ADOPTION OF DIVERSIFIED CROPPING IN RICE IRRIGATION PROJECTS[1]

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INTRODUCTION

In the wake of perceived rice surpluses and market price fluctuations, the controversy over further investment in rice-oriented irrigation projects has received increasing attention. The World Bank in 1982, for example, recommended to the Philippines a slow-down in irrigation projects unless the government could regularly tap export markets. As a result, Phase I and II of the "Study of Food Demand and Supply and Related Strategies for Developing Countries" were undertaken. Policy dialogue between the Asian Development Bank and Indonesia regarding the agricultural sector, including irrigation, began in late 1982 from which came a two-year technical assistance grant on "Study of Food Production and Irrigation Strategy in Indonesia" starting in 1985. The World Bank also conducted the on-going Water Master Plan Study in Bangladesh and the "Thailand Irrigation Sub-Sector Review." These studies reflected the need for change in irrigation investment strategy in Asia.

A principal objective of these studies was an appropriate compromise between cost effectiveness and rice production for national food security. The adoption of irrigation schemes for diversified cropping is considered one of the best compromises for irrigation investment. Such a scheme would be able to continuously support rice production to assure food security. In cases of rice surplus and where non-rice crops have a comparative advantage, the irrigation system could be adapted to support non-rice crop production. Ideally this would maximize exports and/or minimize agricultural imports. In view of the widespread skepticism about future investment in rice irrigation systems, diversified cropping in irrigation schemes would permit a rational use of land and water resources. Since the additional investment for diversified cropping is small in comparison with the total needed for an ordinary rice irrigation system, it would be worthwhile to explore the possibility of adopting diversified cropping in irrigation schemes.

This paper briefly reviews existing diversified cropping in Asia. It then describes the physical operation and maintenance (O&M) requirements for diversified cropping, and identifies constraints to implementing diversified cropping. Finally, it furnishes suggestions on the approach to implementing diversified cropping in irrigation systems.

REVIEW OF EXISTING DIVERSIFIED CROPPING IN ASIA

Non-designated Diversified Cropping

The common practice of diversified cropping on irrigated land is to grow non-rice crops after harvesting irrigated rice at the beginning of the dry

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season. Those crops use residual moisture from irrigation for germination, and then grow in semi-rainfed conditions. Two or three periods of irrigation from the system may be used depending upon the availability of water resources. In some cases, farmers manage to find their own water resources from shallow tubewells, small ponds, or creeks. Crops not obtaining sufficient water from irrigation or rainfall may produce low yields or suffer damage. The farmers who practice this kind of diversified cropping are usually aware of the risks; however, through long-term trial-and-error, they eventually gain enough experience to carry out the most profitable diversified cropping.

This cropping practice may be found in many Asian irrigation systems. Adoption is generally piecemeal and on small areas, but some systems have a significant portion of total irrigation in this pattern. For example, in Bangladesh, around 40 per cent of the potential wheat acreage is already grown under rice-wheat rotation, and that area is expanding at an annual rate of 14 per cent. Thousands of hectares of tobacco are grown after the harvest of monsoon rice under intensive irrigation by using individual wells in the Teesta Irrigation Scheme[2] in northwest Bangladesh. In Nepal, wherever water resources are still available in the irrigated areas from the hills to the Tarai, wheat, mustard, or maize are grown in the post-monsoon season.

A Case Review of a Designed Diversified Cropping System

System design. One of the most sophisticated diversified cropping irrigation systems in Asia, the Chin-nan Irrigation System is located in southern Taiwan. It began operations in 1927 (construction period from 1921 to 1930) and covers an irrigated area of about 150,000 hectare (ha), of which about 8 per cent comprises clay soil and the rest sandy loam to silt loam. Annual precipitation over this area averages 2,500 millimeters (mm). Since the available water resources during development were only enough to irrigate one-third of the total area to grow one crop of monsoon rice, a three-year rotation cropping pattern (rice (monsoon)-upland crop-sugar-green manure) was carried out. In order to implement rotational or diversified cropping, the entire irrigated area was divided into 150 ha units; each rotation unit was divided into 3 rotation sub-units each of 50 ha; 3 crops, rice, upland crops, and sugar, were planted in each sub-unit by rotation in 3-year cycles. The layout of the irrigation/drainage system was also designed to fit the required rotation cropping. In particular, each 50 ha sub-rotation unit had its own separate off-take gate(s) from the irrigation system, so that irrigation water could be delivered separately to each unit.

Support services. To ensure the success of diversified cropping, Water User's Groups and Sub-Water User's Groups were carefully organized, based on the crop rotation units and their sub-units. Several experimental and demonstration stations were organized and operated during the construction period; and other support services such as extension, research, credit, post-harvest facilities (rice mills, sugar refine factories, and seed oil factories) were established parallel to the construction of the irrigation system.

Government intervention. With strong support from government, the operation of this irrigation system gradually moved toward diversified cropping after six years of trial-and-error. For the most cost-effective use of limited water resources, the government gave the first priority to rice, the second to sugar, and the third to upland crops. As a result, rice usually received sufficient irrigation water in its growth period; sugar was irrigated on average only twice in one dry season with 90-100 mm of water. Fifty percent of the time, the upland crop was irrigated once with 60 mm of water, and for the remainder received no irrigation. This water utilization policy has been followed by farmers and policy makers for more than 60 years and is expected to continue in the foreseeable future.

Acceptance of designated diversified cropping. The main thrust of government intervention in operating this system was in expediting the project objectives, mainly achieving self-sufficiency in rice and minimizing imports of agricultural products. Ten years completion, sugar exports provided the largest amount of foreign exchange earnings. Living standards of farmers were significantly improved as well. The farmer's response to government arrangements was positive, and the designated diversified cropping pattern was strictly followed. This response was attributed to the project design successfully accommodating the aim of national food self-sufficiency and the farmer's natural profit motive. This government-designated diversified cropping pattern was strictly followed by farmers until World War II.

There has been tremendous change in the economic, social, and political environment of the last 30 years. Substantial improvements have been made in water resources and irrigation facilities since 1950. However, the three-year diversified cropping rotation technique remains unchanged; the only difference between the existing designated cropping patterns and the previous ones is that one more crop of rice and one more upland crop have been inserted into the three-year cycle. Previously, the crop rotation was grown consecutively in a three year cycle; this has been replaced by the rice-upland crop-rice-sugar-upland crop pattern (Figures 1 and 2).

Farming is a business in Taiwan, and the further it advances beyond subsistence agriculture, the more it becomes so. The officially designated diversified cropping pattern is no longer compulsory for the Taiwanese farmers. The farmer has full authority to decide his own cropping pattern, and the designated pattern is often ignored by farmers. However, this does not necessarily mean that the official cropping pattern should be abolished. On the contrary, it deserves to be maintained as the guideline for formulating water delivery schedules. From the official cropping pattern, farmers will be aware when and how much irrigation water will be available for their land; and they can select the most profitable crop to be grown by optimizing the use of available water.

The farmer's decision on his cropping pattern is usually based on profit maximization and risk aversion. The designated diversified cropping pattern followed is highly correlated to the price fluctuations in both input and output products. In general, about 80-95 per cent of farmers will follow the official cropping pattern if their lands are in turn for growing rice, because rice has a comparatively stable price and thus a reliable profit. Furthermore, the land will be too soggy for individual farmers to grow upland crops if the majority of lands are growing rice.

Figure 1. Irrigation for three year crop rotation. (Note: From November to March, sugar cane will be irrigated two to three times according to water supply and actual need.)

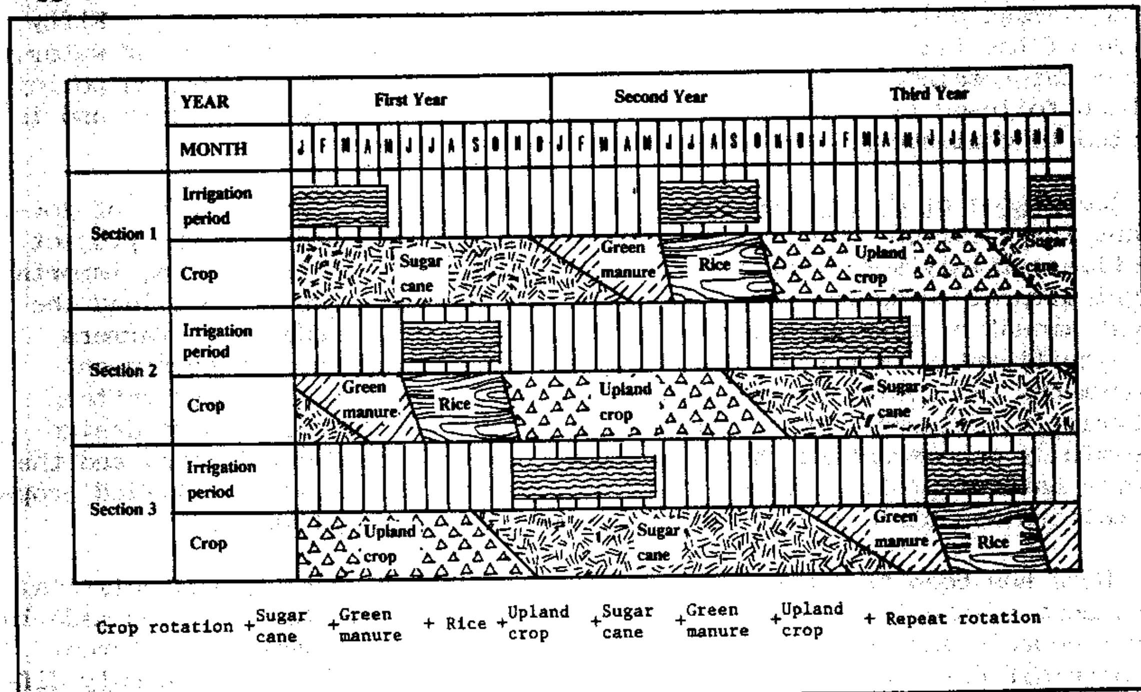
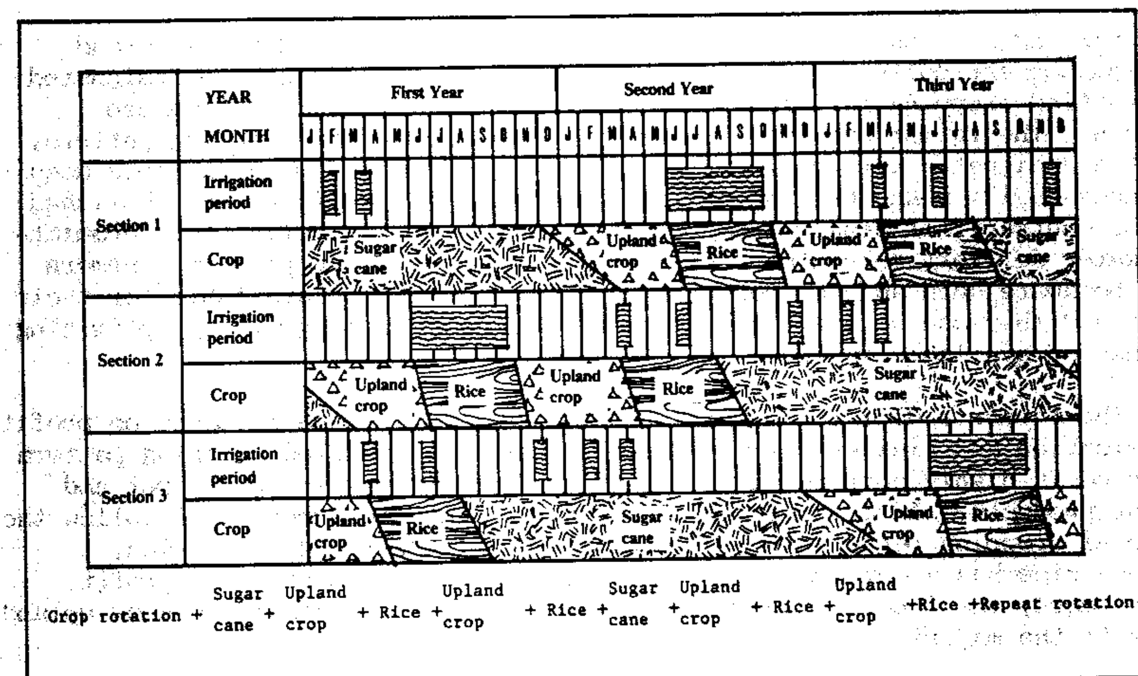


Figure 2. Modified irrigation schedule for three year crop rotation of the Wu-Shan-Tow system after completion of the canal lining. (Note: The upland crop will be irrigated once in March-April and once in late June. Upland rice will be irrigated twice.)



On average, less than 30 per cent of the area selected for sugar will actually be planted due to its low price. As a result, about half the refineries in that area have closed in the last 20 years. Two to three upland crops can be grown on these lands to substitute for one crop of sugar. More than 80 per cent of the area is scheduled for upland crops because the land will not support rice unless the land owners have their own water resources.

Status of Adoption of Diversified Cropping in Irrigation Projects

Notwithstanding widespread skepticism about adopting diversified cropping in rice-oriented irrigation systems, many international agencies financing irrigation projects in Asia have already adopted diversified cropping to some extent. A typical irrigation project usually has sufficient water to irrigate the entire area in the wet season; however, in the dry season, the availability of water may not be adequate to irrigate the whole area, so part of the available water will be allocated to upland crops. Moreover, between the two main rice crops, a small portion of the project area will grow some upland crops. As a result, 210-250 per cent of the multiple cropping index can generally be found in such irrigation projects.

However, diversified cropping is adopted in those projects mainly to enhance the economic viability of the project. Because the capacity of the irrigation facilities is usually dominated by the requirements of wet season irrigation, inserting upland crops either between the two main rice crops or concurrently with rice in the dry season will not affect the capacity of the system. Thus the incremental investment cost to the project for adopting diversified cropping is often considered negligible (though this may not always be true) and a significant benefit will be obtained. Therefore, diversified cropping has been broadly adopted as the guiding project cropping pattern in recent irrigation projects. Whether the necessary inputs have been properly supplied for the implementation of diversified cropping or to what degree the designated cropping pattern has even been realized still remain to be seen.

DECISION MAKING AND ITS CONSTRAINTS FOR CROPPING PATTERN

Adopting a cropping pattern is influenced by three levels of decision making: government, system (irrigation associations), and farmers. Farmers base their decisions on the natural environment and on the economic, social, and structural environment created by public institutions, including agricultural sector policy, land reform, commodity pricing, long-term investments, and special subsidy programs. Identifying how farmers make their decisions must consider the role of these public institutions and the government and irrigation association decision makers. Each group has its own objectives and its own constraints which limit objectives. While their objectives may not necessarily be contradictory, their priorities may differ. The objectives, constraints, and responsibilities for each group are described below.

Government Level

This is the national policy-making level. Agricultural policy objectives formulated at this level usually aim at increasing national, regional, and farmers' net incomes; achieving equitable distribution of income; improving social welfare; and providing food self-sufficiency. Balancing all of these objectives is complicated by the long list of constraints acting on the agricultural sector. Among the most pressing constraints are: finding available cultivable and irrigable land; lack of money for investment, subsidy, operation, repair, and maintenance of infrastructure; poor land tenure system; weak foreign and domestic demand for commodities; and small farm size.

System Operator Level

The primary objectives for cropping patterns and water use at this level are to: distribute water equitably to farmers, use available water efficiently, improve crop yield, and maximize irrigation service fee collection. The constraints which limit these objectives are institutional -- limited budget, lack of control over government subsidies and loans, uncertain agricultural support, inadequately trained or lack of personnel, and weak enforcement and arbitration of water rights -- and physical: uncertain water resources, poor soil and topographic variations over the region, and poor condition of existing irrigation/drainage facilities.

Farmer Level

It is universally true that farmers in an irrigation system still have latitude to make independent decisions on cropping patterns and water use. Their decisions are often guided by the following objectives: a) to increase net income, b) to minimize their exposure to risk, c) to maintain control over farming decisions, and d) to preserve traditional practices. There are a number of factors which limit the farmer from attaining the theoretical maximum of his objectives: soil type, farm location in the irrigation system, condition of irrigation/drainage facilities, designated cropping pattern, availability of water resources, previous experience, level of education, available credit; working capital, and available agricultural information. The crop production and gross income may be limited by one or more of these constraints, or several constraints may be simultaneously binding on a particular farmer's decision-making.

PRIMARY REQUIREMENT FOR DIVERSIFIED CROPPING

While recognizing the possibility of adopting diversified cropping in rice-oriented irrigation projects, the next question is what inputs are needed in the stages of project preparation, project implementation, and project operation. Based on experience gained in the operation of the sophisticated rotation cropping scheme in Taiwan, the physical and institutional inputs necessary for diversified cropping are described below.

Institutional Inputs

Guiding cropping pattern. To realize the government's investment objectives in the irrigation sector a guiding cropping pattern is usually formulated during the project preparation stage as the basis for determining the development scale, cost estimate, and project benefit monitoring evaluation.

In the project operation stage, it serves as a guide to the system operator to carry out the irrigation program; the irrigation water will be delivered mainly according to the farming activities proposed in this pattern. The farmer may, therefore, know when and how much water will be available in the field in advance and can thus plan his farming activities accordingly. This pattern is subject to modification in the project operation stage in accordance with changes in national short term agricultural strategy. Thus, the pattern must be so well prepared that completed irrigation/drainage facilities, whose designs are based on that cropping pattern, can be flexible to accommodate any possible modification.

Agronomists for water management. The complexity of the plant-soil-water relationship for non-rice crops requires advice from an agronomist. For an intensive diversified cropping irrigation system, one agronomist for every 500 ha of diversified cropping is considered necessary.

Experiment and demonstration stations. The tendency to preserve tradition always inhibits farmers from accepting new cropping patterns. A demonstration is one of the best ways to convince the farmer to experiment; and a successful demonstration of farming practice and irrigation management must be supported by field experiments. Therefore, the establishment of field experimental and demonstration stations in the project area should be one of the project components for a diversified cropping irrigation project.

Agricultural support services. The need for agricultural support services, including extension, input supply, storage and marketing, by-product utilization, and agricultural credit in a diversified cropping irrigation system is more critical than in a rice-only irrigation project. The more support services the government provides, the more intervention power the government holds and the more the government's objectives will be realized.

Access to agricultural information. Better access to agricultural information on prices of inputs and outputs, supply and demand of agricultural commodities raise the quality of the farmer's decision-making. This input may be considered as a part of agricultural support services; however, it is so important to a commercialized farming system that it needs highlighting.

Physical Inputs

In essence, the major physical inputs required are the same as for any other irrigation project though sensitivity to the various physical inputs between rice and non-rice crops may differ. Proper physical inputs must be provided for both rice and non-rice crops simultaneously. The additional physical inputs required for diversified cropping are recommended[3] below.

Drainage facilities. Drainage as well as irrigation facilities are essential to growing upland crops. Most upland crops cannot sustain growth in saturated soil for more than one or two days. Without good drainage, an irrigation system cannot adopt diversified cropping effectively. Moreover, the principle of a better yield from a better drainage system also applies to rice. Good drainage facilities may be considered as an incremental investment in diversified cropping. The design capacity for drainage facilities is governed by rainfall, soil characteristics (infiltration rate), ground water table, and how long a plant root zone can remain saturated without adversely affecting the plants, which in turn depends principally on temperature, type of plant, and growth stage. In some cases, the investment cost for drainage facilities may take up a large portion of the total project cost, preventing the adoption of diversified cropping in that project.

Irrigation facilities. Theoretically, the capacity of facilities designed for rice irrigation should be sufficient for irrigating upland crops. Although additional irrigation facilities for diversified crops are usually considered unnecessary, in some extreme cases, if the designed capacity of canals is based on lengthy land preparation (longer than 30 days) and the irrigation cycle for upland crops requires a shorter period (shorter than 10 days), then the canal needs a higher conveyance capacity to meet the requirements of upland crop irrigation. This may happen more often in lateral or sub-lateral canal systems than in main or lateral systems. Temporarily using part of a canal's freeboard for conveying water will adequately meet the requirement of the highest discharge in upland crop irrigation. If the required quality of irrigation management is the same for irrigating rice and non-rice crops, there is no justification for additional water measuring devices.

IRRIGATION MANAGEMENT IN DIVERSIFIED CROPPING SYSTEMS

The Characteristics of Upland Crop Irrigation

Basic differences between rice and upland crop irrigation. The objective of irrigating rice and upland crops is the same, but the concept and characteristics of irrigation is very different for each. Rice is an aquatic plant and can survive or even thrive when its root zone remains saturated. Irrigation water is applied to the paddy in sufficient amounts to keep the right depth of water above the ground surface and to meet the consumption of soil percolation and plant evapotranspiration in one irrigation cycle. The two governing factors for rice irrigation are the soil's final infiltration rate[4] and plant evapotranspiration.

Upland crops survive only for a short period if the rootzone remains saturated. Upland crops extract moisture stored in the soil of their root zone; thus the water depth and frequency of water application in upland crop irrigation varies with the depth of rootzone and distribution as well as with the moisture-holding characteristics of the soil. The rooting depth and the distribution of roots depend mainly on the kind of crop, the growing stage, and the soil profile. The available moisture-holding capacity (i.e., the difference in volume percentage between field capacity and wilting point is predominantly determined by the texture and structure of the soil). There are more variables in upland crop irrigation than in rice irrigation.

Compensation for lack of data. The complexity of upland crop irrigation may inhibit many irrigation projects from extensively adopting diversified cropping if the above-mentioned phenomena have to be identified and relevant data must be collected in the preparation of a diversified cropping irrigation project. Fortunately a lack of such data can be compensated for in two ways. In the project planning stage, data from comparable areas can be used and in the project implementation stage, the adopted data in the project preparation stage can be verified via demonstrations at local experiment stations. More accurate data can be obtained through trial-and-error in the project operation stage leading to improvements in irrigation management.

Formulation of a Cropping Pattern to Guide the Project

Irrigation water requirement. Basic data on the irrigation water requirements for rice and upland crops is required for formulating the optimal cropping pattern to guide the project. If fundamental information is lacking, the modified Penman method can be used to calculate a crop's consumption of water. The fundamental information needed to estimate consumption, such as crop coefficient, climatic data (like temperature, relative humidity, wind velocity, sunshine hours, and evaporation), and effective rainfall should be available. The additional information needed for upland crops is the soil field capacity. The overall irrigation efficiency for upland crops may be assumed to be about 35-45 per cent. The residual soil water content before irrigation can be obtained by sampling the field soil.

Trial-and-error procedure. The optimal cropping pattern can be formulated through trial-and-error by assuming acreage of various crops, multiplying this acreage by their corresponding irrigation requirement and net benefit. Then the annual project net benefit and annual water requirement can be obtained. The feasibility of each trial can be judged against the annual water requirement and water availability. Then the optimal cropping pattern can be selected from those trials.

System analysis approach. The optimal cropping pattern can be directly calculated by using operational research. Government's long-run objectives can be formulated by using areas of various crops to be grown as the decision variables. The net benefit of each unit area of crop is used as the parameter for each corresponding decision variable. It is possible to establish a group of constraint equations for the objective function from the available water resources, available area, the capacity of irrigation facilities as well as the irrigation requirement for each crop. By solving the objective function and the group of constraint equations simultaneously by linear programming, the optimal cropping pattern can be obtained.

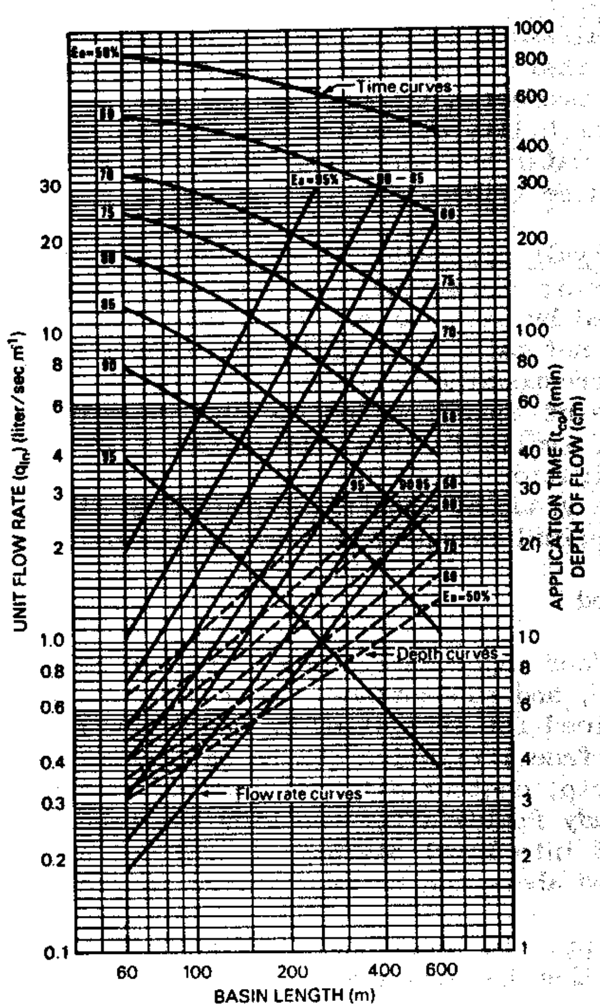
Irrigation Method

There are four major categories of upland crop irrigation: sprinkler, trickle, surface, and sub-surface, among which only the surface irrigation method is practiced for irrigating upland crops in paddy fields. Depending on the crop, surface irrigation can be categorized as: furrow and corrugation; border strip; contour ditches flooding; and basin. When upland crops are grown in paddy fields after the rice has been harvested, the land will have been graded into level basins. Therefore, all the surface irrigation methods indicated above can be implemented in the condition of level-basin.

Basic concept. In level-basin irrigation, the water flows over the basin first and then becomes static. For attaining infiltration uniformity, the water is generally applied to cover the field in a relatively short period on a volume basis. The main portion of the water infiltrates during static flooding. This is different from sloping border irrigation, in which flow rate is balanced against application time to provide uniform and coverage. Without ponding in sloping irrigation, the infiltration occurs while the water is moving, i.e., has dynamic status. Thus, it appears that level basin irrigation is less complicated than sloping surface irrigation.

SCS Design Manual and its application. The factors which govern level-basin irrigation are: unit flow rate, basin length, flow depth, application time, application efficiency (distribution uniformity), Manning roughness value, soil infiltration rate, and net application depth. Correlating all these factors is complicated. The SCS Design Manual[5] is recommended for examining length and design capacity of farm ditches in the project preparation stage, and for determining irrigation time in the project operation stage.

Figure 3. SCS design chart for a 7.6 centimeter net depth of application, roughness coefficient "n" of 0.15 and an intake family of 0.5.



In order to familiarize readers with the Manual, an example is given as follows: referring to Figure 3, for a basin length of 200 meters to attain an application efficiency (distribution uniformity) of 80 per cent, the required unit flow rate would be 3.3 liters per second (lps), the application time (Tco) would be 96 minutes, and depth of flood would be 10.4 centimenters (cm). If total flow were 150 lps, the basin width should be about 45 meters. To increase the basin length to 400 meters with the same distribution uniformity, the corresponding values would be qin = 11.2 lps, Tco = 55 minutes, and the depth of flow would be 18.8 cm. For the same flow rate into the basin, the basin width should be decreased from 45 to 13 meters. The example indicates that the only information required for measuring in the field is the intake rate of the soil; with this information, the Manual can be easily used for the design of on-farm systems as well as for irrigation planning.

Crop and irrigation method. The method of irrigation is mainly determined by the type of crop. An improper irrigation method not only decreases irrigation efficiency but also may adversely affect crop growth. In general, close-growing crops such as peanut and wheat are irrigated by corrugation, borders, border ditches, basin and contour ditches, while row crops such as sugarcane, corn, and sweet potato are irrigated by furrows and borders.

Physical Operations and Maintenance (O&M)

Irrigation planning and execution.

a) Guiding crops. Although there may be more than one crop grown in the upland field, irrigation cannot be planned based on the exact crops in the field. If the project uses an officially designated cropping pattern, the crop or crops proposed would be adopted as the guiding crop or crops for the calculation of irrigation requirements.

b) Water delivery schedule. Based on the guiding crops of the officially designated cropping pattern, availability of water resources and field weather conditions, the water delivery schedule should be formulated one month before the date of delivery. The farmer and relevant agricultural agencies must be informed of the details of the irrigation planning and water delivery schedule as early as possible.

c) Preparatory works. When the water delivery schedule is announced, the farmer should make up his mind what crop to grow and commence land preparation, procurement of seeds and other inputs. Meanwhile, the agricultural extension agency should make all agricultural inputs available before the commencement of water delivery.

d) Water application. Level basin irrigation needs a higher discharge to maintain higher irrigation efficiency, so within one tertiary canal system, water should be concentrated for application on a plot-by-plot basis. If there is a constant water discharge, the volume of water applied to each plot will be based on the irrigation time; each plot of land will share irrigation time in proportion to its acreage. The summation of each plot's irrigation time must be equal to the time of one irrigation cycle. Keeping tertiary canal discharges constant within one irrigation cycle period is important for an equitable distribution of water. The irrigation time allocated to each plot must be strictly followed without any interruption during irrigation. Incidentally, the water may not reach the end of the basin within the allocated time of irrigation. This may occur due to improper basin length, too high a percolation rate or wrong irrigation method, poor land preparation causing a high flow resistance (Manning Value) is often found in this case. There is no excuse for increasing the irrigation time for those who do not prepare their land well.

e) Frequency of irrigation. The frequency of irrigation should be determined according to the moisture content of the soil if water resources are not a constraint; however, in most cases, the available water is often limited, and so irrigation may only be given in the critical period. In areas with 2,500 mm of annual precipitation, three to four irrigation applications will be enough for sugar cane; two to three are adequate for corn, peanut, potato, and soybean. Short root zone crops such as vegetables, melons should be irrigated every 5-10 days; but it is impractical to adopt such frequent irrigation as the standard practice for upland crop irrigation in an extensive irrigated area. This kind of irrigation must be arranged in a small area.

Maintenance of irrigation/drainage facilities. One serious maintenance problem in an extensive, diversified cropping irrigation system is that it is difficult to find enough time to undertake major maintenance of irrigation and drainage facilities. In order to overcome this difficulty, the main maintenance program including necessary investigation, survey, design, cost estimate, and contract tendering should be completed in the last stage of rice irrigation. Then the main maintenance can be launched immediately after the end of rice irrigation.

Aside from the major maintenance required between rice and upland irrigation, regular minor maintenance during the irrigation period is important to assure the security of irrigation and drainage facilities. This regular maintenance for off-farm systems is usually undertaken by contract labor under the supervision of O&M personnel; for on-farm systems, farmers should be encouraged and assigned to carry out regular maintenance, mainly clearing farm ditches. Farm ditch clearing, including drainage and irrigation systems, should be carried out at least once before every irrigation cycle.

Incremental O&M staff. Comparing the number of O&M personnel required for a diversified cropping irrigation to that required for a non-diversified cropping irrigation system, about 30-40 per cent more staff are needed in a diversified cropping area. The actual number of O&M staff required will depend on the quality of O&M expected; on average, one person per 200-300 hectares of irrigated area is considered to be a reasonable allocation.

Farmer's participation. The enhancement of farmers' participation in O&M works is the best guarantee of success, particularly for a diversified cropping irrigation system. The O&M of irrigation systems needs farmers' participation in the following areas.

a) Farming activities. Since the water is delivered according to a schedule, not on farmers' demand, farming activities must strictly follow the irrigation schedule.

b) Proper land preparation. The efficiency of upland crop irrigation greatly depends on land preparation and the right selection of irrigation methods; upland crop irrigation will not be successful unless farmers prepare their land well.

c) Contribution to the maintenance of on-farm system. It is extremely difficult for the system operator (irrigation association) to maintain on-farm irrigation and drainage systems. Usually farmers are encouraged to provide the labor for the maintenance of those canal systems.

d) Cooperation in irrigation activities. The planning of a water delivery schedule cannot be prepared without shortcomings; smooth irrigation requires cooperation among farmers themselves and between the system operator and the farmers.

e) O&M fee. The O&M work will be significantly increased due to the adoption of diversified cropping; the correspondingly increased O&M fee should be generated from the benefits of diversified cropping, in other words, from the farmers' additional payment of O&M fees.

CONCLUSION

The practice of diversified cropping or growing irrigated non-rice crops in irrigated rice areas has prevailed in Asia for centuries. About 60 years' operation of crop rotation in the Taiwan's Chin-nan area demonstrates the potential of adopting diversified cropping in modern irrigation systems. A diversified cropping irrigation system is characterized by more flexibility in adjusting to a variety of crops. Policy-makers should be informed that the technology is available to develop an irrigation project which can simultaneously meet the objectives of assuring national food security, maximizing exports, and minimizing imports in the agricultural sector.

The main physical constraints on the extensive adoption of diversified cropping is heavy clay and poor drainage. However, excluding heavy clay soils and low-lying poor drainage areas, it is approximately estimated that about 50-75 per cent of irrigated land and potentially irrigated areas in Asia are physically suitable for adopting diversified cropping.

Institutional constraints on diversified cropping are: lack of financial incentive and agricultural supports; shortage of competent personnel and operational capital; inadequacy of cultivation techniques; and unavailability of management techniques. These can be counterbalanced to some extent by the efforts of agricultural agencies and by appropriate support from government. In particular, past experience in upland crop cultivation in the West and in some Asian countries has yielded enough technology for irrigation management and agronomic supervision to justify immediate application. As for economic constraints, governments' long-run policy and short-term strategy in the agriculture sector would play the most dominant role in influencing economic and financial constraints. Therefore, only governments can take the initiative in extensively adopting diversified cropping in irrigation projects.

Each government has its own development priority and its own constraints in supporting any specific development. For the long-run objective, if new irrigation projects are still necessary for assuring future national food security, diversified cropping is worthwhile in this kind of new irrigation project, considering that the incremental investment cost of diversified cropping is very limited. In the operational stage, if diversified cropping is not the national priority, government may minimize its intervention in crop diversification, and let the international and domestic market mechanism determine the degree of diversified cropping required. Whenever the national economic situation requires, the government can quickly step in to intervene in diversified cropping by providing more agricultural support services, and price guarantees. The immediate national objective in the agriculture sector can then be realized with less difficulty.

Although the technology required for adopting diversified cropping is available in Asia, the research and experiments for resolving local and immediate problems need to be undertaken in parallel with project implementation and operation. If the diversified cropping irrigation system is acceptable as a standard for future irrigation projects, it is time to invite the attention of international donor agencies and research institutes so they can use their initiative to conduct the necessary research in the most suitable countries prior to commencing new irrigation projects.

NOTES

1. This paper represents only the author's personal views and does not necessarily reflect the views or policy of the Asian Development Bank.

2. This is still under construction.

3. The inputs needed for sprinkler and trickle irrigation are excluded due to rare adoption of these two irrigation methods in paddy fields.

4. Constant value.

5. Soil Conservation Service. 1974. Design manual for border irrigation system. US Department of Agriculture.