LONG MARCH TOWARDS INTENSIVE AGRICULTURE

— Multi-Cropping and Irrigation —

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INTRODUCTION

Modernization of agriculture seems to culminate at maximization of productivity both per unit of land and per head of farmers. Asian agriculture is claimed to have arisen high above the rudimentary stage through traditional farming techniques since ancient days. Agricultural technology developed in this part of the world gradually turned its attention more at yield-increase from a given land than at extension of new land which, in fact, continued diminishing age after age.

Infra-structural renovation, sophisticated cultivation techniques, and socio-economic betterment are commonly accepted as three essential factors for agricultural development. In this connection, 'land improvement' is a positive means to attain the said infra-structural renovation in which irrigation techniques play an important role with those of water-control, drainage, road-construction and other relevant items in raising the use-value of the existing land to such a level as the agricultural productivity there could be maximized. Co-operation and co-ordination of the tools made available through the two other factors of agricultural development, viz. the sophisticated cultivation techniques and the socio-economic betterment are definitely indispensable for the purpose. We may call this an approach for intensification of agriculture.

On the other hand, 'colonization' aimes at spreading of irrigation benefits among the largest possible people through enhancement of irrigation facilities on the widest possible area. Such 'extensive' approach shall likewise need co-operation from other developmental factors. In most of the Asian countries, the former, that is an intensive, approach will occupy a pivotal place.

People speak with good reason that productivity-increase through raising yield per unit of farmland is less easy than that through extension of farmland. It is because, in the latter case, the customary or traditional ways and manners of agricultural production would simply spread over the extended farmland, and no particular renovation or improvement is called for with cultivation techniques or socio-economic structure as in the former case. It is to be remembered, however, that irrigation techniques to be applied for extension of farmland, on one hand, and those for yield-increase, on the other, may not be same, either quantitatively or qualitatively. The choice of technique to be applied for has to depend on the level of 'know-how' and the stage of agricultural development so far reached by the farmers in the locality. For instance, irrigation-water can be made available as well through earth-canal as through concrete-lined canal, and even through pipe-lines; although decision will primarily be made with the measure of 'benefit-cost ratio' or economic justification, comparative studies as between 'intensive irrigation' and 'extensive irrigation' may profitably be made before final decision.

As is well known, 'intensive irrigation' meant for yield-increase has been given more weight in such countries as Japan, Formosa and Korea since a long past, while 'extensive irrigation' or irrigation aimed at extension of farmland has been generally sought in the Philippines, Thai, India and Pakistan. In India, this approach has been justified on the grounds of: (i) natural endowments are less with water-resources than with land-resources, and (ii) social justification in providing the limited resources among the maximum number of people. Yet, 'intensive irrigation' approach seems to be gaining ground in these countries, too.

Rapid agricultural productivity-increase for the last half a century has been mainly due to productivity-increase from the existing land in the U.S.A. as it has been in Japan. In both countries, it is the sum-total of scientific researches in agronomy which have been jealously exploited for technical developments along 'intensive' approach towards productivity-increase.

1. Problem of Irrigation

The choice between 'intensive' approach and 'extensive' approach is governed by individual circumstances prevailing in the Asian countries. In those countries which have a plenty of unexploited arable land beyond the existing farmland and free from technical difficulties, the above decision may not be a sole function of economic considerations, as politico-social influences will claim as much vote as economic.

Under these circumstances and with the limiting conditions of land, water and capital called for irrigation-work, what can be the criteria for choice between 'intensive' and 'extensive' approaches ?

There can be no absolute and universal criterion for such choice because of the very nature of the issue on hand. Merits and demerits need to be considered, case by case, from such angles as technical, economic, social and political.

The same problem was dealt upon in one of the bi-annual bulletins (January 1971) of the International Commission on Irrigation and Drainage (an international academic organization affiliated by some sixty countries of the world with its headquarters at New Delhi, India and known as ICID). The findings were categorized under four different circumstances, as follows:

(1) Scarce Land but Plentiful Water

'Intensive irrigation' or irrigation meant for yield-increase is the straight answer. Speed or tempo of its implementation will be critically influenced by availability or not of the capital required for introducing modern technology there, side by side with the farmers' adoptability or nonadoptability of such advanced techniques for crop-cultivation on the improved land. Yet, insufficiency of capital often urges the people to make an alternative use of the capital for 'extensive' irrigation, and it is at this juncture that political and social considerations assume an upper hand in the final decision. Insufficiency of capital has been apt to let the developing countries appropriate the available fund for 'extensive irrigation' than for 'intensive irrigation.' Meagre as the familywise holdings and simpler the implication, this choice has been the usual practice among the group of countries mentioned in the above.

Under the circumstances which may allow storage of rain-water in the reservoir or supplementary irrigation by ground water, the benefits of surface irrigation will be legitimately provided with as many farmers as possible along the 'extensive' direction.

(2) Scarce Land Coupled by Scarce Water

No alternative choice but 'intensive irrigation' or irrigation for yield-increase.

(3) Plentiful Land but Scarce Water

It is difficult to either create new farmland through 'extensive' irrigation or to switch over to 'intensive' irrigation for yield-increase. There shall be an imperative need to minimize wastage of water unavoidable with the existing irrigation systems, in view of increasing cropping intensity there. Here, again, technical, economic, social and political considerations are inescapable.

Proper combination of the irrigated cultivation and non-irrigated cultivation, or alteration of the current cropping system to that in which the water-demanding crops shall be given the minimum space in their own holdings will have to be seriously acted upon on the part of the local farmers. Poultry, processing of farm products and other supplementary undertakings are recommended. In agriculturally less-important areas, yield-increase from the existing land is the answer, and in non-irrigable area, establishment of smaller industries will help sustain its economic growth. Where there is a lack of capital, social factors ruling in the area will hold a casting vote in their hand when decision between 'intensive' and 'extensive' irrigation will be pressed hard. No hastry decision in this respect, however, shall be made unless adequate balance may be maintained in the socio-economic development among the areas concerned.

(4) Plentiful Land and Plentiful Water

Irrigation program will involve no particular difficulty whether it is for spatial expansion or yield-increase, provided there is enough capital. When water to be used for irrigation purpose is obtainable from a river running into the neighbouring country or state, decision as to irrigation policy inside the area concerned – whether it is a new colonization scheme or a project meant for intensification of the existing irrigation system or systems – shall be crowned by the political considerations.

Among other cases, the most difficult would be the case where local demand for water can not be met with timely distribution in the given space. The general trend inherent to irrigation – the less the water-supply, the bigger the range of fluctuations – will add up such difficulty. The question remains, then, how land- and labour-productivity can be incremented through combination of 'intensive irrigation' and efficient water-management, in the area far from the abundance of water ?

2. Multi-Cropping and Irrigation

Irrigation as a contributing factor for land-productivity-increase (maximization of productivity per unit of existing land) will be studied in its different shapes. Needless to say, drainage which is inalienable from irrigation, and cultivation-technique, plus socio-economic elements will have to accord full co-operation to irrigation-work as so many collaborators in the harmonious manner for attaining the common purpose.

Not few keys are available to solve the question of yield-increase. Introduction of high-yielding varieties, the torch-bearers of the "Green Revolution", will be one of the strongest. Among those characteristics attributed to the improved, high-yielding varieties, (i) shorter growth period, and (ii) bigger water-requirement than the traditional varieties, are significant. While the first characteristics will open a way for shifting the single cropping to multi-cropping, the second one will have to be met and made an effective accelerator for multi-cropping by improved irrigation facilities. The yield of paddy depends upon the content of starch to be produced by sunshine after earing. In southeast Asia, therefore, a significant increase of paddy production will be made possible if its growth-period can be fit into dry season which is brimful with sunshine. It will not be impossible provided there can be adequate irrigation facilities. In fact, monsoon brings early or late rains of varying precipitation year after year, thus interfering with proper germination and ripening of paddy.

Whether people adopt 'intensive' irrigation or 'extensive' irrigation, rational crop-rotation will need to be aspired for in increasing the total production. Crop-rotation can be arranged in term of both time and space. Problem really arises in connection with productivity of each one of the multiple crops coming under the system. Economically speaking, productivity of each crop will be seriously affected by the prevailing economic system and the current market situation, but it is possible to raise productivity of the land as a whole through the technique of multiple crop-rotation. Here are some examples of such technical contrivances to increase yield per acre through combination of multi-cropping and shift of growing season of the crops:

(1) Accumulated Temperature Type (Thornthwaite Method)

It was in October 1952 when the author called upon this meteorologist at the laboratory of John Hopkins University in the eastern part of U.S.A. that he had a happy opportunity of observing successful experiments being conducted by Thornthwaite on multi-cropping of such as pea, potato, carnation, etc. It was made possible through his careful calculation of crop-wise evapotranspiration and soil moisture in his laboratory which had been set up on the field belonging to a commercial company which specialized at cultivation and cold-storage of flowers and vegetables. Assuming that each crop had to have pre-determined amount of 'accumulated temperature' (*) which is adequately necessary for its full growth, Thornthwaite proved validity of this assumption by successfully cutting short and/or shifting the growth-season of a crop by assuring it with its 'accumulated temperature' through seasonal changes of atmospheric temperature. In fact, the accumulated temperature and weight of the dry matter of the crop run in parallel or move in proportion to each other. Thornthwaite brought a noteworthy increase of total productivity per unit of acreage through planned cultivation of multiple crops in a specific field. The company is said to have tripled its profit since Thronthwaite shifted his laboratory onto the company's field, by sending out its products (Christmas trees, carnations, etc.) to market through cold-storage at the best prices because of off-season shipment.

(*) Accumulated Temperature:

Trees and other vegetations generally stop their growth when atmospheric temperature comes down below 10°C on monthly average. The period of time while the atmospheric temperature remains above 10°C (on the monthly average as calculated during a specific number of years) is named the "warm-period"; the sum-total of daily temperature during this "warm-period" forms the substance of the 'accumulated temperature' during the warm-period, and it is assumed to be a substitute for 'non-frost period.'

Cultivation-limits expressed in term of the 'accumulated temperature' are: 2,000°C in case of beat and tobacco; 3,500°C (safe limit) in case of paddy; 4,800° in case of paddy double cropping and beat (warm limit), and 5,000°C in case of sugar-cane.

(2) Mixed Cropping Type (Bradfield Method)

Bradfield's mixed cropping was observed by the author in September 1966 at IRRI in the Philippines. Once an active scholar in Cornel University, U.S.A., Bradfield insisted that out of three broad means for food production-increase, viz: (i) enlargement of farmland, (ii) intensive use of farmland, and (iii) multi-cropping, the last two are open to the developing countries, particularly those in southeast Asia, as quick and cheap means for attaining the purpose, but was pessimistic with the adequacy of the first on the ground that: (a) availability of insignificant land-space of non-fertile quality which defies an easy colonization, (b) most of the local inhabitants do not make themselves able colonists, and (c) prohibitively large sum of money is required.

His emphasis on the advantages of multi-cropping in the tropical-zone are based on the following:

(a) Monthly mean temperature is adequately high for vegetation all through the year;

(b) Monthly mean rainfall is less during dry season (irrigation is indispensable for planting) but is plentiful during wet season (irrigation is still necessary for planting);

(c) Solar radiation is richer during dry season, and

(d) Enough sunshine is available all through the year.

He developed a planting pattern in which the mainstay of cultivation lies at paddy, while subsidiary or complimentary crops are made as multiple as possible. An elaborate control system on both soil and crops could extend the total growth-season of each crop longer than 360 days per year and, in some cases, even 450 days!

His cropping pattern somehow ownes to the concept of the accumulated temperature, but it is technically supported by: (a) sound soil-water control technique through soil-drying, shallow-cultivation and ridge-making; (b) farm-management technique involving improved varieties of seeds and efficient labour, and (c) mechanized farming. He encouraged maximum degree of mixed farming during the early part and the closing part of the paddy's growth curve, the period when the growing speed of paddy is at its ebb.

Bradfield's is as sophisticated as Thornthwaite's. In both cases, the field needs to be so prepared as to satisfy the demand of paddy as well as upland crops. Farm-management program will likewise need most versatile and elaborate care. This method developed by Bradfield has attracted attention and fertile progress along his direction is earnestly hoped for. It is regretful, however, that Bradfield is no more in IRRI's service.

(3) Profit–Water Curve Method (Fukuda) (*)

This is a concept developed by the author himself in a paper as old as 20 years ago. Irrespective of the difference of crop to be grown, whether it is paddy or upland crop, as long as water is available in abundance at negligible cost, there will be no limitation placed on the quantity of water to be used per unit of acreage, and irrigation method is at one's choice as far as water is concerned. When the cost of irrigation, installations, and production is considered vis-a-vis price of the products, one becomes more mindful of the economicality of water-supply per unit acreage. This problem increases its seriousness as the availability of water tends to be less. In many arid regions where there is chronical fear of real or possible shortage of water for full growth of a particular crop on a given land, it may be possible or wise to utilize the same land more efficiently by planting more than one crop, the second or third crop requiring less water than the principal crop. The problem, then, arises as to how much water needs to be applied per acre for each of the various crops planted in order to obtain maximum profit out of the land as a whole. The following is a trial to graphically solve such question by applying the Profit-Water Curve which shows the relations between profit (productivity) of two or more crops y and water-need per acre w.

Ref. Article by Hitoshi Fukuda in AGRICULTURAL ENGINEERING (Vol. 31, No. 7, pp. 350 – 352, July, 1950), the Journal of the American Society of Agricultural Engineers.

This is a case faced by a farmer: he has been customarily cultivating a specific Crop I on his land but, in anticipation of water-shortage, he intends to derive maximum profit out of his land by introducing less water-demanding Crop II on a part of his land which has been entirely devoted for Crop I. The question now arises: what can be the most profitable land-water combinations for Crop I and Crop II ? Let us suppose that y-w curves for both Crop I and Crop II are already established.

Expanding this idea, we may also consider the profitability of introducing Crops III, IV, V . . . . which are less water-demanding than Crop I, on the same land in order to minimize the possible loss due to water-shortage, or in order to increase profit from the land as a whole. Though under the same name of multi-cropping, Bradfield proposes to cover a given land with as many mixed crops as possible over a year, but the author proposes to split the given land into a number of small parcels of varying sizes and for different crops, to raise maximum profit from the entire land. If we may call Bradfield's a timewise multi-cropping in an ordinary sense, the author's must be termed an areal or spatial multi-cropping.

a = price per ton of the crop
c = cost of water
y = yield in ton per ha.
Q = total amount of water used for irrigation
b = cost of production per ha.
A = total irrigable area in ha.
w = amount of irrigation-water per ha. (ha-m)

As y is a known function of w *experimentally, the net profit* per unit of land is:

$$ay - b - cw$$

The gross profit Z will be defined as:

$$Z = ay - b$$

Thus, Z is made a function of w. This is because it is convenient to compare the profit with one another when two or more different crops are put under consideration. Now, let only x ha. in the total area A be irrigated. The net profit will be:

$$P(w) = x \{Z(w) - cw\}$$

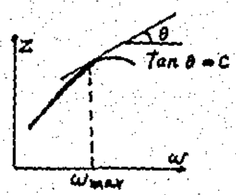

Fig. 1 Profit Z – Water w Curve

(1) When water is abundant and freely available, it is of course profitable to irrigate the entire area:

$$x = A = \text{a constant}$$

For the maximum P, we may follow the Z – w curve until we find a point where the slope of the tangent is equal to c, that is the point which gives the value of w for the maximum profit per ha. (w_{max} in Fig. 1):

$$\frac{dP}{dw} = A \left(\frac{dZ}{dw} - c\right) = 0$$

It means a definite loss to apply more water than w_{max}, even if water is plentiful.

(2) We consider the case in which water-supply needs to be regulated. From the above notations, mean w may be given by:

$$Q/A = w_0$$

When w_0 remains same as w_{max}, we may always use the total water Q and such water cost may be maintained constant.

Thus, land and water most profitably allocated for Crop I, Crop II and Crop III can be determined and, accordingly, maximum profit which may accrue from the total land will be estimated. To use the above Profit-Water Curve effectively, the relations between yield and irrigation-water needs to be clearly known or at least experimentally or empirically obtained with each crop to be grown by irrigation.

This method will be useful when and where water-shortage is either anticipated or feared of at the time of planting the crops, or in case irrigation-farming of two or more upland crops is going to be undertaken on a newly reclaimed field with comparatively small amount of irrigation-water. In this connection, we know one practical case of an irrigation association in Ibaraki Prefecture, Japan, which could successfully check the decline of the members' profit by converting a certain portion of their paddyfield for cultivation of upland paddy, because they could anticipate that the water available for the specific year would not suffice for irrigating the entire paddyfield belonging to the association-members. Acreage of paddyfield thus converted for upland paddy cultivation in this case, however, was determined not on any calculated figures but from the past knowledgeable experiences.

Admittedly, this Profit-Water Curve Method is scarcely less sophisticated or elaborate compared to Thornthwaite's or Bradfield's. It may, therefore, be used with apparent benefits only when and where the farm-management will have reached at a certain level of intensity, for instance, under such circumstances as Thornthwaite found himself, or with horticultural production of glass-house origin enjoying high market price. However, it belongs to a category of the simplest problems dealt by today's system engineering, and shows the manner in which a group of related factors is striving to attain a common target.

CONCLUSION

We started this paper in discussing modernization of agriculture in term of productivity-increase per unit of land and labour and, through arguments around the merits and demerits of 'intensive irrigation' and 'extensive irrigation', or land improvement vs. colonization, together with the differences between the two in their technical contents and level of intensity, eventually arrived at the significance of multi-cropping as an important means of intensive agriculture. The author hopes that the concept of irrigation – water-control in each individual field, in particular – being the key-problem for successful multi-cropping, could have been appreciated by the reader through introduction of three concrete methods of characteristics and of the author's personal interest.

Although they are unquestionably meant for highly intensive pattern of farming, the author hopes that their principles would be brought to practical application wherever possible. The target has probably been set far above farming communities in southeast Asia who have not yet made modern agriculture based on irrigation their own. It must be, therefore, a time-consuming task to bring home the advanced irrigation farming technology among them, particularly those who have been accustomed to traditional modes of cultivation.

Agricultural development will remain a vain slogan until and unless infrastructural renovation and techno-economic as well as social betterment takes firm ground in the rural community. As countless factors of undefineable and non-categorical nature should work in full harmony and close co-operation, progress of agricultural development would be that of constant adjustment to the environment with fluexible tenacity to the principles. Yet, steady march towards intensive agriculture with a target of multi-cropping both in term of time and space is earnestly hoped for. Painstaking is the approach to the goal and uneven is the road leading to it, but the scenery developing on its way is not totally bleak but pleasant enought to comfort the travellers. Author will be most thankful for any comments and suggestions from the readers on the subject-matters dealt in this humble paper.