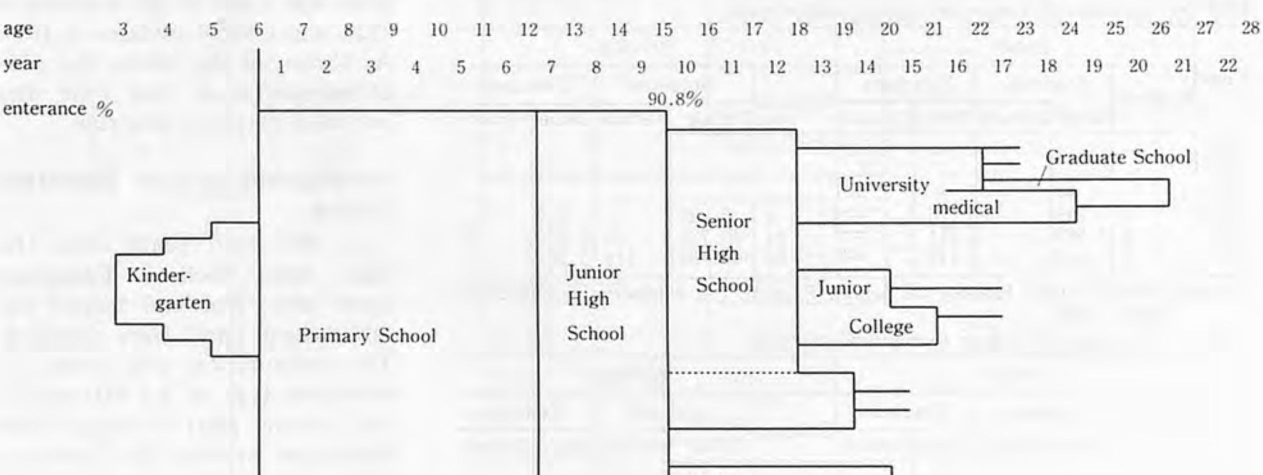

Fig.2. Education system since 1952 in Japan. (Source: Ninety Years' History of School System, Japan Ministry of Education, 1964.

Development in the Old System of the College/Universty Education for Agricultural Machinery in Agricultural Engineering

The courses and syllabi of the college/university education in the field of agricultural engineering with agricultural machinery in Japan developed in the old education system so as to suit to the Japanese social and agricultural conditions.

Switching on Modernization

The Meiji government invited many foreign experts from several Western countries for national reclamation and colonization projects.

The then U.S. President Ulysses S. Grant (1822-1885) appointed Agriculture Secretary Horace Capron (1804-1885) as the leader of American experts for Japan.

In 1871, he arrived in Japan with two American experts. He stayed in Japan up to 1875.

It is said that fourty-five in the sixty-three (seventy-five by another source) foreign experts were Americans called by him for the project. The name of Mr. Capron has been remembered in Japan as a leading spirit of introducing Western farming and implements to Japanese agriculture.

According to his suggestion, "Commissioners" School of Colonization" was established in 1872 in Tokyo. The school transferred to Sapporo city in 1875, and in 1876 "Sapporo Agricultural College" started. It is said that this school was the first agricultural college with Western culture in Japan. It was about 100 years ago.

In 1876, Dr. William S. Clark (1826-1886), President of Massachusetts College of Agriculture at Amherst at that time, participated in the education of Sapporo Agricultural College. His stay was only nine months, but he has had much influence on most Japanese young men since then. Because in leaving Japan, Dr. Clark gave next words to Japanese students who came to send him off;

> "Boys, be ambitious. Be ambitious not for money or for selfish aggrandizement, not for that evanescent thing which men call fame. Be ambitious for the attainment of all that a men ought to be."

These words were widely spread from Sapporo to all over the country and have been remembered by most young students. (Sapporo Agricultural College became the College of Agriculture of Tohoku Imperial University in 1907, and transferred as the College of Agriculture to Hokkaido Imperial University in 1918.)

There was also another important origin of Agricultural Engineering in Japan. In 1874, the Agricultural Training School, predecessor of the Komaba School (College) of Agriculture, was established in Tokyo. (The official name was Komaba School of Agriculture, but the system was the same as Sapporo Agricultural College. A bachelor's degree was given to the graduates of both schools.)

The lectures in this school were started by five scholors from England and one Japanese teacher, in 1877.

Formal starting of the Komaba School of Agriculture was in 1878. The Komaba School of Agriculture was amalgamated with Tokyo School of Forestry to become the Tokyo School of Agriculture and Forestry in 1882. (In 1886, the Imperial University was established in Tokyo as the first imperial university in the country. In 1890, the Komaba School became the College of Agriculture of the Imperial University, having three departments: Agriculture, Forestry and Veterinary Science. In 1897, the name of the university was changed to the College of Agriculture of Tokyo Imperial University, as the number of imperial university increased.)

In the area of agriculture, the traditional education system was modified and reorganized, after the models of these two schools, Sapporo and Komaba colleges.

From 1875 to 1882, many public agricultural schools were established by prefectural governments as follows:

1875············Miyagi Pref.
1875············Niigata pref.
1876············Kyoto Pref.
1877············Ishikawa Pref.
1878············Gifu Pref.
1879············Hiroshima Pref.
1880············Fukuoka Pref.
1880············Fukushima Pref.
1881············Tottori Pref.
1882············Yamaguchi Pref.

There was one problem that imported culture had the advanced technology for upland farming but not for paddy rice cultivation. This became one of main causes of closing of most prefectural schools of agriculture by 1890, except three schools of Ishikawa, Tottori and Miyagi prefectures.

However, there were several remarkable achievements done by graduates from Komaba school. One of them was the achievement of "Brine Assortment of Rice Seed Grains" by Professor Tokiyoshi Yokoi at Fukuoka School of Agriculture in Kyushu island in 1882. Another one was the publishments of two books on rice cultivation, written by Professor Tsuneaki Sakou at Tokyo School of Agriculture and Forestry in 1887, and Professor Tokiyoshi Yokoi at Kyushu in 1888. They mixed traditional Japanese rice farming with Western culture. Many important farm works were theoretically explained with traditional farm tools and implements.

Prof. Sakou started the lecture on "Farm Tools" in Tokyo in 1886. It is said that his lecture mey have been the first one on farm tools done by a Japanese in the college/university education.

Thus, after that, the development of education system on agriculture was done under the strong leadership of the government in mainly governmental schools but not in public and private ones.

Development in the Imperial Universities for Agricultural Eneering Fields

In 1899, accepting the useful advices proposed by the foreign exparts, the government established the "Arable Land Readjustment Law". This law was drafted for the modernization of the Japanese agriculture.

At that time in rural area, however, they met some difficulty in enforcing this law because of lack of agricultural engineering knowledge.

Then, the government requested Tokyo Imperial University to bring up capable graduates of professional agricultural engineers. Two short courses of one-year training were prepared for the students both inside and outside the Tokyo Imperial University.

The first regular lectures to the students, who were the graduates from other colleges/universities and wished to become agricultural engineering specialists in Japan, were started by Associate Professor Eizaburo Ueno in the College of Agriculture, Tokyo Imperial University in 1904.

He wrote two textbooks of "Agricultural Engineering Textbook of Irrigation, Drainage and Reclamation" (published in 1903) and "Textbook of Farm Tools" (published in 1904).These textbooks were used in his lectures. The contents of his lectures were the conbination of what he studied on Western culture and Japanese one. From 1905, the students started to be spread in the society.

In 1906, the lectures in the short course of agricultural engineering to the senior students in

Table 8. Establishment Year (in north-to-south order)

Imperial University	College of Agriculture	Department of Agric. Eng.	Course of Agricultural Machinery and the First Professor
Hokkaido	1918	1949[1]	1947…Prof. Sakae TSUNEMATSU
Tokyo	1890	1935[2]	1947…Prof. Fusanobu SHOJI
Kyoto	1923	1924	1925…Prof. Yutaka TAMURA
Kyushu	1919	1942[3]	1941…Prof. Shuroku MORI

Source: *Eighty Years' History of Hokkaido University, 1965
*The University of Tokyo, Catalogue, 1966-1967
*Fifteen Years' Memory of Agricultural Machinery Course, the Course of Agricultural Machinery, the University of Tokyo, 1964
*Seventy Years' History, Kyoto University, 1967
*Fifty Years' History of the Faculty of Agriculture, Kyushu University, 1971

Note: 1) Its original name was the Department of Physics, which was changed to the Department of Agricultural Engineering afterwards.
2) The Special Course of Agricultural Engineering was established in 1925.
3) The Special Course of Agricultural Engineering was established in 1923.

the Department of Agriculture, College of Agriculture, Tokyo Imperial University, was started by also Assoc. Prof. Ueno.

His lecture of agricultural machinery was replaced (because of Prof. Ueno's trip abroad) by Lecturer Tatsuzo Hirobe, who was one of the first graduates from the course and is called the first agricultural machinery specialist in Japan.

Some of the graduates began to teach in other colleges/universities. A pair of a soil & water specialist and a agricultural machinery specialist was usually prepared in each college/university.

The formal establishment of the course of agricultural machinery, the department of agricultural engineering and the college of agriculture in the imperial universities is shown in **Table 8.** (The department of agricultural engineering was not organized in Osaka and Nagoya Imperial University.)

Development in Technical College

From the last quarter of the 19th century to the first half ot the 20th century, many national technical colleges, in the fields of engineering, commerce, mercantile marine, agriculture, etc. were established as shown in **Table 4.**

Eight of them were "College of Agriculture and Forestry". Their names and establishment years were as follows:

Morioka ……………………1902
Kagoshima ………………1908
Tottori ……………………1920
Mie …………………………1921
Utsunomiya ………………1922
Gifu…………………………1923
Miyazaki …………………1924
Chiba ………………………1929

These colleges were carefully established so as to keep the whole technical area of agriculture and forestry and also emphasizing one or two specialties to meet local structures and requirements. Most teaching staffs in the colleges were graduates from the imperial universities.

In 1921, the Department of Agricultural Engineering was set up in Mie College, through the recommendation of Professor E. Ueno. This setting up was the first one in the college/university education in Japan. The department of agricultural enginerring was established in the other four imperial universities and seven colleges one after the other. (refer to **Table 8**)

Through these historical stages, the education system to bring up many agricultural engineering specialists had been prepared in the country.

At that time, howeverr, Japan had World War II that disturbed the whole education systems from 1941. Schooling term was shortened and shortened to become only two years in 1943. Many college students had to be enlisted for the army only with a temporary graduation diploma because of the "Student Mobilization Order" by the government.

Progress in the New System for Agricultural Engineering and Machinery Education after World War II

The old system was dissolved and changed into new schooling system in 1947. In the case of higher education system, new system started in 1949. The imperial universities became national universities, and many new national universities were born at the same time in every prefecture.

Former independent colleges of agriculture and forestry became the agricultural faculties of national universities.

In the universities changed from the imperial universities, the graduate schools of M.S. and Ph. D. degrees were set.

In other universities, the graduate school of M.S. degree was set in order of the completion of staffs and facilities.

In 1964, the "Department of Agricultural Machinery" was established in the Faculty of Agriculture, Mie University, as the first case in Japan.

Namely, the agricultural engineering department was specialized and divided into two departments of agricultural machinery field and irrigation, drainage and reclamation engineering field.

In 1967, Iwate University followed it and had the department of agricultural machinery. Adding "University of the Ryukyus" in Okinawa and the University of Tsukuba, there are thirty-six colleges/universities which have the department related to agricultural engineering, including the course of agricultural machinery at present (1976). Most of these departments are in the Faculty of Agriculture. Twenty-eight of them are national, and five, public, and three, private as follows:

National Universities
(in north-to-south order)
(D.A.E. means Department of Agricultural Engineering)

1. Hokkaido University
   D.A.E. (Ph.D., M.S., B.S.)
2. Obihiro University of Agriculture & Veterinary Medicine
   D.A.E. (M.S., B.S.)
3. Hirosaki University
   D.A.E. (M.S., B.S.)
4. Iwate University
   Department of Agricultural Machinery
   (M.S., B.S.)
   Department of Irrigation, Drainage & Reclamation
   (M.S., B.S.)
5. Yamagata University
   D.A.E. (M.S., B.S.)
6. Ibaragi University
   D.A.E. (M.S., B.S.)
7. The University of Tsukuba
   This university was specially established for the future, in 1973. They have Cluster, College, and Research Institute systems.
   (Ph.D., M.S., B.S.)
8. Utsunomiya University
   D.A.E. (M.S., B.S.)
9. Chiba University
   Department of Agricultural Production & Management
   (M.S., B.S.)
10. The University of Tokyo
   D.A.E. (Ph.D., M.S., B.S.)
11. Tokyo University of Education
   This university is changing and transferring to the University of Tsukuba, to be closed soon.
   D.A.E. (M.S., B.S)
12. Tokyo University of Agriculture & Technology
   D.A.E. (M.S., B.S.)
13. Niigata University
   D.A.E. (M.S., B.S.)
14. Gifu University
   D.A.E. (M.S., B.S.)
15. Mie University
   Department of Agricultural Machinery
   (M.S., B.S.)
   Department of Irrigation, Drainage & Reclamation
   (M.S., B.S.)
16. Kyoto University
   D.A.E. (Ph.D., M.S., B.S.)
17. Kobe University
   Department of Agricultural Technology
   (M.S., B.S.)
18. Tottori University
   D.A.E. (M.S., B.S.)
19. Shimane University
   D.A.E. (M.S., B.S.)
20. Okayama University
   D.A.E. (M.S., B.S.)
21. Kagawa University
   D.A.E. (M.S., B.S.)
22. Ehime University
   D.A.E. (M.S., B.S.)
23. Kochi University
   D.A.E. (M.S., B.S.)
24. Kyushu University
   D.A.E. (Ph. D., M.S., B.S.)
25. Saga University
   D.A.E. (M.S., B.S.)
26. Miyazaki University
   D.A.E. (M.S., B.S.)
27. Kagoshima University
   D.A.E. (M.S., B.S.)
28. University of Ryukyus
   D.A.E. (B.S.)

Public Colleges/Universities

1. Miyagi Agricultural College (2 years system)
   D.A.E.
2. Akita Prefecectural College of Agriculture (2 years system)
   D.A.E.
3. Toyama College of Technology (2 years system)
   Department of Agricultural Machinery
4. Agricultural College of Ishikawa (2 years system)
   D.A.E.
5. Osaka Prefectural University
   D.A.E. (Ph. D., M.S., B.S.)

Private Universities

1. Hokkaido Junior College, Senshu Univ. (2 years system)
   Course of Agricultural Machinery

2. Tokyo University of Agriculture
   D.A.E. (B.S.)
3. Nihon University
   D.A.E. (M.S., B.S.)

Post Graduate Education

Preparatory Development

When the modernized education system started in 1886, it was an important research to unite the science of Western agriculture and Japanese one.

In 1899, eight Japanese scholors who performed leading achievements in the field of such agricultural research in the university were officially given the degree of Doctor of Agriculture in Japan. They were authorized to judge the doctoral thesisses submitted by applicants. This is called "Thesis-doctor System".

In 1933, Associate Professor Shuroku Mori in Kyushu University was doctorated as the first case in the field of agricultural engineering in Japan.

His theme was "Research on Traditional Japanese Plows". He applied modern science to analyzing the traditional Japanese plows of animal draft.

This achievement encouraged many agricultural engineers. From 1933 to 1942, before World War II, four doctors were born in the field of agricultural machinery in the country.

When the old education system was changed to the new education system in 1949 after the war, five years' graduate schools, which were almost the same but a little different from American system, was established, adding to 6-3-3-(4) years education system.

Present System of the Post Graduate Study

At present, this country has two systems of the post graduate study as follows:

1) "Thesis-doctor System" is the system which is kept at it was before the war. Whoever has graduated from the B.S. course and has done some valuable achievements for the academic society, can submit his thesis, the collection of his main researches, to the competent professor at any time. In this case, M.S. degree is not required. The doctorate degree by this system, however, will be given to the thesis author whose researches have contributed sufficiently to the progress of the academic fields.

2) "Course-doctor System" is the system newly formulated in 1949. The senior student in undergraduate course, who is expected B.S. degree, has to apply and pass the enterance examination of the M.S. course of two years schooling. When he is expected to finish M.S. course, he has to apply again and pass the enterance examination of Ph. D. course of three years schooling. The graduate of five years graduate school (shorter schooling is not permitted) will be qualified for only submission of his Ph. D. thesis within five years. The doctorate degree by this system will be given to the thesis anthor who is expected certainly to achieve valuable research activities for the academic fields in the future.

However, by the thesis-doctor system mentioned above, any engineer has a possibility to continue his post graduate study (research) in his office by himself, not only in the graduate school.

Development of Academic Societies and Course/Syllabi

It is important for the structure of Japanese universities that education and research activities should be balanced with each other.

(There are very few extension services in Japanese college /university structure. The structural essence of the Japanese college/university is to give better education to the students in the campus and to have research activities also in the campus. Extension activities are expected to be done by the graduates in the society.

The course and syllabi development in the field of agricultural engineering in Japan has kept pace with the progress of the research activities in the Japanese societies of agricultural engineering.

Progress Pattern of Academic Societies

Japan has the traditional social structure based on small scale farming of mainly paddy rice cultivation in narrow country land with a great number of population. It was the modernization of irrigation and drainage of paddy rice fields and land reclamation that Japan needed 100 years ago.

Accordingly, the first organization in the field of agricultural engineering was the sectional meeting of "Arable Land Readjustment" in 1899, which was established in the Japan Society of Agriculture (JAS), which had been organized in 1887.

In 1907, the meeting became the Research Committee of Arable Land Readjustment (RCALR). Then in 1929, this committee became independent, under the name of the Japan Society of Irrigation, Drainage and Reclamation (JSIDR) from JSA. These committee and societies had also research activities on agricultural machinery and mechanization problems.

At that period, development and utilization of farm powers such as man, animal, steam, wind, water, gas and liquid fuels and also improvement of field equipments and grain processing machinery were nationally important matters as estimation of foreign-made machinery for paddy rice farming condition. In 1937, Japan Society of Agricultural Machinery was organized.

Then in 1942, Japan Society of Agricultural Meteorology (JAM) was set up, for the meteorological relation between wether and farm cultivation was an important problem of the nation, especially in the field of paddy rice cultivation.

In these ways, the Society of Agricultural Engineering or Engineers has not been organized yet in Japan. This is much different point of the society development from other countries. Only the Japan National Commission of C.I.G.R. (JNCCIGR) was established in 1964, because of national internationalization.

Course/Syllabi Development

There were two to three courses in the department of agricultural engineering in the college/university of the old education system in the first half of the 20th century in Japan. Although there were a little different courses by name, etc. depending on the college/university, they are as follows:

Department of Agricultural Engineering

Irrigation, Dranage and Reclamation Course

Agricultural Machinery Course

(Agricultural Physics or Meteorology Course)

After 1950, three to six courses in the following specialties have been established in the department of the colleges/universities:

Irrigation and Drainage
Agricultural Physics
Soil Science
Water Engineering
Land Reclamation
Agricultural Meteoriogy
Farm Structre
Farm Machinery
Farm Power Unit
Field Equipment
Harvesting & Processing Mechinery
Farm Machine Design
Machinery of Animal Husbandry
Agrictltural Production Engineering
Labour Science
Agricultural Environment Control
Farm Production Control

It can be also said that in the new education system after 1950, mechanical engineering knowledge as important as basic education of Mathematics and Physics has become more important to learn than Biology and Chemistry. Actual examples will be described.

The Department of Agricultural Engineering, Tokyo University of Education, consists of following courses in 1975;

Farm Land Reclamation Course
Irrigation Engineering Course
Drainage Engineering Course
Agricultural Machinery Course
Agricultural Products Processing Machinery Course
Agricultural Structure Course

The department related to the fields of agricultural engineering, Mie University, consist of following courses in 1975;

Department of Agric. Machinery
Farm Power & Machinery Course
Field Equipment Course
Harvesting & Processing Machinery Course
Machine Design Curse

Department of Irrigation, Drainage & Reclamation
Agricultural Physics Course
Water Utilization Enineering Course
Farm Land Utilization Engineering Course
Civil Engineering & Stucture Course
Civil Enginnering Construction Course
Agricultural Environment & Structure Course

The Department of Agricultural Engineering, the University of Tokyo, consists of following courses in 1975;

Hydro Techniques (Irrigation & Drainage) Course
Farm Land Reclamation & Conservation Course
Soil Physics & Soil Hydrology Course
Agricultural Environmental Engineering Course
Farm Power & Machinery Course
Agricultural Processing Machinery Course

Some examples of actual curriculum are as follows:

Curriculum for Agricultural Engineering, the University of Tokyo

(by University catalogue) 1966-1967

DEPARTMENT OF AGRICULTURAL ENGINEERING (under graduate)

(Agricultural Civil Engineering Program)

Required:	Units
Drawing	2
Surveying I	1
Soil Science I	2
Mathematics (A-I)	1
Dynamics (A-I)	1
Strength of Materials (A-I)	2
Hydraulics (I)	1
Applied Mathematics	2
Surveying II	2
Soil Mechanics	2
Soil Physics	2
Hydraulics	2
Hydrology	2
Land Reclamation Planning	2
Land Consolidation Planning	2
Land Consolidation Engineering	2
Irrigation Engineering	2
Drainage Engineering	2
Water Works Construction	2
Water Lifting Machinery	1
Environment Control in Agriculture	2
Soil Science II	2
Principles of Crop Production	2
Farm Management I	2
Design of Farm Works	2
Exercise in Applied Mathematics	1
Exercise in Strength of Materials	1
Exercises in Soil Mechanics	1
Exercises in Hydraulics	1
Exercises in Land Melioration	2

Testing Materials Laboratory 0.5
Experiments in Soil Mechanics 1
Experiments in Soil Physics 1
Experiments in Hydraulics 1
Experiments in Environment Control 0.5
Practice in Surveying and Drawing 2
Practice in Land Reclamation Engineering 2
Farm Practice 2
Graduation Thesis 2

Elective:

Physics I 2
Physics II 2
Physical Chemistry I 2
Fertilizers and Plant Nutrition I 2
Introduction to Agricultural Economics 2
Outline of Technical Measurements (A-I) 1
Concrete 1
Advanced Lectures in Technical Measurements 2
Agricultural Rheology 1
Outline of River Engineering 1
Utilization of Water Resources 1
Land Conservation Planning 1
Economics of Land Melioration 1
Dam Construction Engineering 2
Construction Machinery and Execution of Civil Engineering 2
Farm Power 3
Agricultural Machinery 3
Rural Electrification 1
Structure and Construction for Environment Control 1
Construction Materials in Environment Control 1
Agricultural Architecture 1
Utilization of Coastal Sea-water 1
Fisheries Engineering 1
Outline of Agricultural Engineering 2
Agricultural Meteorology 2
Agro-forestrial Geology 2
Plant Physiology 2
Food Crops 2
Town and Country Planning 2
Soil Improvement 1
Pasturage 2
Agricultural Policy I 2
Strength of Materials (A-II) 3
Reinforced Concrete (I) 1.5
Road Engineering (I) 1.5

DEPARTMENT OF AGRICULTURAL ENGINEERING
(under graduate)
(Agricultural Machinery Program)

Required:	Units
Drawing	2
Surveying I	1
Mathematics (A-1)	1
Dynamics (I)	1
Strength of Materials (B-1)	2
Hydraulics (I)	1
Applied Mathematics	2
Soil Mechanics	2
Soil Physics	2
Farm Power	3
Agricultural Machinery	3
Pumps for Agriculture	1
Agricultural Processing Machinery	4
Processing Plant Engineering	2
Land Consolidation Planning	2
Land Consolidation Engineering	2
Environment Control in Agriculture	2
Principles of Crop Production	2
Food Crops	2
Farm Management I	2
Design of Farm Works	2
Exercises in Applied Mathematics	1
Design and Drawing of Agricultural Machinery	2
Experiments in Soil Mechanics	1
Experiments in Soil Physics	1
Practice in Agricultural Machinery	3
Farm Practice	3
Graduation Thesis	2

Elective:

Physics I 2
Physics II 2
Soil Science I 2
Fertilizers and Plant Nutrition I 2
Introduction to Agricultural Economics 2
General Zootechnical Science 2
Machine Design (I) 1
Outline of Technical Measurements (A-I) 1
Introduction to Electrical Engineering (I) 1
Applied Measurements 2
Agricultural Rheology 1
Hydraulics 2
Rural Electrification 1
Farm Building 1
Land Reclamation Planning 2
Land Conservation Planning 1
Irrigation Engineering 2
Drainage Engineering 2
Construction Machinery and Execution of Civil Engineering 2
Struture and Construction for Environment Control 1
Construction Materials in Environment Control 1
Outline of Agricultural Engineering 2
Soil Science II 2
Soil Improvement 1
Feeds 2
Vegetable Crops 2
Pomology 2
Agricultural Chemical Technology 3
Technology of Animal Products 3
Chemical Engineering 2
Experiments in Environment Control 0.5
Practice in Surveying and Drawing 1
Mathematics and Dynamics (A-II) 6
Strength of Materials (B-II) 3
Mechanism and Dynamics of Machinery 3
Mechanical Technology 1.5
Machine Design (II) 3
Metallic Materials 1.5

Curriculum for Agricultural Machinery, Mie University (by university catalogue) 1971-1975
(under graduate)

DEPARTMENT OF AGRICULTURAL MACHINERY

Basic Items	Credits
Applied Mathematics I, II	6
Applied Physics I	1.5
Applied Mechanics I	3
Numerical Analysis	3
Agronomy I	2
Reading in Farm Machinery	3
Theoretical Economics	2

Computer Science	2	
Seminar in Farm Machinery	2	
Sub Total	24.5	
Compulsory Items		
Engines I	2	
Tractor Engineering I	2	
Hydraulics and Pumps	2	
Tillage Machinery	2	
Other Field Machinery	2	
Farm Mechanization I	2	
Harvesting Machinery	2	
Farm Processing Machinery	2	
Machine Mechanism	2	
Drawings	2	
Machine Design	2	
Metallurgy	2	
Machine Tools I	2	
Electrical Engineering	2	
Instrumentation	2	
Farm Management	2	
Agronomy II	2	
Experiment in Agr. Physics	1	
Experiment in Agr. Machinery	2	
Practice in Agr. Machinery	2	
Farm Practice	2	
Excursion		
Practice out-side of University		
Sub Total	41	
Graduation theesis	6	
Total	71.5	
Selective Items		

Note;

A: For the students who are going to work as manufacturers.

B: For the students who are going to work as users.

Applied Physics II	1.5	A B
Applied Mechanics II	3	A B
Soil Mechanics II	3	
Tractor Engineering II	2	A B
Construction Machinery	2	A
Chemical Machinery	2	A
Forestry Machinery	2	
Farm Processing Mechanization	2	B
Automatic Control	2	A B
Heat Engineering	2	A B
Soil Physics	2	
Crop Science	2	B
Farm Management	2	B
Engines II	2	A
Farm Mechanization II	2	B
Machine Tools II	2	A
Processing Machinery	2	
Farm Structure	3	
Pneumatic, Oil Hydraulics	2	A
Environment Control	2	
Mechanization of Tropical Agriculture	2	
Marine Culture	2	
Farm Machinery Design	3	
Farmstead Engineering	2	
Practice in Farmstead Engineering	1	
Agr. Hydrology	2	
Soil Conservation	2	
Construction	2	
Land Survey and Practice	2	
Meteorology	2	
Industrial Engineering	2	
Patents	2	A
Agr. Policy I	2	
Agr. Policy II	2	
Farm Association	2	
Agr. Extension	2	B
Farmstead Management	2	B
Food Crops	2	
Feed Crop	2	
Horticulture	2	
Livestock	2	
Insect Control	2	
Pest Control	2	
Wooden Material	2	
Soil Science	2	
Fertilizer and Nutrition	2	
Livestock Processing I	2	
Livestock Processing II	2	
Applied Geology	2	
Special Lectures		
Total	100.5	

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Driver-less Combine Harvester Realized

Agricultural Dream Comes True

by
Iseki Agricultural Machinery Mfg. Co. Ltd.
1-3, Nihonbashi 2-chome, Chuo-ku, Tokyo, 103 Japan

When considering future of the farming machinery, the automatic, non-attendant operation of the agricultural equipment has been a main theme. In the fields agricultural facility, there are some automatic facility have been succeeded and operated. As for the machinery working in the agricultural fields, however, automatic operation without attendant has been still a dream.

In 1974, ISEKI Agricultural Machinery Mfg. Co., Ltd. anounced Head Feed Combine Harvester with an automatic direction control mechanism provided named HD 700 FEA. at the beginning of the year, ISEKI introduced the prototype combine harvester Model X-HD 1500 D. No driver is needed for this machine. The machine alone moves around the harvesting fields to finish the work.

The prototype should be a key to realize the dream for automatic agricultural machinery.

We would like to introduce functions and features of our prototype machine, based upon the way of future farming and farming machinery.

Toward Comfortable and Rich Farming Works

As Japanese main agricultural production has been the rice. Therefore, main farming works are; tilling paddy fields, transplanting the rice seedling and harvesting of the rice.

The methods of work has been changed in great extent. As a result, the tractors, rice transplanters and combine harvesters have become most popular machineries in Japan. Of course their mechanisms have been improved considerably.

According to the report on the agricultural work production cost in 1974, the average labor hour for 10 a rice fields are 87.1 hours. As for the larger fields exceeding 300 ares, the labor hours required is decreased to 62.3 hours/10 a.

In 1950s, it took more than 200 hours. It is clear that this is due to rapid improvement of the farming machine.

The modern machinery has already been developed to the maximum peformance. There is only a little room left for further improvement of the performance of the machine itself. Recently, the target of effort to improve the machine has been safety, operating comfortability and simpleness in control, based upon human engineering.

However, one operator can operate only one machine at a time. And, he has to work riding on the machine while the machine is operating. That is why we sometimes feel that man uses the machine or the machine uses a man. In this situation, there should be a limit on improving safety of machine as an operator must touch the machine all the time during operation.

The basic reason why ISEKI has developed the automatic combine harvester is the challenge to overcome the limitation of today's machinery. Today, the machine is used to improve working efficiency. ISEKI believes that the farming machine in the future should be a help in providing agriculture with "comfortability" and "richness".

The man should not work to meet efficiency of the machine. He has to be able to use the machine to meet his free schedule. The enable this, unnecessary large-size machine must be avoided. Instead, he should have the machine most suited to his farming size, and shoul use the machine in the way to improve its efficiency. To realize future dream, the automatic, driverless machine will play important roll.

The detailed targes of ISEKI's program in developing the future machine are;

1) To be the machine for everybody:

For example, man who can not understands the functions and construction of the TV receiver or electric calculator buy its function. Because he can use it sufficiently by easily operating its channel selector or control buttons without mistake.

Even a combine harvester, everybody will be able to operate it if simplification and reliability will be improved to necessary level.

2) To be the machine with minimum operating fatigue:

In case of the machine today, the skillful operator must ride on the machine. This kind of work gives him great fatigue by vibration, noise, dust or the like. Furthermore, the operation is always continuous and monotonous work to observe the direction of movement and gauges or the like. This gives him only annoying mental fatigue added to the physical fatigue. To solve this problem, there is only one solution. He has to operate the machine being away from it.

3) To be the machine providing time for man:

If the machine will not require the driver, only roll of the man is pushing the start button, after setting the machine. Then the machine proceed the work by itself to finish it. After pushing the start button, he has time available to do anything. He can go anywhere leaving working site.

4) To be the machine improving the efficiency of human being:

While the automatic machine is working alone, a man can do other works. He is able to set other automatic machines for its work. In this way, he will be highly efficient to control more than one machine at a time.

There has been a concept; only way to improve working efficiency is to build larger machine. Now, the concept must be changed; to improve the working efficiency is to improve efficiency of human being. Then, he can prepare various kinds of machines, and proceed works continuously and multiply in short period of time.

5) To be the machine of high working precision, stability and long service life:

The basic purpose of automatic machine is to enable continuous high precision work stably. The man makes a mistake, especially when he is tired or in unfamiliar operation. When he is in a hurry to finish the work, overload operation, rough handling or misoperation is often resulted. By eliminating a mistaken operation, overloaded or rough operation, machine troubles must be minimized resulting in longer service life of the machine.

6) To be the machine changing the concept of farming work:

The machine moves around the field, and proceeds work correctly without help of a man. If it comes true, there will be a new kind of relation of human beings and the machine.

Automatic Combine Harvester and Its Function

In this magazine, various examples of study and ideal for automated agricautural machineries have been introduced. However, it may be the first introduction that the practical study is accompanied on the automatic, driverless combine harvester.

ISEKI's experimental combine harvester X-HD 1500 D was tested in Autumn, 1975. The test was succeeded to be able to establish the way of technical development in future.

Photo.1. Automatic Combine Haruester X-HD 1500 D.

As shown in **the Table 1**, the machine has six main automatic control systems. The detailed explanation is started by its outer view. Its mother machine is a combine harvester ISEKI Model HD 1500 D. Therefore, its outer view is not so different from the mother machine.

Main difference in outer view are; the control panel is changed. One control lever is added at

Table 1. Automatic Controls of X-HD 1500 D

Name	Function
1. Automatic Controller of Direction (ACD)	Moving along the side of unreaped plants, it controls forwarding direction to prevent plants from unreaped.
2. Automatic Controller of Reaping Height (ACH)	It controls the reaper position to optimum reaping height according to the terrain of the fields.
3. Automatic Controller of Stalk Feed (ACF)	It controls feeding depth of reaped plant according to its length so that its ear is positioned correctly for the thresher.
4. Automatic Controller of Packing (ACP)	It packs the harvested grain in the bag. When the bag is filled, next empty bag is replaced.
5. Automatic Controller of Turn (ACT)	When a harvesting path is finished, it turns the machine to enter next path continuously.
6. Automatic Controller of stop (ACS)	When all plant is reaped in the fields, it stops the machine finishing harvesting work.

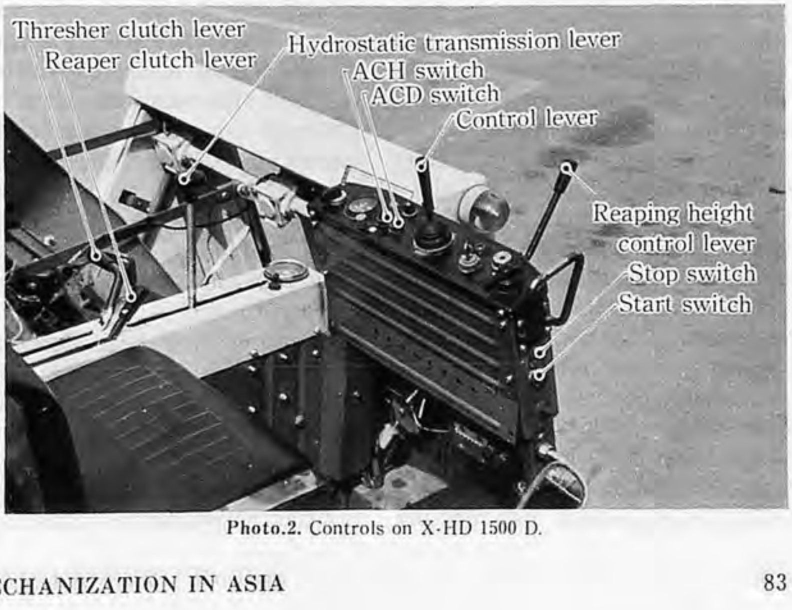


Photo.2. Controls on X-HD 1500 D.

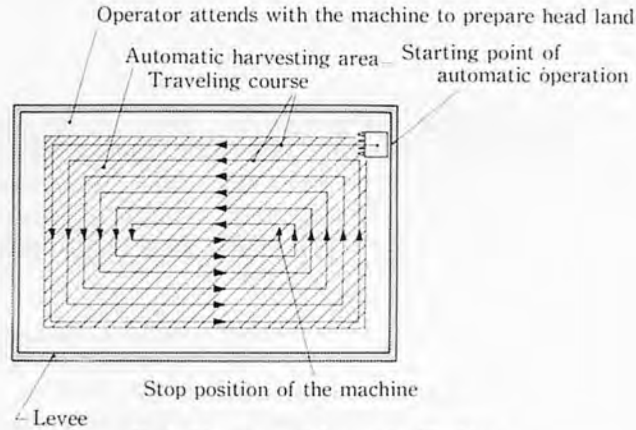
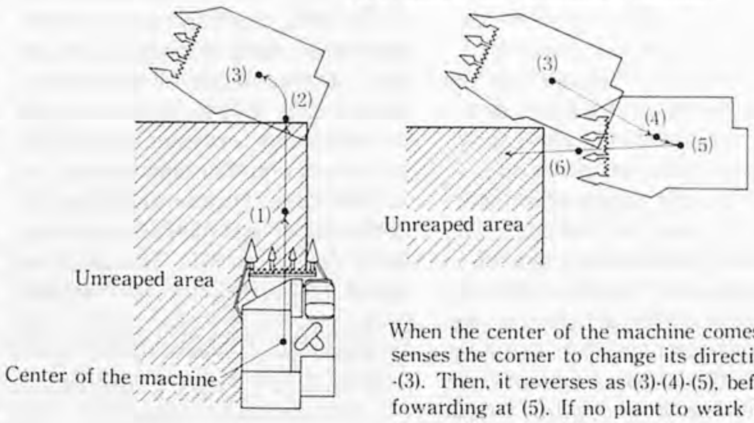


Fig.1. Movement of Automatic Machine.



When the center of the machine comes to(1), it senses the corner to change its direction as (2)-(3). Then, it reverses as (3)-(4)-(5), before fowarding at (5). If no plant to wark is left, the machine stops its operation at (6).

Fig.2. Automatic Turning Method.

middle of the panel.

The conventional hydraulic lever at the right side of the operator's seat is eliminated. A push button switch to start and stop the machine is newly provided at the outside of the instrument panel. Due to addition of autmatic packing device, the shape of the grain auger and packing device are changed.

Operation and Function of the Machine

1) In conventional Operation Fully attended by an Operator.

Even in the conventional way of operation, the machine has a few features.

1) A hydrostatic transmission (HST) is able to attain all necessary speeds both in forward and reverse with only one control lever.

2) A control lever in front of operator's seat controls moving direction as well as reaper height. By bringing the lever to the left or right, the machine travels to the direction of the lever set. By pushing the same lever forward, reaper is lowered. While pulling it on, the reaper is kept on raising.

3) Only setting vacant bags to the position before starting, the grain is automatically packed in the bag. Then, the bag is ejected to outside the machine. In full conventional machine operation, automatic grain packing—bag ejection—bag replacement cycle is counted as a big feature.

2) A partial automatic Operation with man attended

Three types of automatic controls are selectable;

1) By putting on the ACD switch, the automatic machine direction control system automatically controls working direction sensing the side of unreaped plants. When reaping is not made, this control system is put off automatically.

2) When placing the ACH switch to On, reaping height control system starts its function after pushing the control lever. Then, the reaping height is automatically adjusted to optimum working position according to the terrain. If the control lever is pulled back, the reaping section is elevated until it is returned to the neutral position. At this lever position, the reaper is remained to the position raised. By bringing the lever foward, the automatic height control is recovered.

3) When putting on the ACF switch, the automatic feeding control system starts its function to feed the ear of plant to optimum position on the threshing section, to meet the lenght of the stalk of plant.

This enables the Thresher to work stably for long period of time with ideal load and separating performance.

For preparing head land for harvesting work, use of these three controls as required will result in easy and fast preparation work.

3) Full Automatic Operation

After preparing the head land, the machine can start work by itself requiring no attendant.

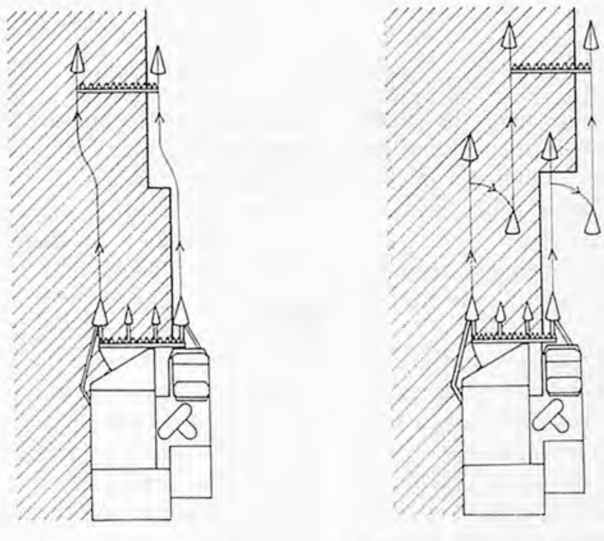
At first, put on ACD and ACH switches. Then, automatic operation OK lamp is lit. Final operation is just putting the start switch.

Before starting automatic operation, it is naturally needed to check the machine, and to set the bags.

By pushing the start switch after facing the machine to correct direction, the machine starts. If it senses out the plant stalk, it keeps on going straight to reap plants in full width of the machine, sensing the outer side of unreaped plant.

When the opposite end of working area is reached, the machine changes its direction by 90 degrees as shown in the **Figure 2.**

Repeating these processes, the machine alone running around all the working area to finish the work. If the machine harvests last crop, it stops there to wait the man who carries it as far as storing place.



Smoothly changes its course　　Moves reverse once and change its course

Fig.3. Movement of the Machine when encountered with irreguler Rows.

Photo.3. Model HD 1500 D-Base of our Prototype.

Other automatic features are:

1) If there is no stalks after the machine is started, it moves forward further by two to three meters before completely stopping there.

2) If rows of crops suddenly increased or decreased, the machine changes its direction as shown in the **Figure 3.** If rows increased, the machine moves reverse to change its direction.

If decreased on the contrary, it takes a curve to meet the plant position correctly.

3) In emergency case, the machine is stopped immediately by pushing the stop button.

Iseki's Way of Development and General Way of Development of Driverless Machine

The farming machinery such as tractors and combine harvesters have two main systems; the traveling system and the working system. To automate the machine, it is necessary to develop both automatic systems.

Since the machinery today has been highly improved to have reliable working or processing system, the conventional machine is fully used as it is as a base of automated prototype.

Another method to develop the driverless machine is to develop a totally new machine.

Features in developing the X—HD 1500D

ISEKI's prototype is developed using our reliable conventional harvester. Various automatic control systems were added on the machine which is succeeded to become an automatic harvester.

1) The X—HD 1500D was developed using our most popular model HD 1500D as its base. The HD 1500D is almost perfect machine as a conventional combine harvester. Its superior technics and constructions are employed as they are. Automatic operation of it resulted in providing further precision and working stability.

2) In 1973, ISEKI had already put the HD 2000 combine harvester in the market. This machine was equipped with the hydrostatic transmission. The transmission has been installed other models to enable easy and efficient harvesting.

On the X-HD 1500 D, the hydrostatic transmission is also used to automatically control forwarding, reversing, stopping and starting the machine, added with various automatic control devices.

3) In 1974, the Model HD 700 FEA was put into market. This machine installs the automatic controller of machine direction. Then, it is equipped on other models gradually gathering high reputations of many users. This mechanism has added with pulse control system. It will be employed to control reaping height and feeding position of plant reaped.

Comparison with conventional Idea in Automation

The comparison of ISEKI's automating example with the conventional idea is made here in summary.

1) The range of automatic operation must be considered. If the machine automatically starts from it storage place and comes back there alone after finishing the work, it should be called as 'perfect driverless machine.

Our prototype needs an operator when going to and from the working sites, and when preparing the head land.

Then, the machine can harvest all the field left. In this range of work, of harvesting, monotonous and continuous operation and required. The operator has to repeat the cycle of straight-going to reap and turning the machine to next straight-going, having mental and physical fatigues. By our experimental machine, this range of works are automated.

2) The information needed for automatic operation is sensed out directly from the plants and terrains of the fields. As for the method of driverless operation of the machines such as tractors and rice transplanters, a following-up method of tilled land, a remote control method radio controller, a crane control method have been studied.

ISEKI's prototype employs the following-up method. As the biggest feature on the prototype, it is prouded that the automatic turning of machine which has been considered to be difficult can be achieved by only collecting the direct imformation from plants and terrains of the fields.

Construction of X-HD I 500 D

Six types of automatic control systms are provided on this prototype machine. As shown in **Figure 4**, each control system consists of the electronic/electric controls and hydraulic controls.

The direction control, reaping height control, turning control and stop control are closely related in their functions. The information obtained by four sensors at front part of the reaping mechanism is input to the single control box. The control box mainly consists of comparison circuit, feed back control circuit, program control circuit and output circuit. It sends output signals to each control system. The signal output is converted to hydraulic signal by function of solenoid valve housed in the hydraulic control section.

The machine direction control output controls the left and right side clutches and brake by way of LH and RH steering cylinders separately mounted. The reaping height control output is sent to the reaper elevating cylinder to adjust the height of reaping mechanism. The steering and stop outputs operate the hydrstatic transmission (HST) control cylinder to move automatically forward and reverse, and to stop the machine.

In addition to the signals from sensors, the ordering signals from human being such as machine direction signal and reaping height signal by control lever, and start and stop signals by control switches are input to the control box. These ordering signals are input to the priority circuit to provide safety-first feature.

The automatic controller of feeding position and the automatic controller of packing are independently mounted on the machine excluding a part of their hydraulic systems.

The newly developed technics upon preparing this prototype are;

1) As for the sensor on the control system of combine harvesters, the tactile type sensor can provide practical performance.

2) The electronic/electrical circuits are widely employed. The mechanical system in the control system can be replaced with electrical system resulting in the concentrated control section.

3) The hydraulic control devices are widely employed in operating system. The solenide valve is used to convert electrical signal into hydraulic signal. This enables On-Off control.

4) The bag changing system is newly developed together with newly designed grain bag.

Detailed explanation of indivisual control system is made in the following;

Automatic Machine Direction Control System (ACD)

As explanation of the system is mentioned before, the difference of this new system from conventional system will be explained.

The conventional ACD has main purposes of minimizing operator's fatigue as well as allowing him to operate and observe the machine composedly, by eliminating necessity of continuous observation of the direction of machine movement.

The new system has been improved so that it becomes possible to reap the plant-in-row laterally and to reap the plant of scattered seeding. In addition, auxiliary direction sensor provided can senses increased or decreased rows of plant to change direction of the machine as required.

The conventional sensor (both-side sensor), as shown in the **Figure 5**, passes through between rows of plant to detect the relative position of the machine with plants at both sides of the sensor.

The new sensor (single-side sensor) passes through the outer side of the unreaped plants to detect the machine position.

As shown in the Figure 5, when the right face of the conventional sensor touches with the plant, the machine goes to the left slightly. When the left face of it touches with the plant, it goes to the right slightly.

When the new sensor (single-side sensor) lightly touches with the plant, the machine goes straight. When it is separated from the plant, the machine chenges to the left. If it is deeply touched with the plant, the machine goes to the right.

Table 2. X-HD 1500 D Main Specifications

Model Name		ISEKI X-HD 1500 D
Dimensions	Total length Total width Total height	3,290mm 1,670mm 1,830mm
Weight		1,280kg
Working Efficiency		0.5~0.8hr/10 a
Engine	Type Output	Diesel engine 18.5 PS
Reaping Section	Nos. of rows reaped Reaping width	3 ~ 4 1,050mm
Thresher	Type Cylinder dia. × width	Axial flow type 400 × 570mm
Machine Speed		Variable by hydrostatic transmission
Automatic Control Systems		Machine direction, reaping height, feeding position, packing, turning and stop control systems

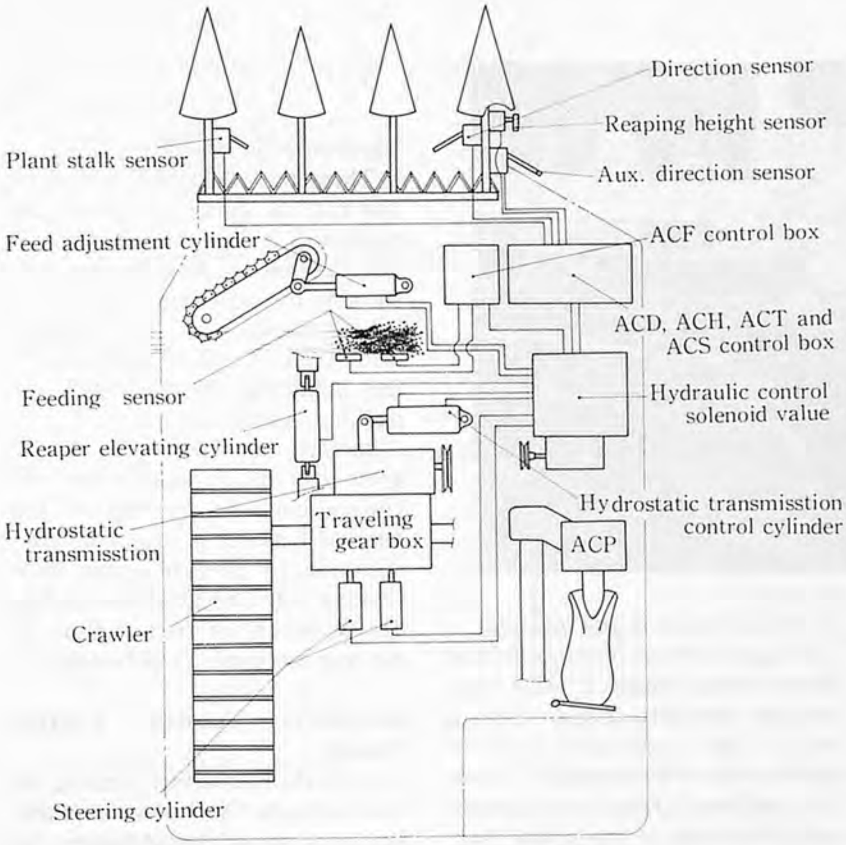


Fig.4. Control System on X-HD 1500 D.

In case of conventional sensor (both-side sensor), the sensor signal can operate the solenoid valve directly.

The new sensor (single-side sensor), however, is impossible to function the valve directly. To solve this problem, the pulse conversion circuit is added to the control system.

The new sensor has been improved to suit driver-less operation of the combine harvester.

Automatic Reaping Height Control System

In actual operation, this control system is especially needed when quickly adjust the reaper to its optimum position to start the next path after turning the machine with the reaper raised at the end of the path, and when it is needed to adjust the height upon machine pitching on rough field terrain.

To develop this control system for automatic machine, the following requirements have to be achieved.

1) It must be possible to select required reaping position before starting work.

2) Both manual control and automatic control must be selected freely.

3) Stable control must be obtained on fields having fine roughness such as foot prints.

4) The sensor must be installed on suitable position with high sensibility.

5) The sensor must be small in size as much as possible.

ISEKI has succeeded in developing such control system. It is mounted on the machine adding the electronic control circuit.

Automatic Feeding Depth Control System

The most important and difficult control is feeding depth of the head of reaped stalk. It is ideal to adjust the feeding depth to meet difference of stalk length reaped. With the manually control system, it is too difficult to control correctly. And, sometimes

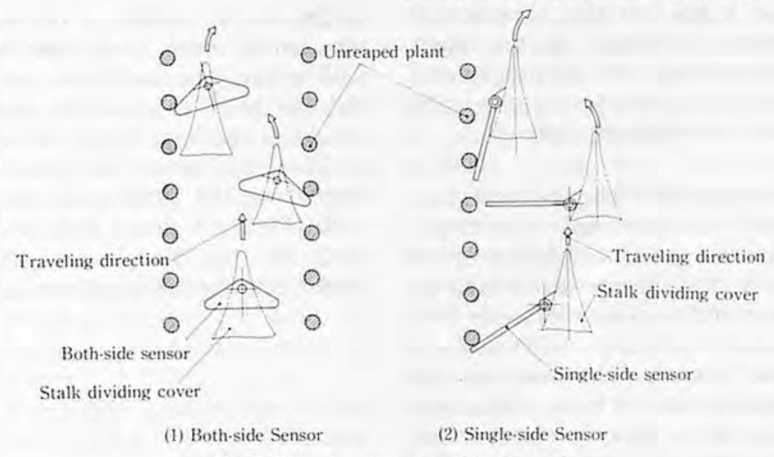


Fig.5. Direction Sensor and its Control.

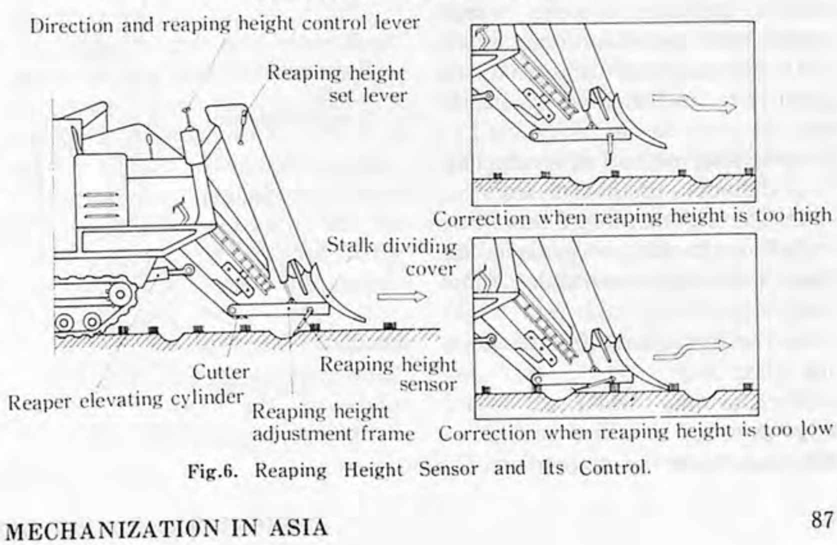


Fig.6. Reaping Height Sensor and Its Control.

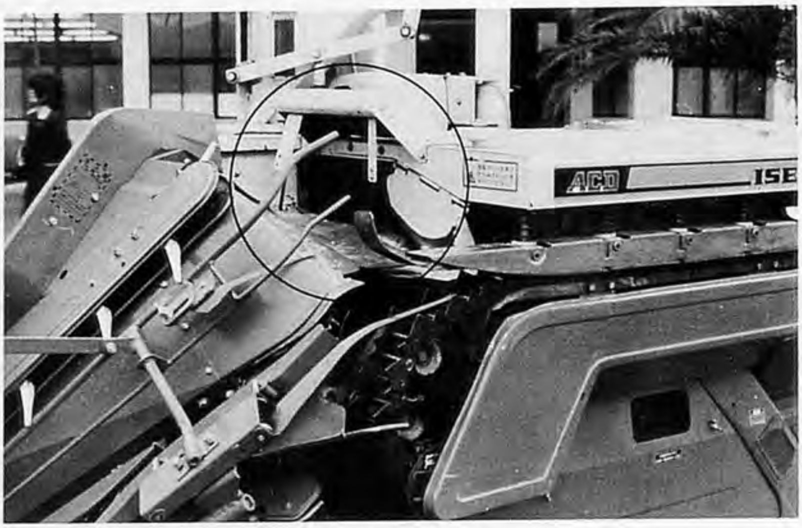


Photo.4. Feeding Sensor.

no control is made.

To automate this control system, it is important to correctly check out the average center of plant ear being fed. The countermeasure for difference in lengths of stalk actually fed must be also considered.

The experimental machine is proveded with feeding sensor at the inlet for the thresher to detect the head of the plant. Furthermore, the feed depth control in the former process is fed back for accurate control.

Automatic Packing System

In conventional harvester, threshed grain is collected in the grain tank, in manually chucking grain pack or other system. This lowers working efficiency in great extent. However, it has been considered to be difficult to improve as many problems must be solved. To develop the automatic packing system, many theme have been overcome.

1) Construction and size of grain bag and method of handling.

2) Setting method of empty bag

3) Changing method of bag

4) Opening method of spare bag

5) Even packing of grain in the bag. Detecting method of filled bag

6) Timing and method of ejecting filled bag

7) Alarming when all spare bags are used or when troubled

These theme have to be solved in limited space in the machine.

Rough drawing of the system is shown in the **Figure 7.** Once bags are set manually before starting work, the automatic system carries out all necessary work for packing. The bag opening arm functions to open the bag. The shooter is inserted to the opening. When at bottom dead center of the shooter is reached, the shutter opens to fill the bag with grain. The oscillator under the bag helps to pack the grain evenly in the bag. When the bag is filled, the sensor provided at bottom of the grain tank functions (**Figure 7** shows this condition). By the signal from this sensor, the shutter is closed, and the shooter is raised.

Then, the filled bag moves on the rail to going out from the machine. If suitable stopper is provided on the bag feeding rail, suitable bag ejecting position can be obtained. The bag opening arm, then, starts to function at the biginning of next cycle of packing operation.

In this machine, 20 to 30 kg grain can be packed in the exclusive bag. At the top of the bag, inlet mouth is of double construction to prevent grain from flowing out. The grain in the bag can be taken out from bottom of the bag by opening the fastener.

Automatic Turning Control System

To realize automatic turning of the combine harvester, several functions should be added on the machine.

1) Correct position for turning must be correctly detected after finishing straight-line harvesting.

2) Correct turning angle must be calibrated.

3) After finishing its turning, the machine must travels precisely toward next plant.

4) It is necessary to minimize area of head land.

The flow of imformation and

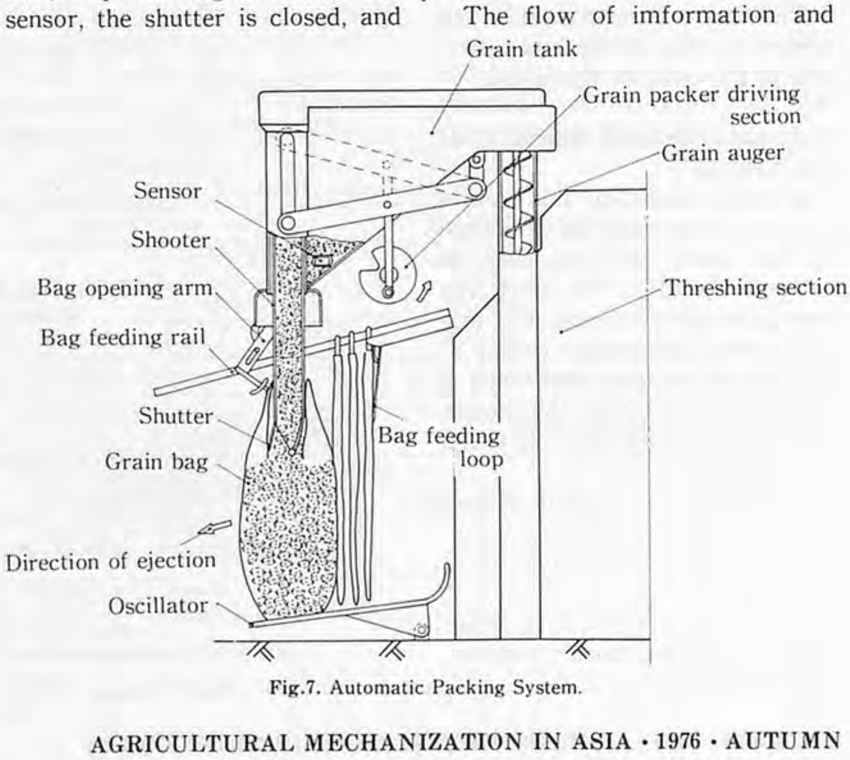


Fig.7. Automatic Packing System.

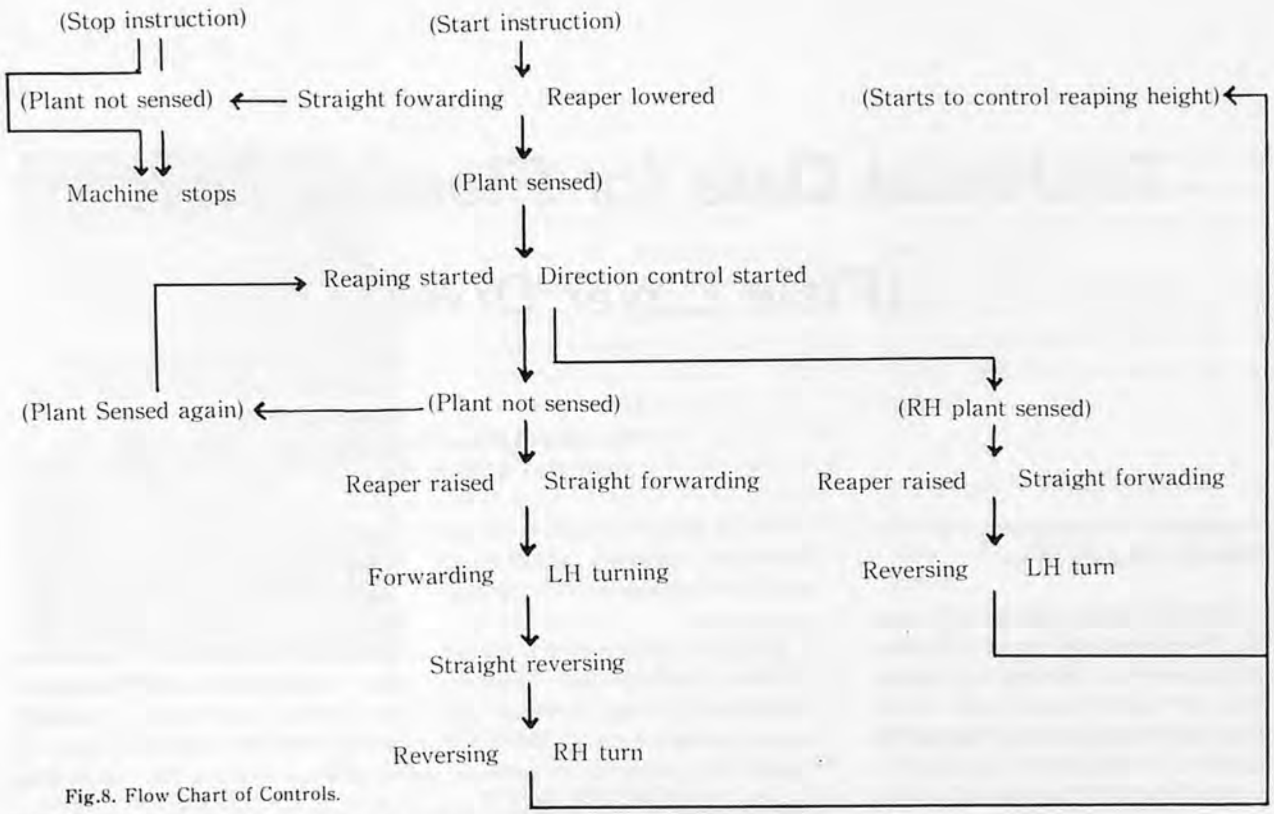


Fig.8. Flow Chart of Controls.

function are shown in the **Fig. 8.**

Its main functions are;

1) Sensing by the plant stalk sensor:

If the man pushes the start switch, the machine starts when there is plant. If there is no plant, the machine stops at the position.

If no plant being exists during straight-moving work, the machine keep on moving for some distance to check out if a partially lost plant or not. When no plant is checked during this operation, the machine determines that the position is end of the row and starts to turn. When the sensor inputs the signal 'No Plant', the machine will not function the ACD for safety.

2) Detecting of machine position by the traveling distance calibrating sensor: Since machine position is not computed by the machine when the plant stalk sensor is not touched with plants, this sensor is employed. This sensor calibrates relative position of the machine mainly when the machine is on turn.

3) Working instruction by program control:

According to the program preliminery input in the electronic circuit, the signals of 1) and 2) above are processed to control the machine during its turn.

4) Feed back control in hydrostatic transmission operation: The hydrostatic transmission controls machine speed variably from forward, stop to reverse. According to the signal of forward, stop and reverse, its control lever is operated automatically by feed-back-control through On-Off type servomechanism.

Automatic Stop Control System

When all the work is done, the machine automatically stop on the spot.

There is big difference: a man is waiting for the work finished; and a machine stops to wait for a man to come.

It is planned to add other functions to this control system. For example, when the machine is troubled during work, when a man stands near dangerous part of the macine, the machine must be stopped its operation. Or, the engine should be stopped after the machine finishes the operation.

On the automatic control circuits for this prototype, other necessary sensors will be easily added for future improvement.

Conclusion

The ISEKI's driver-less combine harvester Model X-HD 1500D is designed to enable three types of operations. The machine is operated as conventional way with an operator on it. A partially automatic operation is also possible. And, full automatic operation is, of cource, available.

It means that this prototype machine will be able to meet any conditions of works and fields. Therefore, we believe that the machine will find out its way of improvement to smoothly meet the requirement of users in near future.

Although there are opinions that it is not practical to develop automatic field-working farming machiney because its short working hours per year.

This type of automating the machine will be the best way to develop future machine.

By adding common technics and know-how on the conventional machine which is already highly reliable, development of automatic machine will progress smoothly.

This is ISEKI way to realize agricultural dream by continuous effort from past to the future. ■■

Technical Data for Floating Dryer

(Flow Layer Dryer)

by
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Purpose of Development and Principle of Floating Dryer

Recently, due to mass diffusion of head-feeding type combine, manpower in harvesting operation of paddy, barley and so on has been marvelously saved. In addition, manpower shortage in young laborers, operators and so forth which was one of the sources of troubles in agricultural districts could be settled, obtaining superior reputation in high-performance harvesting mechanization system. However, on the other hand, an important problem of process in moisture-rich paddy which was harvested by combine has been derived.

As a premise of combine diffusion, development of dryer which can dry moisture-rich paddy harvested by combine was a pressing need. However, this problem has been settled in a private farm-house by practically using a circulation type dryer. On the contrary, in a group drying workshop such as a rice mill and so on, some problems still remain in spite of full-scale rush into the combine age. Among these problems, drastic solution in drying capacity of moisture-rich paddy has been expected.

The purpose of this floating dryer development is to increase simply the drying capacity as much as possible in the aforesaid situations.

Problems confronting a rice center which was designed to final drying operation when it receives moisture-rich paddy harvested by a combine are:

(1) A flow in dryer or on conveyer becomes insufficient due to differences in paddy properties.

(2) Since moisture-rich paddy is dried, drying time becomes considerably long, because 2-3 times moisture must be dried compared with in conventional drying operation.

Consequently, when paddy harvested by combine is first processed to a half dried condition, the above-mentioned problems are settled, and even a conventional machine can exhibit a suf-

Table 1. Comparison of different points between ordinary flow layer dryer and the floating dryer.

		Floating dryer	Ordinary flow layer dryer
Construction	Flow plate	Slit type, and the air is designed to blow out in the direction of diagonal front	Perforated plate
	Flow adjusting valve	Exhaust valve only	Both feed valve and exhaust valve
	Scattering preventive plate for grain	Built in the body	In the majority of cases, no scattering preventive plate. Grains are gathered outside the machine body with a cyclone
	Weir	None	Installed
	Side slipping preventive plate	Installed	None
Function	Pressure loss	Small	larger
	Blasting-power	Small	Larger
	Blasting temperature	Low (around 65°C)	High (around 200°C)
	Drying time	Short (around 3 min.)	Upto several tens min.
	Flow layer thickness	Layer thickness may change according to variation of blasting pressure and ventilating resistance of grain	Adjustable with weir height
	Flow condition	Limit flow condition of high density	The condition may change from a high density condition to low density condition according to weir height and an amount of grain feeding
	Adjustment of grain flow	Controlled by revolution of exhaust valve	Controlled by revolution of feed valve
	Operation at the time of running	Fuel quantity only	Complexed with grain feeding speed, weir height, fuel quantity and so forth

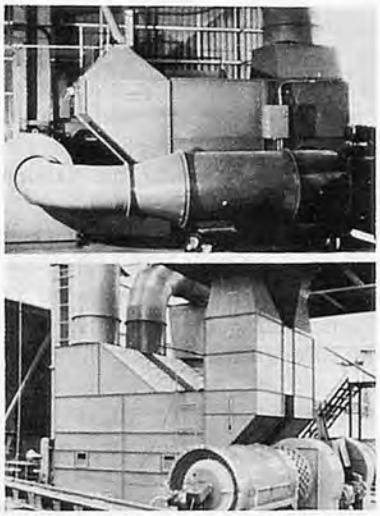


Photo1. Floating Dryer

ficient performance.

The technical purpose of this floating dryer is that, "The received combine harvested paddy should be promptly dried to a half dried condition so that an existing dryer system can perform its drying operation as is planned".

Our company has been wrestling with this problem since several years ago and has developed the floating dryer based upon the flow layer drying system, which is the most suitable means for the above-mentioned purpose.

Principle of floating Dryer

The floating layer dryer adopted a method that a hot blast is supplied from the lower position of granule materials placed .on the perforated plate or the like above the rectifier, then drying operation is performed by mixing the granule materials with the hot blast severely while the granule materials are floating in the hot blast.

The flow layer was originally developed in Germany as a conveying method of grain materials, then it was put to practical use as a dryer in the U.S.A. during the World War II.

Here in Japan, a study was started in and after 1958 and a dryer was effected in 1961. After that, the dryer came to be widely used in the industrial field.

Generally, the flow layer dryer has the following features:

(a) Since a contacting surface of material with the hot blast is larger, a great amount of heat is transferred to a certain capacity of material, largely raising the drying effect.

(b) Heat transfer in the flow layer is quick and the temperature is uniform, then the material is constantly stirred and floated. Accordingly, unevenness in drying operation is eliminated.

(c) There is few movable sections in the dryer. Therefore, the machine suffers almost no trouble.

(d) The machine can be minimized in size. Thus, a small space can suffice the installation at lower building cost.

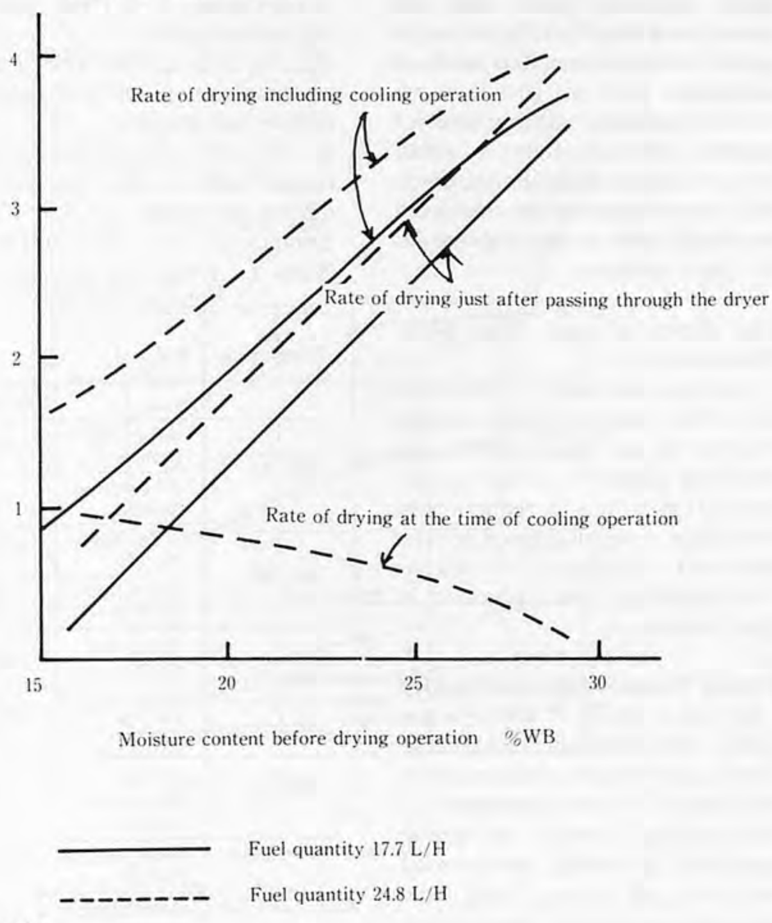
The above features indicate that the flow layer drying method is an ideal system as pre-dryer of the rice center.

From the comparison table (**Table 1**) it is comprehended that the floating dryer has many excellent features for grain drying purpose.

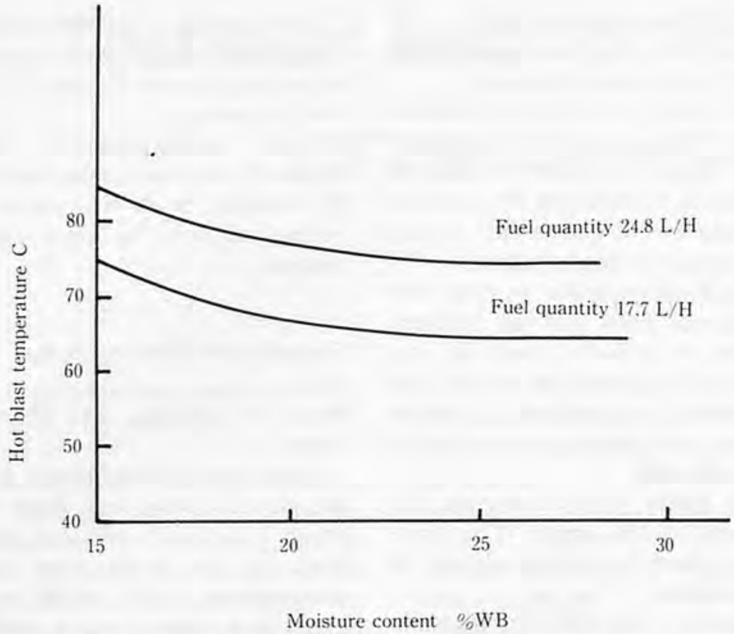
Functions of Floating Dryer

Rate of Drying of Floating Dryer

Grain passed through the floating dryer comes out from the dryer in a dried condition. However, at the same time grain temperature is also raised, so the grain is cooled through ventilation. In this process, dryness is further advanced. **Graph 1.** iindicates these relations.



Graph1.



Graph2. Relations between moisture content and hot blast temperature

From **Graph 1.** it is understood that the higher the moisture content in paddy is the larger the rate of drying of the floating dryer becomes, and that the capacity of the floating dryer is greatly raised when it is used as pre-dryer.

Drying amount at the time of cooling shows rather a small value at high moisture content. This means that grain temperature is difficult to rise when grain has high moisture.

Fuel Quantity and Hot Blast Temperature

Hot blast temperature indicates high value when moisture content of grain to be dried is low even the same quantity of fuel is supplied. This is due to reduction in ventilation amount caused by the increased resistance of ventilation depending upon reduction in grain diameter.

Drying Temperature and Quality

In case a grain is dried, sometimes heat damage may occur when a hot blast temperature is too high. To check existence of heat damage caused by drying operation, generally, germinating rate, enzyme power, fatty acid ratio and so on are investigated. As a result, temperature limit for drying operation is said to be as follows:

(a) Do not exceed the grain temperature of 40°C at paddy drying operation.

(b) Do not exceed the grain temperature of 50°C at wheat drying operation.

(c) Do not exceed the grain temperature of 40°C at barley drying operation.

Sometimes it is very difficult to measure the grain temperature at a dryer. However, since a grain thermometer is installed on the floating dryer, fuel quantity can be adjusted by checking this thermometer, giving no damage to the grain during drying.

Table 2. is the actual data of survey for fatty acid degree and activity degree, in which no influences are observed after passing through the floating dryer.

Variation of Hot Blast Temperature at Floating Dryer

Even when the hot blast temperature given to the floating dryer is uniform, the exhaust temperature is usually low at the grain feeding port, and is high at the discharge port. **Graph 3.** shows the variation of temperature.

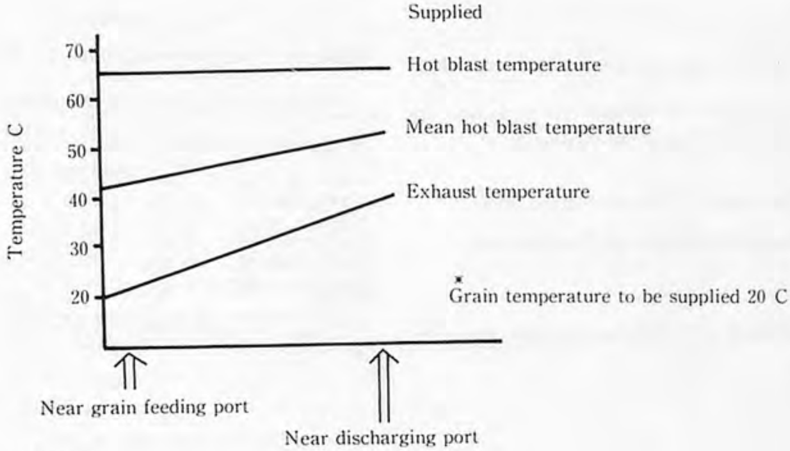
As cleared from **Graph 3** ., even when a hot blast of 65°C is supplied, the air temperature which actually contacts with grain will become 42°C to 52°C. Namely, these are considerably low temperatures.

Problem of cracked rice in Floating Dryer

Almost process manufactures will certainly have a fear of in-

Table 2. Actual data of survey for fatty acid degree and activity degree (at Hokkaido University)

Harvesting date	Time of measurement	Fresh paddy		Paddy after passing through the floating dryer	
		Fatty acid degree	Activity degree	Fatty acid degree	Activity degree
Oct. 18	After one month	15.65	99.5	12.99	97.5
	After three months	11.04	95.8	12.76	96.0
Oct. 20	After one month	11.35	98.8	13.68	97.8
	After three months	10.11	97.5	13.31	97.8
Oct. 21	After one month	12.64	97.0	12.96	96.8
	After three months	15.33	95.5	16.53	96.5
Oct. 25	After one month	13.64	98.3	13.77	97.0
	After three months	16.38	95.8	15.85	96.0
Oct. 27	After one month	13.41	94.3	15.12	96.8
	After three months	14.03	95.8	16.19	95.3



Graph3.

creasing in cracked rice when adopting the floating dryer. However, processors need have no misgivings about the problem. According to our investigation, cracked rice increasing rate is confirmed that it is about zero.

Graph 4 indicates the hot blast temperature and drying time when 1% of cracked rice increasing rate is permissible. However, in the case that the hot blast temperature is 65°C and the moisture is 26%, the drying time is allowed for 17 minutes. Since the drying time of the floating dryer is only for 3 minutes, it is comprehended that there is no fear of cracked rice.

Effect for Shortening Finish Drying time by Floating Dryer

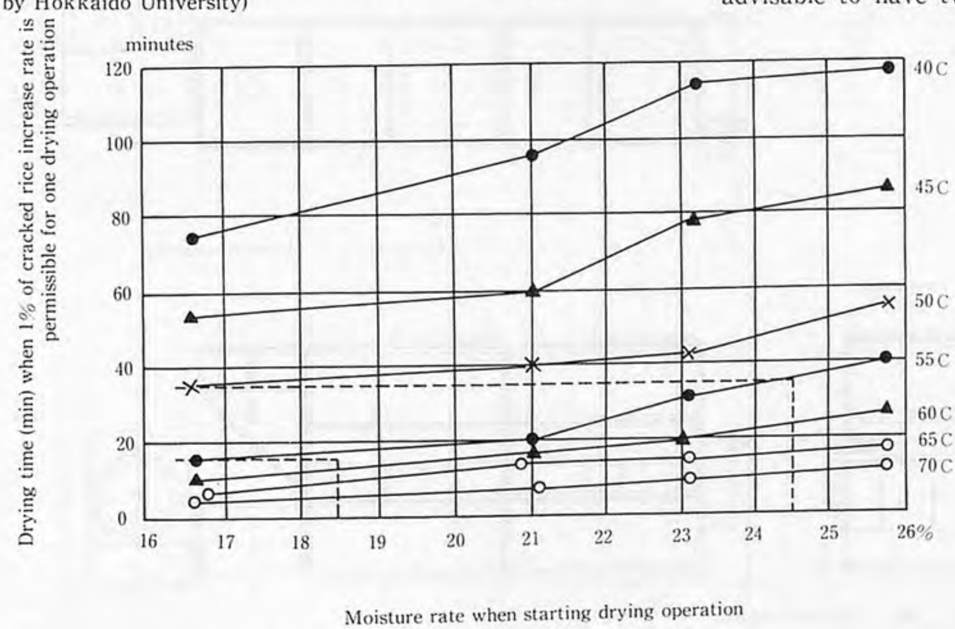
Graph 5. indicates differences of drying time between a drying operation in which fresh paddy is directly fed into the circular type dryer, and a finish drying operation of the same performed in the circular type dryer after pre-dried in the floating dryer. It is cleared that the finish dried paddy which was dried twice in the floating dryer necessitated only 60% of the time as compared with that of direct finish drying from fresh paddy.

There is no clear difference between paddy dried twice and the same dried thrice in the floating dryer. This is because of the lowered efficiency of the floating dryer due to the fact that moisture of grain is inevitably eliminated before the third drying operation. Consequently, for the most efficient practical use, it is advisable to have two passes on

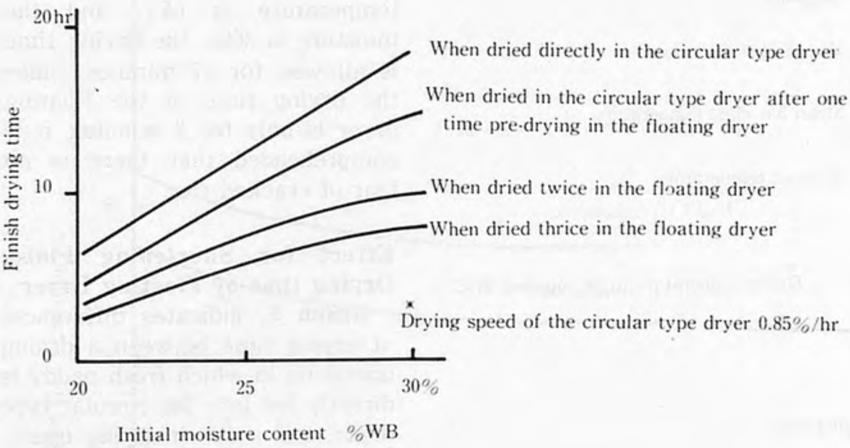
Table 3. Test Results of Cracked Rice

Sampling Date			Oct. 18	Oct. 20	Oct. 21	Oct. 25	Oct. 27
Fresh paddy	Heavily cracked	%	0.5	0.3	0.0	0.3	0.3
		No. of grains	(3/600)	(1/300)	(0/600)	(1/300)	(1/350)
	Lightly cracked	%	2.8	1.7	0.5	2.3	1.1
		No. of grain	(17/600)	(5/300)	(3/600)	(7/300)	(4/350)
Paddy passed through the flow layer	Heavily cracked	%	0.5	1.0	0.0	1.0	0.0
		No. of grain	(6/1,100)	(3/300)	(0/600)	(3/300)	(0/350)
	Lightly cracked	%	2.3	1.3	0.7	2.3	1.7
		No. of grain	(26/1,100)	(4/300)	(4/600)	(7/300)	(6/350)

※Table 3 shows actual measured values for cracked rice increasing rate. (Measured by Hokkaido University)



Graph4. An example of relations between moisture rate, hot blast temperature at the time of starting the Drying operation, and ventilation time for one operation



Graph5.

Table 4. Dust removing capacity of the flow layer (Measured at Hokkaido University)

Composition	Fresh paddy	Paddy passed through the floating dryer
Clean paddy	77.5%	85.3%
Head tip cut	10.5%	6.7%
Damaged paddy	2.5%	0.7%
Hulled paddy	4.6%	5.7%
Unriped paddy	2.3%	0.8%
Others	2.7%	0.8%
Total	100%(160gr)	100%(125gr)

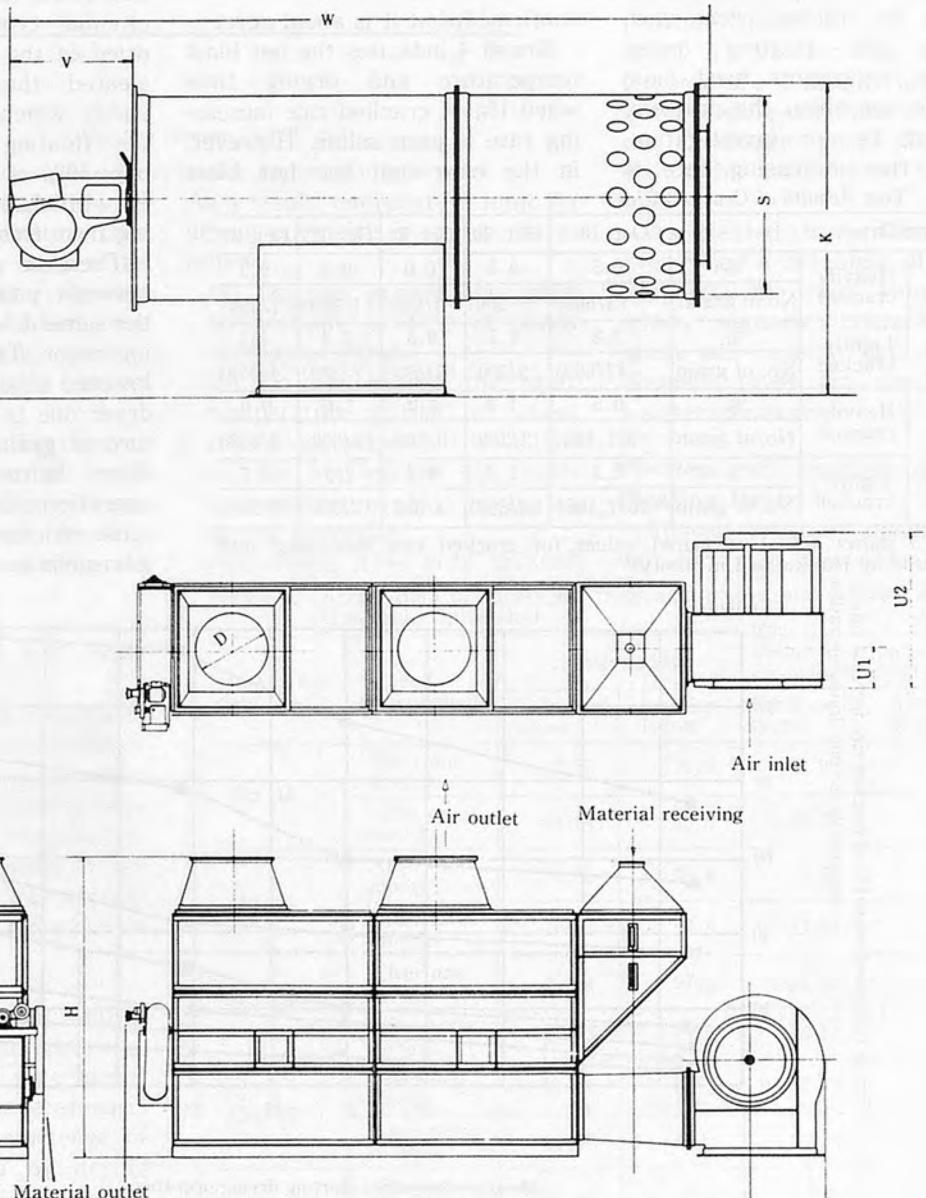


Fig.1. Construction of Floating Dryer

the floating dryer before the finish drying operation.

Regarding Rough Separating Function of Floating Dryer

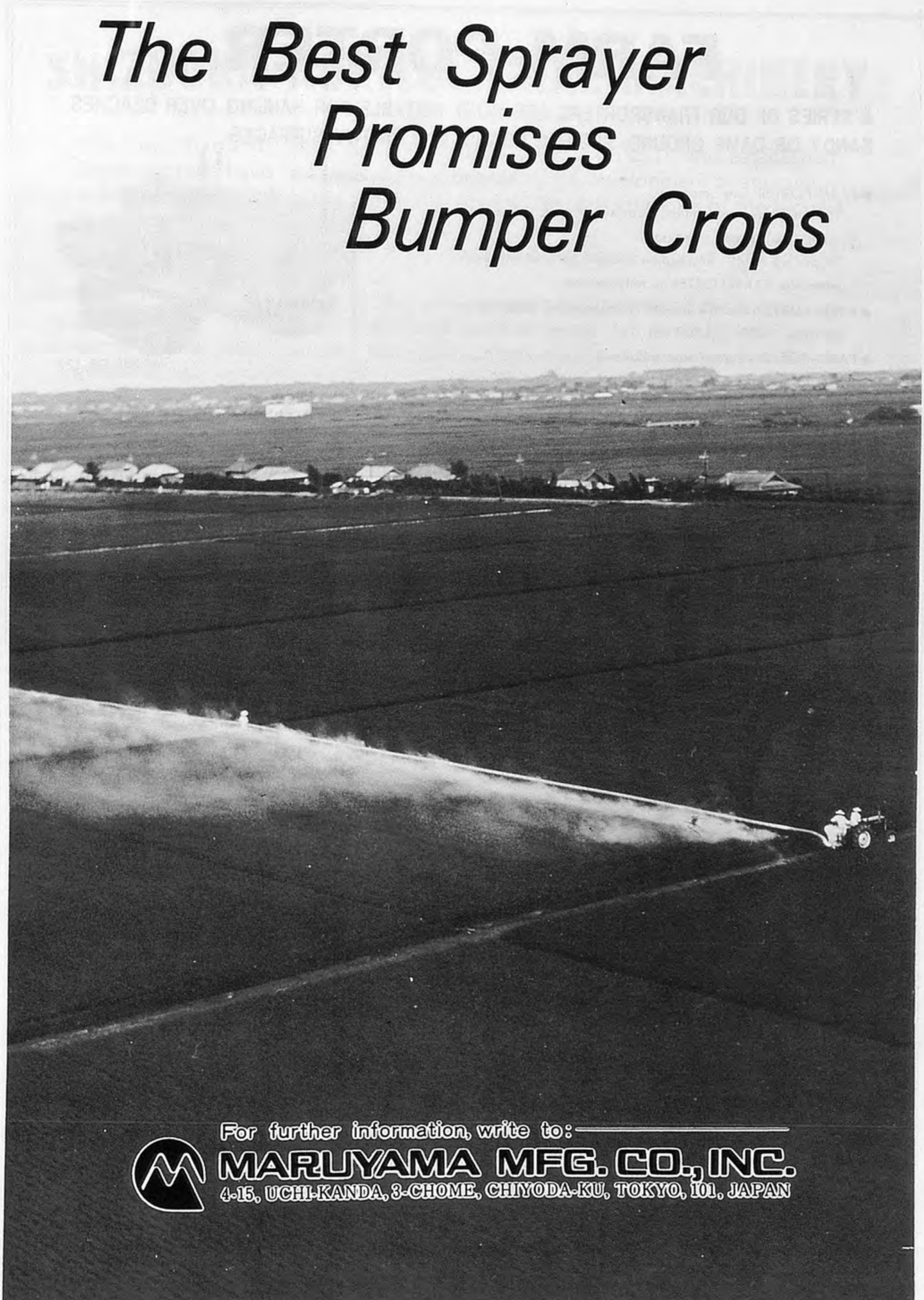
When paddy is being dried in the floating dryer, the weight of small and lightweight foreign elements adhering on the grain become lighter. They become easy to separate as the grain surface dries, and are discharged outside the dryer together with the exhaust air.

When paddy passes through the floating dryer, rate of clean paddy is widely increased. It is comprehended that unriped paddy and straw chip are sharply reduced. Thus, foreign elements are reduced and moisture becomes lower, which can accelerate fluidity of paddy. Accordingly, the subsequent processes are raised in efficiency, reducing troubles on the conveyer system. ■■

Table 5. Specification of Floating Dryer

	Model	FD-180	FD-300	FD-450	FD-600
	Processing capacity	3t/h	5t/h	7.5t/h	10t/h
Blower	Model	SRB-4	TBA-4 1/2	TLA-5	TBA-5.5
	Air flow	120m/min	200m/min	300m/min	400m/min
	Static pressure	180mmAq	180mmAq	180mmAq	180mmAq
	Power required	7.5 KW	11 KW	15 KW	18.5 KW
Heat source	Model	AH-10	AH-15	AH-25	AH-25
	Fuel	Kerosene	Kerosene	Kerosene	Kerosene
	Burner	Gun type	Gun type	Gun type	Gun type
	Nozzle employed	4 gallons	7 gallons	12 gallons	12 gallons
	Motor	200V 3ϕ 0.4 kw	200V 3ϕ 0.75 kw	200V 3ϕ 0.75 kw	200V 3ϕ 0.75 kw
Dimensions of main body	L	4,230mm	4,375mm	5,700mm	5,970mm
	H	2,500mm	2,500mm	2,700mm	2,750mm
	W1	760mm	1,200mm	1,200mm	1,200mm
	W2	940mm	1,380mm	1,380mm	1,380mm
	U1	290mm	315mm	335mm	355mm
	U2	880mm	965mm	985mm	1,005mm
	D	580ϕ	770ϕ	630ϕ×2	770ϕ×2
Dimensions of burner	W	1,943mm	2,230mm	2,730mm	2,730mm
	V	355mm	480mm	480mm	480mm
	R	465mm	775mm	870mm	870mm
	S	560ϕ	740ϕ	925ϕ	925ϕ
	K	808mm	1,125mm	1,350mm	1,350mm

BACK NUMBERS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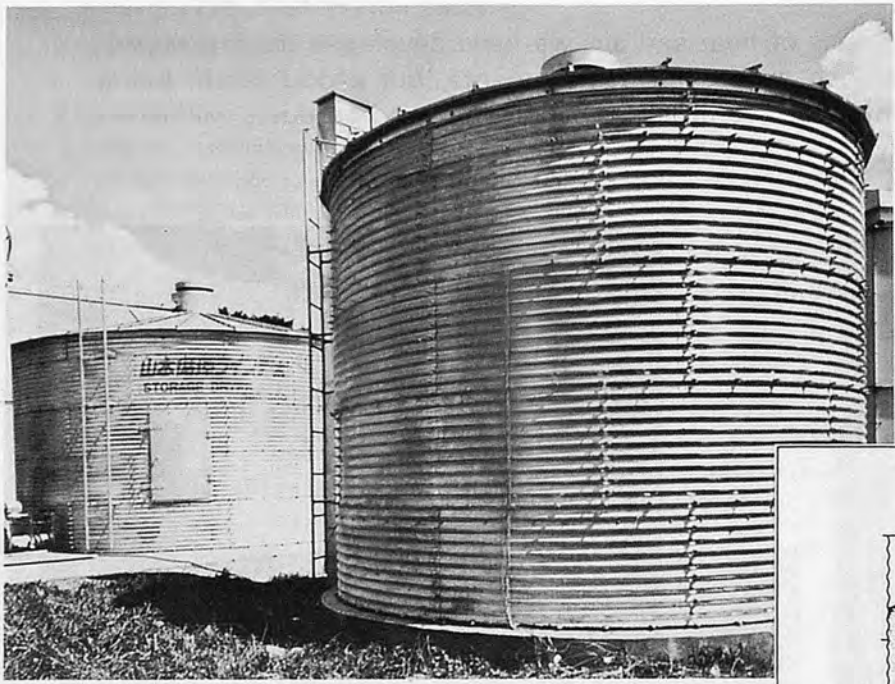
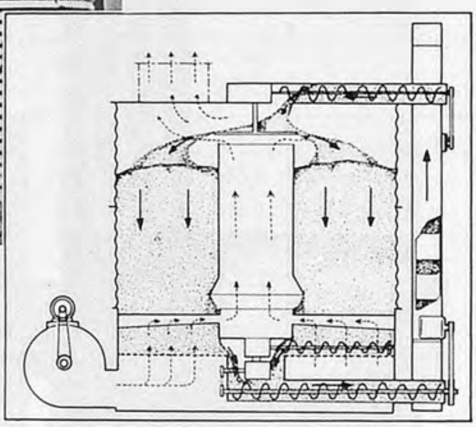
Rice harvest depends on right cultivation. As YAMAMOTO RICE DEPOT makes a new dryer system which fits with any regions and enterprises, it perfectly dry and store.



Rice Depot

YAMAMOTO RICE DEPOT can manage any amount up to 8 tons.



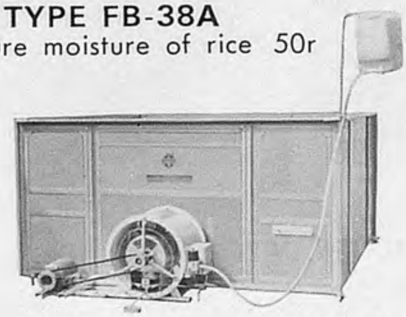
Explanation of Circulation Dryer

Specification

Type: SBD-3
Dimention: 4.3m (wibth) × 3.5m (length) × 3.4m (height)
(size of bin: 3m (diameter) × 2.7m (height)
Maximum capacity: 8 ton, 10 ton, 20 ton, 30 ton

LAYER TYPE FB-38A

to measure moisture of rice 50r



MOISTURE METER

for drying the small quantity of rice

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