1. WATER MANAGEMENT FOR PADDY FIELDS TROPICAL ASIA

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I. Introduction

Rice in tropical Asia is mostly grown in the river valleys and deltas such as the Ganges-Brahmaputra in India and Bangladdesh, the Irrawaddy in Burma, the Manam Chao Phya in Thailand, the Mekong in South Vietnam and Cambodia, and the Red River in North Vietnam. In countries such as Indonesia, Philippines and Sri Lanka rice fields are loacted along the narrow valleys and their surroundings slopes. There are similarity of natural conditions.

Successful paddy cultivation depends on adequate water management during the greater part of the growth period of the crop. This sounds simple enough, but in practice this requirement is reached only after solving a number of pre-requisite problems that vary in importance in each particular case. In many areas it becomes not so much a matter of supplying sufficient water but to control the water; not always the supply of water but its drainage; or again, it may be the supply of water at one time of the season and its drainage at another. When water is in short supply or expensive, it is necessary to give special attention to effective use of water resources. Good water management not only helps to boost the yield of the rice crop, and to expand the rice area, but also makes possible full use of water, time and land by allowing multiple cropping to be done. This intensive farming practice makes possible an increase in total yield per unit area per year.

A broad account of water management in paddy areas of the tropics is given in this paper. Since there are different kinds of paddy growing systems based upon the source from which water is received and each has its own problems only broad generalizations are possible.

Of the total area grown, only about 15–20% is under irrigation and only a part of this is under full water control. The main problem, therefore, is the lack of regional control of water; good water management at the village and field level is not possible where no regional control exists. Hence, much of the farmers efforts have been directed towards adapting their cultivation practices to the difficult conditions in which water availability is often uncertain, and choice of varieties adapted to particular conditions has played a large part in the systems that have been envolved.

II. Rain-fed and Flood-fed Paddy Fields

Lowland rice is generally grown on the paddy fields. There are usually leveled and diked with mud bunds in such a manner that water can be held on them. In flat basins ditches thread between the fields for the purpose of bringing water on. In rolling country, many adjacent fields may be flooded and drained by opening or closing small outlets at the earth bunds of the fields, depending on the force of gravity for desired flow of water. Methods to control water effectively are usually beyond the power of indivdual villagers or farmers in tropical Asia. Since the vast paddy growing areas in wet

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tropical Asia are found adjacent to rivers that seasonally overflow their banks and inundate the surrounding country.

Paddy fields are generally classified as rain-fed and flood-fed. Rain-fed paddy fields simply catch and hold water on the place where it falls, any excess water being allowed to flow out through the outlets of the earth bunds. In most of the tropical rice areas, the rainfall of about 1500–2000 mm. annually, comes mostly in the summer is sufficient therefore, for the summer rice crop without irrigation in the normal year. The season of rice cultivation has to be adjusted so as to coincide with monsoon. It is however, not unusual to experience water scarcity during the growth period, since rainfall is often shortage at the beginning and/or at the end of the monsoon. In places where the annual rainfall is below 1500 mm., with only 1000 mm. during the summer, supplementary irrigation of rice is needed.

The flood-fed paddy fields receive and retain water brought to them by the rise in the level of the river, after the river level falls, any excess water not needed is allowed to flow out. The rivers usually overflow at least once a year and supplement the rain so that little irrigation is necessary for the rice crop. Often, however, a portion of the crop falls because of too little or too much flooding. The rise of river flow deepnds on the amount of rain in the mountains where the rivers have their source. It should not be too early or the crop may not be sufficiently well grown to withstand inundation, nor so deep as to inhibit tillering or damage the crop. If the inundation is delayed, the crop may be too far advanced to take full advantage of the water. An exceeding late flooding may affect flowering and interfere with harvest.

It will be seen, therefore, that water control under such situations is almost impossible and the risks of rice growing under flood conditions are high.

Over large parts of the rice areas in Northeastern India, Central Bangladesh, Lower Burma, Central Plain of Thailand and Vietnam and Cambodia along the Mekong River valleys, there is often too much water during the growing season and no drainage is feasible because of topographical conditions. Planting is often delayed and carried out in deep water with overgrown seedlings, and the crops, suffer, therefore from poor planting conditions as well as floods in the active growing stage. In many areas it is necessary to grow floating or deep water rice varieties, the range of which is being increased by the introduction of special varieties which can adopt to different depths of water from 1–4 meters.

Near the sea, advantage is sometimes taken of high ocean tides to force fresh water into the nearby paddy fields. For instance, in the Ganges delta in lower Bangladesh, the Chao Phya delta in Thailand, the Mekong delta in South Vietnam and Cambodia and the Red River delta in North Vietnam the rise and fall of the tides is utilized to hold up or drain water according to crop requirement. Embankments with slucies are constructed as a protection in low-lying regions against floods and canals for drainage. These broad regional measures are essential before good water management can be applied in the fields.

III. Paddy Fields in the Irrigated Areas

Paddy cultivation does not depend on heavy rainfall, but on adequate water supply. With irrigation, cultivation may be expanded to areas of low rainfall. Through the efforts made by the people in the past many paddy fields are supplied with water in addition to rainfall or flood by various artificial means. Diversion ditches are built from small streams and the paddy fields fed by gravity; in flat valleys, water is pumped or lifted from streams or wells, or caught in open tanks during the seasonal rain or floods. Large scale irrigation from permanent structures has been practised in this part of world for about seventy years and has been extended in recent years. These projects were concerned with the elevation of river flows by means of diversion weirs or pumping plants and systems of feeder channels to distribute water to a wider areas. The assurance of a controlled supply of water in these areas has led to introduction of improved practices and varieties in these areas and to higher yields than in rain-fed or flood-fed systems, but the areas are relatively small in relation to the total rice producing area of the region.

Early irrigation projects were mainly designed and constructed to stabilize the production of a single crop of paddy rice against seasonal water shortage in the rainy season. However, the heavier rainfall in the later part of the rainy season, often cause floods in the depressions in which, because of topographical limitations, the costs of any remedial measures would be extremely high. Improvements in drainage systems have not generally matched the expansion of irrigation facilities.

The canal water from the diversion weir is generally diverted by gravity through turnout gates to laterals or sub-laterals. Gravity irrigation cost little in both operation and maintenance as compared with pumping irrigation. It should be the farmers responsibility to dig farm ditches near their farms but in many countries very few of them have done so. Because of the lack of active participation of water users, farm ditches were either non-existent or of very poor distribution in many of the project areas. Water from sub-laterals flows throughout the turnout gates into the nearby fields. It overtops the earth bunds of higher fields to the lower fields until the whole area is flooded. This practice of flood irrigation is wasteful when compared with furrow irrigation, but the latter needs a network of farm ditches which means more investment or more work.

Except in periods of extreme water shortage or excess, most of the proects are operated in a continuous flow basis serving water on a 24 hour day and 30 days a month basis. Continuous irrigation is wasteful when compared with intermittent irrigation, but a complete net-work of farm ditches together with proper number of check gates is needed for the later to be used: this entails high construction costs. Any irrigation system without farm ditches and attached structures must be considered as imcomplete and good water management can hardly be achieved under such a system.

Both flood and continuous irrigation are the primitive ways of water distribution which are suited only to paddy rice as the crop is grown under submerged conditions. Upland crops which need aerated soil conditions cannot be grown until furrow and intermittent irrigation are established and drainage facilities installed. These conditions are essential for sequences of rice and upland crops to be grown.

A survey made by FAO several years ago indicated that the cost per hectare of the irrigation project in Thailand was US$92 as compared with US$500–652 on similar projects in Malaysia and US$1,500 to 2,500 Taiwan, the average rice yield in Thailand is 1.8 tons/ha as compared with over 2 tons ha in Malaysia and over 4 tons/ha in Taiwan. While conditions vary from place to place, these figures indicate the size of problems of providing complete irrigation and drainage systems in many countries in Asia.

Diversion weir systems usually have very limited storage capacities so that their usefulness for providing water for a second crop after rice is very limited. They have the merits, however, of being relatively cheap to construct (compared with storage reservoirs) and of being reasonably satisfactory for ensuring the success of a single crop in the wet season.

Multi-purpose storage reservoirs for year round irrigation have been completed in recent years. The reservoir has the capacity to store a part of river flow during the rainy season and to release it in the dry season for year round irrigation. The construction of this type of scheme involves careful planning, heavy investment and effective management, but it offers the greatest potential for increasing agricultural production per unit area through intensive farming practices, since the yield of the main crop grown in the wet season can be increased and also enable the farmers to grow one or two additional crops during the dry season. However, there is often competition for water for other purposes as power generation, industrial and municipal water uses; consequently, dry season irrigation is often only possible in parts of the project areas.

IV. Water Management under Partial Water Control

Good water management is hardly possible in the present flood-fed and rain-fed areas. These fields suffer either too much or too little water during the rice growth period: in depressions water depth during the flood period may range from one to three or four meters and floating rice is the only crop that can be grown: there is no way of any water management under such water depth and drainage is impossible. Cultural practices and varietal adjustment are, therefore, the only means available to minimize damage to the crop due to sudden rise of water level.

In order to gain sufficient vigor for combating flood, rice seedlings should be at least six weeks in age before the advent to flood. In Bangladesh, floods occur usually by the middle of June and farmers generally sow seeds in late April or early May. The heavier soils of the depressions are extremeily hard and compact in the hot dry months of March and April and the paddy fields have to be opened in January after the harvest of the previous crop. If this opportunity is missed, cultivation must wait for the first monsoon rains, sowing is delayed and the young crop becomes liable to the damage by flood or to complete loss by early flood. Thus a cultivation practice in one season can have a marked effect on the next season crop.

In the rain-fed fields the problem is the seasonal drought which often damages the standing crop in the field. The cultivators task is to trap and hold rain water and keep it continuously in the fields as long as possible. In most of the tropiacl countries, the practical way is to maintain a deep water about 130 to 200 mm. (5 to 8 inches) in the field up to the ripening stage. This depth of water serves as a reservoir for meeting possible water shortage. However, there is no means of control depth to meet the requirements of different growth periods of the crop. Deep water is also beneficial in controlling weeds especially barnyard grass. Attention must be paid to land levelling and earth bund construction. Adjacent fields can be at different levels depending on the topography of land. The surface within the field plot should be so flat that when flooded the depth of water in each corner is uniform. Land levelling is therefore the pre-requisite for good water management. In flat regions, the size of field may be large, but in hilly terraces, small plots with curved bunds are constructed with a gradually fall in level. Space between bunds varies with texture of soil and the slope of the land. It can be relatively wider for fine clays but is mostly narrow for lighter soils.

Newly formed or reclaimed lands consume much more water than long cultivated ones, since seepage may reach three to five times the normal value and 4–6 years may be needed for stability to be reached.

The degree of water management in paddy fields also depends on the efficiency of the bund construction. Water is lost by seepage and overflow through badly constructed bunds. Soils of too light texture are generally not used. During construction, binding the soils is essential to make materials more compact and the inside surface of the bund should be pastered before the field is ready for transplanting. Seepage from paddy fields can be reduced by shallow water depth, thick and higher bunds and good maintenance. Both level surfaces and strong bunds help a great deal in achieving good water management during the growth period of rice crop.

Whether the paddy fields should be drained and maintained in a certain dry period in the middle of the growth period is a debatable point. In rain-fed areas the cultivators have no choice in this matter; the crop relies on rainfall so that there is no certainty that water will be available to refill the fields which have been deliberately drained. Periodical or mid-seasonal drainage is impossible if water supply is not certain during the whole of the growing season. It is common practice in China and Japan for paddy fields to be drained and weeded for two or three times, followed by the application of fertilizer and reflooding after several days. But in the tropical rice areas it is not common to weed after transplanting and little of any fertilizer is used.

In the rain-fed areas where water shortage happens frequently the beginning of wet season broadcast method is generally practised. In places where the rainy season ends earlier short season varieties are commonly adopted to avoid the seasonal drought.

V. Water Managemenr under Perfect Water Control

The pre-requisite of efficient water management is adequate control of irrigation and drainage throughout the rice growing period. It must be managed to supply adequate water during seasonal shortage and to drain out sufficiently and rapidly in period of excessive rains. Unfortunately, most of the irrigation projects constructed in the past have never reached this standard. The improvement measures and rehabilitation works taken up in the recent years have achieved some results in several project areas. Land consolidation programmes have been carried out and irrigation associations have been organized. Well planned water management can be started in these areas as pilot schemes for large scale promotion.

The unsystematic methods of constructng paddy fields in the irrigated areas, one after another, over a long period or time, has led to inefficiency in the location of irrigation and drainage ditches, and consequently waste of labour and water. Revised programmes for remedying this situation have been made in certain countries. The main efforts were to rebuild the whole cultivated areas belonging to villages by redesigning whole irrigation and drainage systems and laying out all paddy fields. After completion, each consolidated piece of land was regular in size and shape and was accessible by a distribution ditch, drainage channel and farm road. Thus, skilled water management could easily be operated resulting in an increase of crop yields and saving in water consumption.

Double or triple cropping systems are gradually adopted in areas where the fields can be drained or flooded to growers requirements. Good drainage is needed for the harvest of main crops and consequently facilitates the cultivation of succeeding crops in proper time. Irrigation is essential especially for crops grown in the dry months.

The key ingredients in practising multiple cropping are perfect water control and early ripening varieties. The shorter the growing season required by individual crops, the greater the possibility of raising one or two additional crops within the available growing season. In most cases, early maturing varieties yield lower than the long duration ones. But the high yielding varieties released recently by the International Rice Research Institute and several other national stations are also early ripening in nature. They consume however, large quantities of fertilizers and need better water management during the growth period. Their distribution is, therefore, limited to the areas with good water control.

Effective water management involves a knowledge of the available water supply, its distribution and application to the fields, the crop conditions, consumptive use at different growth periods, etc. Water management must also take into account such factors as water depth to suit crop needs, rate of application for particular soil types, and environmental factors in relation to plant growth. The development and maintenance of good water management requires these factors to be understood by individual farmers and members of the irrigation services as well as the agricultural agencies, so that the maximum production can be obtained from available amount of water. In many cases, group action should be done under a single authority in advance of individual actions.

This paragraph is intended to give briefly information on water management for both individual farmers and government officials concerned. This is subject to adjustment under special conditions and does not necessary have to be adopted everywhere.

1. Seasonal Water Requirements in Different Growth Period of Rice

The complete life cycle of the rice plant can be divided into four periods, viz, the seedling, vegetative growth, reproductive growth, and ripening periods. The amount of water needed varies with different periods, so that irriagtion must be regulated according to meet these requirements. Little water is consumed in the whole of seedlings stage. The vegetable phase covers the recovery and rooting after transplanting, non-effective tillering, and effective tillering stages, and ample water is required during the early part of this phase. Subsequently, shallow water is adequate during the major part of the vegetative growth period, and shallow water possible helps to promote the establishment of tiller and to check the development of non-effective tillers.

The reproductive growth period starts after the maximum tiller stage, and covers the panicle primordia development, booting, heading and flowering stages. A large amount of water is consumed throughout this period, and deficiency at this stage causes a serious decrease in yield. In preparing irrigation plan in areas where water is insufficient to submerge the field for a whole season, priority should be given to water supply during the post-transplanting stage and the whole reproductive growth period. Ripening period includes the milky, dough, yellowish and full ripening grain stages. Water is less needed during this period until finally no water is necessary after yellowish ripening stage.

It is hardly feasible to give any definite figures for the amount of water needed to grow a crop of rice from planting to harvesting because these amounts are determined by many factors. For instance, the amount of water already in the soil, the water holding capacity of the soil, the fertility of both the top and subsoils, the length of time that a crop occupies the land, the methods of cultivation all influence the amount of water that may need to be added to give best results. It is however, possible to find the relative amount of water generally required by rice by using field water measurement. Consumptive use is the quantity of water transpired by the rice crop together with that evaporated from the water surface of the paddy field. Water requirement is equal to the sum of consumptive use plus deep percolation. Variation is very large in percolation but rather small in evaporation. Percolation loss is greatly affected by natural conditions especially by the soils. These is a large variation of soil textures and structure within the tropical Asia. Total water requirement however, covers also water for seedling nursery and for land preparation of paddy fields. These can be measured by inflow-outflow method and following estimates may be used. A total of 1240 mm. of water will be required for the complete growth cycle of rice grown in tropiacl Asia. This total can be split into 40 mm. for seedling nursery, 200 mm. for land preparation and 1000 mm. for irrigation of the paddy field.

Rice cultivation starts with land preparation or tillage of soils. After an extreme drought period, the soil may be so hard, the plowing without soaking in water is absolutely impossible using animal power and primitive plows. A thorough moistening of the soils requires a considerable quantity of water in order to obtain suitable conditions for plowing and puddling. Poorly puddled fields cause heavy loss through deep percoration.

2. Depth of Application

Because of different moisture needs at the different growth periods, the depth of water should be adjusted accordingly as follows:

a. *During transplanting:* The puddled field should be drained for transplanting the seedlings. Deeper water is not desirable since this causes the growers to transplant the seedlings too deep. Deep planting will delay the development of new root systems.

b. *After transplanting:* Water must be maintained at a depth of 5 to 8 cm. immediately after transplanting to facilitate the reestablishment of the seedlings and to stimulate rapid growth of new roots. Water depth can be reduced gradually to facilitate field operations such as top dressing of fertilizers, weedings and intertillages.

c. *Panicle primordia development stage:* Before the beginning of panicle primordial development stage, field must be flooded to a depth of 5 to 8 mm. as shortage during this and later stages will bring about sterility and cause a big loss in production.

d. *After full flowering:* The paddy field must be drained gradually again 15 to 2 days after the full flowering stage. Late drainage will make it impossible to harvest the crop and to prepare the land for the succeeding crops in places where double cropping are practised.

3. Water Saving through Intermittent Irrigation

In places where irrigation water is scanty especially during an extremely dry weather, water saving methods have to be practised to minimize the waste of water. An intermittent supply of water was developed in Taiwan, China. The water was supplied at definite intervals (once every three to eight days depending on conditions). The whole region was divided into several areas with an average size of about 50 hectares each. Each area was again subdivided into several units. Each unit got its share of irrigation application in proportion to its area at the proper time. The sum of all application periods of the unit in an area would be the rotation interval.

Before irrigation was started, an irrigation schedule was prepared. This schedule gave both the date and time period of water distribution in each field of the unit. Each unit required two common irrigators to take care of water application and every 300 ha. of land needed one operator dealing water control and regulation work. It was reported that 20–30% of water could be saved through this practice. The important fixed installations were turnout gates, measurement devices and division boxes in addition to the complete water distribtuion system. The system only works, however, when the work force and farmers have been convinced of its effectiveness.

When water is in short supply or expensive, it is also necessary to give special attention to the water requirements of prospective crops. Two or three hectares of certain grains, legumes and vegetables can be grown in the same amount of water as required for one hectare of rice. A full consideration should be taken before to adopt double rice or a rice followed by an upland crop as the major pattern in the project area.

4. Group Action in Water Management

In principle, the distribution of water and the maintenance of farm ditches should be left to the farmers themselves, but some of cooperative actions may be necessary. It is impossible, therefore, for the individual growers to act independently. Certain kinds of group action may be promoted under the general charge of a single responsible head office.

Economic and efficient use of water and simplification of water control could be achieved if the growers prepared their lands and plant rice at almost the same time on a unit basis. Between units, the rotational schedule is formulated in an overall plan. Such system is more urgent if the quantity of available water is scarce or when several parties are interested in water distribution all at the same time.

The division of irrigated area into units for effective water control can be done several ways. In areas where the distribution and delivery systems are not complete, the sub-lateral plot is taken as one unit. Generally, the farm ditch plot is an ideal unit. From the point view of water distribution, the small unit is more preferable. The units are interchanged each year so that the fields of every farmer come once in the first unit and once in the last unit.

The exact date of planting within each unit should be fixed and announced by the local irrigation office. These commencing dates may differ in each year depending on the rainfall and discharge of the river. Within the same unit, field operation of each field may be done at the same time. The best arrangement is to establish cooperatively one common seed nursery for each unit.

This measure is not only beneficial to the water management but also facilitates the application of better seeds, fertilizers, pesticides, etc. It will serve the purpose of progressive farming on cooperative basis.

An uniform cropping pattern in certain parts of the irrigated area would economize the use of water. Water control will also be easier and simpler when a large acreage of land is planted with the same crop although it may belong to numerous cultivators. The farmers may be organized into units and be persuaded to cultivate continuous fields with the same crop following the same cropping pattern.

In Southern Taiwan, China with 80% of the annual rainfall concentrated in the summer season and the limited capacity of existing irrigation scheme, the water resources of this area were relatively poor. A special cropping system was therefore, developed to use water in a rational basis. In this area, the growing of rice, sugarcane and general crops such as sweet potato, groundnut, soyabean, jute, etc. was regulated by the supply of irrigation water. Farms were divided into areas of 150 hectares. Each area was subdivided into three units of 50 ha each. In any year, one of the unit would receive irrigation water sufficiently for growing one crop of rice in the summer the second unit would be given necessary irrigation only in winter and spring months for growing sugarcane; and the third unit would receive no irrigation at all for growing general crops. In the next year, the second unit would be given water to grow rice. The different types of water supply were given to the three units on a three year rotation basis. The system is therefore, called the three year crop and irrigation rotation system. It was only by the adoptation of this special system that a limited amount of water resources could be fairly distributed to a rather large area without disputes among the users.

Ordinarily, the water distribution to the field was carried out by farmers themselves. The common irrigator was introduced to avoid any misuse and waste through a strict control of field irrigation by experienced personnel under an overall plan. They were employed and paid by the local irrigation service for doing all the irrigation routine for the rice growers. Two irrigators formed a team taking care of water distribution of 50 ha. of lands. Each of them worked for 12 hours a day. They were provided by the service with the irrigation schedule showing frequency and interval of irrigation and date and time of starting and finishing irrigation and maps showing location, acreage and owner, of each fields. Common irrigators were in charge of the supervision of the upkeep of farm ditches and also were responsible for preventing illegal irrigation by farmers. They also supplied information to the local irrigation office about the conditions of crop, the seasonal water requirements, the progress of water distribution and water losses in the ditches within their unit. They played an important chain between the irrigation service and farmers.

5. Water may Become Limiting Factor in Future Rice Production

The human population of the World continues to soar while the increase of food production continues to lay behind. Some scientists feel that an increase acreage of irrigated lands will solve our future food problems, but water is becoming more valuable also for industrial and culinary purposes. It is estimated that by the year 2020, industrial, municipal, domestic and power requirements will be three times to day's total requirements. Thus, the use of water for agriculture will indeed become more competitive during the next 30–40 years. This will indeed be a water crisis in the near future, and may emerge as a limiting factor in meeting man's nutritional requirement. How to make effective use of the limited water resources for rice production will be a challenge to agriculturists, irrigation engineers and farmers in near future. Multiple cropping is getting more and more popular in the near future, very soon there will not be enough water available for further extension of dry season irrigation in the existing projects. Let us think over what we can contribute for our part to solve the problem.

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Question and Answer

Cheong Chup Lim, Malaysia: The speaker mentions of mid-season drainage as part of the recommended water management practice. May I know the rational for this?

Answer: Mid-season drainage helps very much to such field operations as weeding, intertillage and application of fertilizers. After these operations are over, field can be reirrigated. Japanese scientists have done a lot of research in the past. I hope that Dr. Yamada brings some lights of this subject.

N. Yamada, Japan (Comment): Mid-season drainage in Japan is practiced mainly on very fertile soils in order to avoid overgrowth of rice in fertile soils. By drying the soil NH_4-N in the soil is changed to NO_3-N, and the NO_3-N is leached down after re-irrigation. This practice causes a great loss of nitrogen.

Under the shortage of fertilizer supply in tropical countries, this practice, I think, should not be recommended in most cases.

Answer: I wish to follow Dr. Yamada's suggestion.

John Aroonkumar Lewis, Sri Lanka: Is it your view that water is to be used for maximum production of rice per unit area or the same quantum of water is to be used to bring more land under cultivation regardless of maximum produtcion.

Answer: It depends on local condition depending on the availability of water. There is no general rule.

I believed firmly that good water management not only helps to promote the production of rice but also saves water consumption per unit area. The water saved in one area can be used for other area.

J. A. Lewis, Sri Lanka: Is the water use policy to increase irrigated area under a given quantum of water or to increase the yield per unit area?

Answer: Please refer to the other sheet.

S. Okabe, Japan: You have referred a couple of times to the on-farm development and land consolidation in Japan. It has taken, however, 200, 300 years or more for the Japanese farmers to achieve the present level of on-farm development. I understand that among the tropical Asian countries there exists a great variation of development levels, in terms of crop fielding level, of technological advancement, and of income situations, and that each level would require a different type of on-farm development which should be the most appropriate to the respective conditions. Do you have any idea in developing on-farm works which should meet the respective development levels?

Answer: I agreed that it will take time to reach the on-farm development in tropical Asia so far water management is concerned. But I also believed that the implement of land consolidation programme solved the major part of problem. Government initial in this respect is necessary. Price incentive of farm products is also essential. When the farmers have really been benefited by the project, it will cut short the time needed to reach the on-farm development to a great deal.

In th present rain-fed and flood-fed areas, water management is almost impossible, let along with any kinds of on-farm development. What the individual farmers can do to minimize damages due to natural disasters such as droughts or floods to their crop is to select special varieties or to regulate the cultural practice meeting the difficult conditions.

T. Saito, Japan: What kind of attention is required after the work of the land consolidation in the tropical area?

Answer: When land consolidation program is completed, the farmers of the area should soon be organized into farmers association and the practice of double or multiple cropping should soon be demonstrated. Or in the other words a group action should be promoted in order to facilitates the implemention of integrated approach.

Sebastian I. Julian, Philippines: On page 12, Paragraph 2.a—With 2 to 3 cm. depth of water before transplanting the seedlings in puddled field, are you still able to transplant in straight rows without the benefit of lines which could only be done if the paddy field is surface dry or saturated? On surface dried paddy that are being transplanted, are there some effects on the yields? Which of the two conditions would you recommend and, why?

Answer: In general, farmers always keep deep water in the paddy field during transplanting period. They also use the over-aged seedlings (say 40–45 days old) which are rather long. My suggestion is to keep water depth as shallow as possible (2–3 m) and to use young seedling of 20–25 days. When line marker is used to guide transpalnting in straight row, dry surface of paddy field is preferred.