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PROBLEMS OF HYDROLOGICAL RESEARCH IN PADI AREAS

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The paper's aim is to discuss problems associated with the study of water management in padi irrigation. Problems are both theoretical and practical, associated firstly with the development of a theoretical framework to apply in a particular area and secondly with regard to instrumentation, methods and practical problems in the field. The paper only deals with problems relating to the planning of a single research project, undertaken towards a Master's thesis and subsequently abandoned, and the preparatory work involved in the collection of data. It was prepared as a guide for students especially those who are intending to undertake research on hydrology for the first time.

The aim of the research project was to firstly work out a water balance in the 7th mile Gombak Irrigation Scheme to solve for change in storage; and secondly taking water-table movement to reflect the dynamic equilibrium between the various items of the hydrological equation, to use a knowledge of water-table movement and ground water flow for working out an efficient system of water management.

Water is a crucial factor in the cultivation of rice. Not only does it facilitate the intake of nutrients but it also acts as a coolant by dissipating excess solar energy by transpiration and thus prevents excessive temperatures in the plant cells. Moreover it aids in land preparation and weed control while a lack of water can have pronounced effects on the yield of rice. In rice irrigation not only is a knowledge of the quantity of water necessary for irrigation required but also how it is to be distributed over a given area.

The term water requirement has been used differently; ecologists and physiologists take it to mean the 'consumptive use' of water by the rice plant through evapotranspiration, agronomists consider it to mean the irrigation requirement to replace losses incurred as evapotranspiration and percolation, while design engineers compute it to be the total quantity of water required to keep a project functioning efficiently. The last concept is synonymous to Kung's 'diversion requirement' (1965). This includes besides the irrigation requirement, the amount of water required for presaturation, conveyance loss in canals and also in the 'flowing water' system of irrigation as in Japan and Malaya (as opposed to the 'stagnant water' system practised in Taiwan) the amount of farm waste incurred to keep a continuous flow of water from lot to lot under the influence of gravity. The problem in irrigation is to obtain a sufficient quantity of water in time. Water quality is not as crucial.

According to interests, estimates of water requirement have been derived by the application of the basic hydrological equation which in its simplest form reads:—

Eq 1

I (Inflow) − O (Outflow) = S (change in storage) Chow (1964).

Generally it has been applied in three forms. Kaneko (1957) and Fujioka (1963) employed equation two, expanded from equation one, in a complete hydrological unit where almost all the items that would normally feature in a water balance appear.

EQ 2

$$P + I + Ir + Is = S + E + T + DV + Ds$$

(Woudt 1967)

P = precipitation

I = irrigation i.e. artificial application of water

Ir = inflow through rivers, creeks etc. at boundary of area

Is = subsurface inflow

S = storage in or on the soil

E = evaporation } water loss through

T = transpiration } vaporisation

Dv = percolation or vertical drainage of water

Ds = surface drainage through drains, river etc. at boundary of area

On the other hand particular items of the balance can be studied under rigidly controlled conditions as done by Kaneko (1957), Thongtawee (1965), Manalo (1964), and Kuang (1965). A third intermediate method was used by Thongtawee (1965). The Drainage and Irrigation Department (D.I.D. Memo 69- 1962) and Goor and Zjilstra (1963) in a balance worked in a few acres of padi isolated from the rest hydrologically by a perimeter bund of some sort. This involved a slight modification of Equation two to:—

Eq 3

$$P + I + Is = S + E + T + Dv + Dh + Ds$$

(Woudt 1967)

Dh = drainage through surface soil ie. seepage including that through levees.

In Gombak the equation had to be further modified to suit local conditions. The whole of the Gombak 7th Mile Irrigation Scheme (Map 1) established in 1934 (Robinson 1939), was far too large to be studied by one student. Thus the area on the right of the Gombak, served by the Taliayer Kanan (Rightbank Irrigation Canal) was considered. Being a complete hydrological unit, theoretically it was suitable for the application of equation two. However the numerous streams flowing down the hillside into the main canal and the indiscriminate and wasteful discharge of water by farmers at various points along the Gombak River posed a problem with instrumentation. Thus though the entire area on the right was studied with respect to the second aim, the area had to be further limited for establishing a water balance.

The possibilities of conducting an inflow minus outflow experiment on a very restricted scale was considered, but the setting up of a lysimeter was difficult. Besides the low gradient and waterlogged messy conditions during the growing season, farmers were distrustful of growing their crops in a tank especially since farm sizes are already very small in the area. Moreover the writer was interested in comparing the relative losses through evapotranspiration and percolation with farm waste in relation to water management. Again the derivation of losses through a change in storage (S = ET X P) studied by Thongtawee (1965) in a plot isolated from those around by a system of multiple metal levees, which excluded surface flow and seepage in the soil, was not possible in this area where water flowed from lot to lot.

Thus the intermediate method was adopted and recommendations made in Memo 69 and by de Goor and Zjilstra were carefully considered with regard to the site. The scheme being an old one had a downstream transmission of water in a system of main and branch canals unlike in recent schemes such as in Negri Sembilan where there is a crosswise distribution of water. The principles of both types are given in the D.I.D. Manual (1961). Under an older scheme it was much more difficult to exclude an area of sufficient size without affecting the general water distribution. Neverthless a site consisting of about 8 acres was found, which could be effectively isolated from the surrounding fields. It was not really ideal as it was surrounded by padi on only three sides. Moreover it included within it a sizeable area of slightly elevated dusun land, which would complicate the calculation of a balance because while it contributed precipitation, it neither took the same amount of irrigation or for that matter transpired at the same rate. It is also acknowledged that the area was far too small to offset errors sufficiently, but as it was only undertaken as a pilot study, it was maintained. It had on the other hand the advantage of being regularly planted and having an assured water supply.

The main canal intercepted all surface flow from the surrounding slopes such that Ir from equation 2 was eliminated. This particular site was not fed directly from the main canal as in recent schemes, but water was drawn through two offtake points from the branch canal which formed one of the boundaries of the site (map 2). A single outlet at the downstream end drained the site. Other than for these there was no surface inflow or outflow into or out of the area as the entire area was contained by a perimeter bund. It is acknowledged that there must have been subsurface seepage into and out of the area. As there was no means of measuring this it was assumed that inflowing seepage was balanced by seepage out thus eliminating terms Is and Dh from equation 3, leaving **equation 4a.**

$$P + I = S + ET + Dv + Ds$$

Eq 4b

$$(P + I) - (ET + Dv + Ds) = S$$

As the writers interest was in ground water movement, all the other items were either to be measured directly or estimated such that change in storage was left as the unknown (equation 4b). This allowed a comparison with actual difference in the height of the ground water under different site conditions in connection with the second aim. It was also hoped that the values of the other items would provide a useful comparion to values found elsewhere.

Equipments and Methods

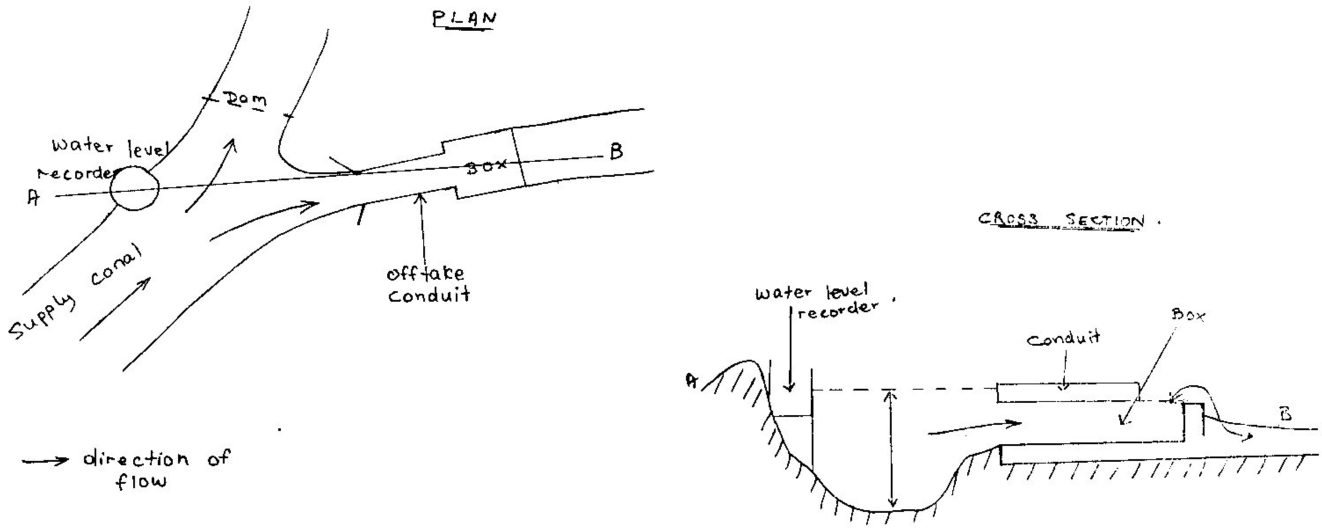
The area being restricted in extent, the only available daily rainfall recorder, checked by a check gauge, was sufficient. These were installed within reasonable distance of the evaporation pan (refer map 2) to allow significant comparison between the two. As rainfall occurance and intensity can vary over short distances, rainfall readings from a single station was reliable only for calculation of the water balance within the 8 acre site. It had to be treated with caution in studying ground water movement over an area extending over hundred acres.

Surface inflow into the experimental area (I), was measured at two intake points where water entering the area was forced through closed conduits of known internal diameters and into a box, overflowing when the latter was full as shown in diagram 1. Flow through this structure was maintained by a dam on the main supply channel just downstream of the offtake point. The discharge through the conduit could be directly related to the head of water in the supply channel (h) through laboratory tests for the required apertures of conduits. Two automatic weekly water-level recorders were loaned from the Drainage and Irrigation Research Station for measuring the change in head (h) of water in the supply channel.

Drainage out of the area (Ds) proved extremely difficult to measure owing to inherent disadvantages in the site. Firstly, the slope of the drainage canal was too small to create a sufficient head if discharge was to be measured by a permanent wier or V-notch across the drain, as this would have required an impounding of water ahead of the structure, which would have aggravated the already existing problem of flooding during heavy rainfall. On the other hand while the canal was staisfactory at high flow for discharge measurements with a current-meter, this posed a problem during low stage. It was on the other hand the better of the two as it could be done without evoking the farmers' wrath and thus adopted.

Evaporation, the loss of water from moist soil and water surfaces and transpiration, the evaporation of water from growing plants through plant stomata and epidermis, can be measured or estimated in various ways.

CONSTRUCTION OF OFFTAKE POINT.



In this study evapotranspiration was taken to equal, after a correction factor for rice, evaporation from standard United States Weather Bureau Class A Evaporation pan loaned from the D.I.D. Johnson (1967) states that the amount of water evaporated from a flooded field without plants is about the same as water evaporated from a growing or ripening crop of flooded rice. For the reduction in evaporation due to the shade factor with the growth of rice would be compensated by the additional losses through transpiration. He takes evapotranspiration to be only 10% more than evaporation from a flooded field without vegetation. Thongtawee (1963) worked out following from results obtained from different experiments.

Evaporation (mm/day) r = 0.987	=	0.0108 x Total Gross Solar Radiation (gm cal/sq cm/ day)

If a radiometer was available it was hoped that this could be applied in Gombak. However even Thongtawee suggested the use of a Class A pan owing to the difficulty and expense of measuring gross solar ridiation and evapotranspiration directly.

No doubt instead of a lysimeter, which is messy under flooded conditions and required padi land (the difficulties of which have already been mentioned, simple inflow-outflow tests could have been carried out in isolated tanks and pots as done by Matsushima (1962) and Kung (1965); or the more popular Penman's or Thornthwaite's equations be used. It is acknowledged that the use of pan evaporation results would have introduced some degree of error; the question was however whether the other methods would have been any the more accurate for all the extra trouble taken. Pot experiments would require some knowledge of the physiology, cultivation and diseases that the rice plant was liable to, and it is quite difficult to construct in pots conditions representative of ground conditions. Indirect methods through the use of climatic data as with the Penman and Thornthwaite formulae not only involve tedious calculations and almost all the data that are normally measured at standard weather stations, but the results so derived were found by Ward (1963), Green (1957 and 1959) and others to show significant differences between themselves and with measured evapotranspiration during specific periods of the year. This having been found in the very climatic regions where they were developed it was decided that the accuracy of the pan evaporation results would suffice.

The final items in the water budget, percolation (Dv) and depth of ground water necessitated the digging of bores. Ward (1962) suggested inserting within augerholes of 2 inch diameter zinc mesh tubes bound with strips of hessian to prevent rusting and inwashing of fine material; and an electric probe inplace of a dipstick to avoid displacement of water.

In Gombak, as at least 20 tubes were required to sample some 100 acres, it was cheaper to use condemned asbestos tubes (4 inch internal diameter and 6½ feet long) available free from Hume Industries. Though these did absorb moisture, the tubes were perforated with holes on all sides and at close intervals such that the water level within the bore would rapidly adjust to water level around. The top 6 inches of the tubes were left unperforated as this portion was to remain above ground level to prevent surface runoff from entering the tube.

The sampling network finally adopted was not entirely satisfactory owing to many difficulties. The only available largescale map of the area, surveyed in prewar days and retraced in 1954, did not give a complete picture of the kampong channels and was also not really representative of ground conditions at present. Nevertheless using it as a base a theoretical network was established as shown in Map 3 to get an adequate sample to show the effects of variation in soil type, topography and depth of water table on percolation and water need for irrigation. Sampling stations were so distributed that conditions close to the Gombak River, at the margin of the floodplain and at intermediate locations were represented.

This had to be further modified on the ground owing to various reasons. Firstly the auger could not dig into gravel or buried trunks and on the other hand could not lift loose coarse sand saturated with water. The latter not only slipped off the auger but also collapsed from the sides of the bore filling up the hole. Hence, except where such conditions occured at some depth, these locations had to be abandoned; which meant that the effect of such conditions on percolation and irrigation requirement had to be overlooked. Moreover bores had to be sited close to footpaths as the farmers did not take to padi being trampled on. Again in sites close to settlements, children often choked up the bores with rubbish. Hence the sampling network on the ground varied somewhat from that on paper.

At each site a hole large enough to take a 5 inch (external diameter) pipe had to be dug. The Engineering Faculty was kind enough to not only loan a 6 inch auger but also to make for it a connecting rod to reach depths of 6 feet. Soil samples of the various layers were collected and the depths of these from the surface was also recorded. The depth where water was first reached (boring having been done just before and after the harvest) and the final height of the water table were recorded. The water bubbled up or rose at least slightly where coarse sand occured, suggesting that water was under pressure at these localities. This led to the hypothesis that these sandy layers provided an underground route for water, which could affect water management.

However the study of groundwater flow during presaturation was a complete failure due to faults in the installation of the asbestos pipes. The pipes were lowered into auger holes a little too big for them, and as a result packing of the hole around the tube with soil to a depth of 6 feet could not be effectively done. As a result during presaturation, the surface inflow of water easily found its way through the loose soil around the tube and into the bore, eliminating the effect of impervious layers where present.

As the main pipes were of 6 foot depth, to study the effects of the impervious layer, shallower 2 inch auger holes were dug fairly close to the main pipes to variable depths depending on the depth of the compact clayloam layer at each site. Daily measurements of the water table and occassional percolation test were carried out in both bores. The depth of the water table was measured with dip-sticks to which tapes graduated in inches were attached. This did cause some displacement of water in the bores, but as simultaneous measurements of water depth in all bores was required during presaturation, electric probes with galvanometers would have been more costly.

Percolation, the rate of downward flow of water through a depth of soil has been measured in isolated tanks using inflow minus outflow principle, for example by Kung (1965). This was unsuitable where field measurements under conditions of not only different soils, but also topography, depth of initial water table, and the slope of the latter to the river were necessary. Thongtawee (1963) and Manalo (1964) also applied the hydrological equation under very strictly controlled conditions in the field to solve for percolation involving multiple metal levees and standing water in the field; this again was impossible in private property especially under 'flowing water' system of irrigation. Thongtawee also used piezometers and Darcy's Law to find percolation. In Gombak however as the aims required only an average rate within the 8 acres and relative rates at various sites with regard to water management a very simple though not very accurate method was adopted.

As the emphasis was on vertical losses rather than horizontal seepage, galvanised iron tubes of slightly less than 4 inch external diameter was made to slip within the asbestos tubes, such that there would only be a downward escape of water. In prescribing the dimensions, expansion with heat was overlooked and in the field the tubes would not fit. Nevertheless in theory once the tubes had been inserted, the bores were to have been filled with water to the surface at each instance irrespective of initial water level, in order to standardise procedures and to have a constant initial pressure of water. However, when it came to practice, it was found that where the water level was very low to begin with, this proved impossible owing to very high percolation rates and hence readings commenced from as high a level that the water could be raised to. The procedure was to note the initial level of groundwater and at time of origin the level the water was raised to. Subsequently, the rate was measured every half, one or suitable minutes for the first two hours and then if the rate was very slow every half or one hour as found necessary. It is not the intention of the writer to discuss any of the results in this paper. The procedure was repeated at least twice at each site and in both the deep and shallow bores.

Besides the measurement or estimation of individual items in the water balance, a planemetric map of some degree of accuracy of the 8 acre site was necessary to find the area of the site, and the proportion of area under padi, dusun and huts and also to fix the positions of the various equipments and bores. The plane table survey of this site carried out by students is attached as Map 2. Students also helped to fix by means of a Dumpy Level the heights of the various sample points above an arbitrary datum as well as the slope of the Taliayer Kanan such that comparative profiles of the ground surface and ground water levels could be drawn for purposes of studying direction of ground water flow, the relationship between topography and ground water and the effect of the river on ground water level. The Levelling survey was accompanied by a Compass survey to give a rough idea of scale and relative positions of points as the writer did not have much confidence in the base map.

Besides the above considerations with regard to theoretical and practical implications, a postgraduate student should also pay due attention to other factors of time. Sites easily accessible from the University seem to lack certain criteria of site and hence the student would have to decide for himself on compromises to be adopted. Again the study requires expensive instruments all of which are not available in the department. This means that the student is dependent on other government, University or private departments and this involves waiting and adjustment in the programme of work to allow for the schedule of the departments concerned. Again installation of equipments requires manpower and advice where the student is not familiar with the equipment. Even after installation, the study requiring much data involves long hours in the field, and very often assistance from reliable persons. Also due to the seasonality in climate and farm operations, the study has to be run for at least one year preferably two years. As the preparatory work itself involves considerable time, the author feels that such a study is not suitable for a Master's programme.

Nevertheless for those with the time and interest, the study is very challenging especially since the distribution network varies in irrigation schemes. There is a distinct difference between coastal and riverine schemes with regard to environmental factors and also between old and recent riverine schemes. Again in schemes as with the present one under study which are fairly close to urban areas, there is an increasing demand for water for domestic and industrial use. Hence soon change in agricultural patterns would have to occur to accomodate the reduction of available water for cultivation. Under such circumstances, the opportunity arises for studying in the same area the water budget, and management under a different crop or method of farm husbandry.

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