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Soil Moisture Studies for Ground Water Resources Evaluation

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Abstract : *Soil moisture aud soil physical studies are useful in evaluating the groundwater resources for estimation of actual evapotranspirational losses & specific yield of the shallow aquifer zone, to quantify the soil moisture storage variations useful for water balance studies & agricultural operations, and to understand the mechanism of recharge to ground water through the unsaturated zone & to quantify the same.*

Two case studies giving the details and results of the soil moisture and soil physical studies carried out by the Central Ground Water Board (i) in the upper Betwa river basin, Madhya Pradesh under the Indo-British Betwa Ground Water Project and (ii) in the Chinnatadgam, Avanashi - Upper Vattamalaikarai sub-basins of Tamil Nadu & Kerala, under the SIDA assisted Groundwater Project, have been presented.

The studies in the upper Betwa river basin showed that (i) the actual evapotranspiration during the period 14-10-77 to 2-6-78 is 307.1 against the calculated potential evapotranspiration was about 31% of PET. (ii) the specific yield of different depth zones upto 2.5m varied from 1.36% to 0.48% and (iii) in case of areas with deep soils the structured clay 'black cotton soil' forms an upper aquifer system which is virtually isolated from the more conductive weathered basalt aquifer beneath by the interevening thickness of unstructured and poorly conductive yellow clay.

Studies in the Chinnatadgam; Avanashi & U. Vattamalai Karai sub-basins indicated that (i) the specific yield of soil layers varied from 6.2 to 19% (ii) the average actual evapotranspiration in these 3 sub-basin is 0.71mm / day, 0.79mm / day and 0.55mm / day respectively and (iii) the final rate of infiltration varied from 5 to 150mm / hr for black soils, 40 to 190mm / hr for Red insitu soils and 20 to 390mm / hr for colluvial and alluvial soils.

Introduction

Soil contains pores of various sizes and shapes. whose amount and nature are determined by the arrangement of soil particles. A very large fraction of water falling as rain on the land surface of the earth moves through unsaturated soil during the subsequent processes of infiltration, drainage, evaporation, and the absorption of soil water by plant roots. Water that enters the soil either is retained in the pores (a part of it later transpires and evaporates) or percolates through them to lower horizons. Air is found in the pores that are not filled with water. In general, the larger pores given soils their aeration permeability and the smaller pores their water holding capacity The movement of water through a given volume of soil must take place throngh the soil pore space. Water movement may occur in the liquid or vapour phase. Movement in the liquid phase is brought about either by the action of gravity or by capillary forces, alone or in combination. According to the dominance of the moving force, water movement may be considered with reference to unsaturated soils, where movement occurs in the presence of numerous air-water interfaces or with reference to saturated soils, where the large pores or involved and movement occurs primarily under the influence of gravity. The water in unsaturated soils is not free in the thermodynamic sence because of capillarity and adsorption, the latter tending to be significant in soils. The energy state of the water is commonly expressed by the moisture potential, (ψ) which has as well been known variously as hydraulic potential, capillary potential, capillary pressure, moisture tension, moisture suction, negative pressure, presure head etc. Soil moisture studies are useful in evaluating the actual evapotranspirational losses, estimating the specific yield of the shallow aquifer zone and to quantify the soil moisture storage variations useful for water balance studies & agricultural operations. Soil physical studies help to understand the mechanism of recharge to ground water through the unsaturated soil zone and to quantify the same.

Some Basic Principles of Soil Physics :

Water in the soil moves in response to water pressure gradients, expressed in terms of total hydraulic potential ψ, representing the potential energy of the water within the soil. The two principal components of total potential are the gravity potential ψg and the matric potential ψm. The gravity potential is that arising from the earth's gravity field. The ground surface is normally taken as the datum (zere gravity potential) so that the gravity potential below the soil surface is less than this and therefore always negative. The matric potential is due mainly to the surface tension acting on the air-water interfaces in the soil and is always negative in unsaturated soil, although it becomes positive in saturated soil, when it is equivalent to the positive pressure head.

The two components are therefore both negative in unsaturated soils and are additive, i e.

$$\psi = \psi m + \psi g$$

So that total potential is always negative in unsaturated soil.

Potential is commonly expressed in terms of centimeters of water head (cm H_2O). Total potentials between 0 and–800 cm H_2O are generally measured using tensiometer, and lower potentials (higher tensions) can be measured using calibrated gypsum resistance blocks (although with much less accuracy.)

Total potential data are presented as 'potential profiles', the total potentials measured within a soil profile being plotted against depth; in these plots gravity potential, ψg, is represented by the dashed line (Figure I). When expressed in units of centimeters of water head, ψg at any point in the soil is equivalent to the depth below ground level in centimeters. The area to the right of the desired line represents the unsaturated phase and the area to the left, the saturated phase. The water table corresponds to the depth at which the potential profile crosses the gravity potential line (i.e. where $\psi m = 0$).

Water movement in both saturated and unsaturated soil is described by Darcy's Law :

$$V = -K\frac{d\psi}{dz}$$

where

v is the flux

K is the hydraulic conductivity of the soil

$\frac{d\psi}{dz}$ is the potential gradient

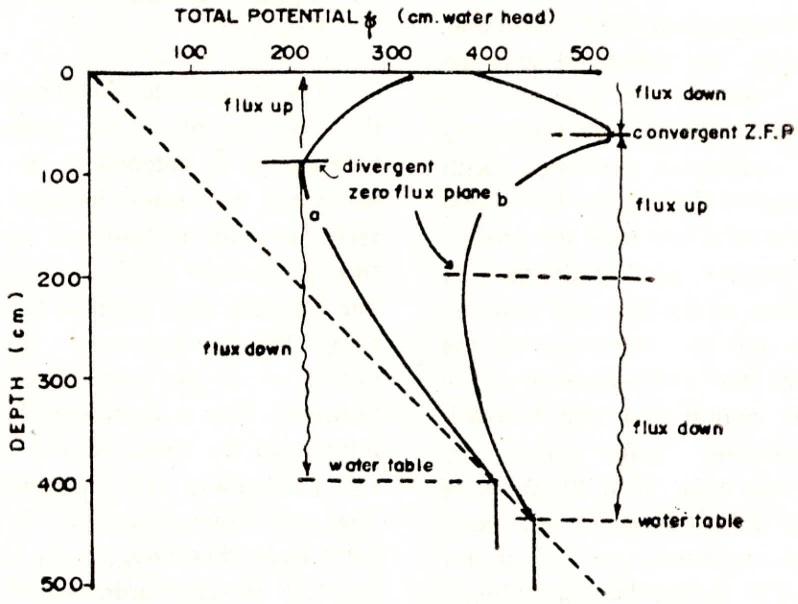


Fig. 1—The use of profiles of total soil water potential to identify the position of the zero flux plane (ZFP)

(a) early in a dry period, the ZEP moving downwards because evaporation exceeds rainfall

(b) at a later stage heavy rainfall has created a covergent ZFP at the top of the profile

The hydraulic conductivity (K) is a sensitive function of both the volumetric moisture content (θ) and the matric potential of the soil (ψm). The relationship between θ and ψm is known as the 'moisture release characteristic' or, if ψm is expressed as log ψm, as the 'pf curve'.

The direction of the potential gradient indicates the direction of the moisture flux. The zero flux plane (ZFP) is a point in the potential profile at which the gradient is zero, indicating no flux, on either side of which the fluxes, can either diverge or converge. In the dry season a divergent ZFP forms, and this separates an upper zone of upward flux (supplying evaporation) from a lower zone in which the flux is downward (drainage). The two potential profiles shown in Figure 1 illustrate this. Profile (a) shows the position of the ZFP at a depth of about 100cm. The potential gradien. above this point is upward flux, whicle the potential gradient below it is downwards, indicating downward flux The ZFP in profile (b) (later in the season) is at a greater there depth, and rain entering the upper part of the profile has caused the potentials there to rise and thus created a second, convergent ZFP (equivalent to a wetting front). If there is sufficient rainfall this will move rapidly down the profile unntil It meets with, and cancels out, the lower divergent ZFP allowing resumption of drainage throughout the profile.

When a divergent ZFP is present at a known depth within a profile the deplection of moisture storage may be partitioned into upward and downward fluxes, attributable to evaporation and drainaga, respectively. This forms the basis of the 'zero flux plane method' for determining evaporation and drainage. Water content profiles are measured with the neutron probe at intervals of, for example one week. The difference between the profile water contents on successive occasions, with due allowance for any rainfall which fell in that period, represents the total loss from the profile, the sum of evaporation plus drainage. By knowing the position of the ZFP this loss can be partitioned into the two components, the moisture loss above the ZFP representing the evaporation for the period and that below it representing the drainage: fluxes across any depth can be calculated also. (Fig. 2) Because the position of the ZFP is normally not static, morection may be necessary to adjust for ocvement of the ZFP during the period being considered but for most purposes there is no great loss of accuracy if the ZFP is assumed to move stepwise with time, i.e. to remain constant in depth between each pair of measurIng dates.

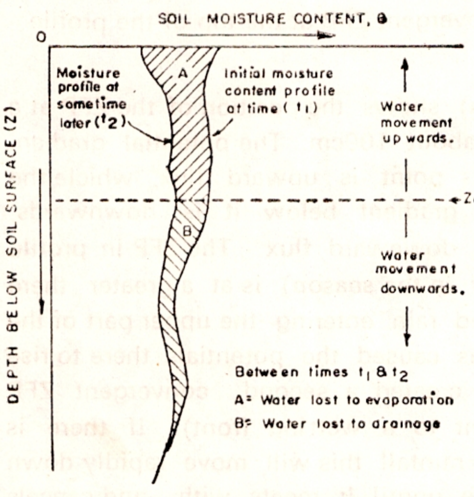


Fig. 2 Calculation of moisture fluxes from a pair of moisture content profiles determined on dates f_1 and f_2 showing the position of the XPP the moisture losses above and below can be designed to evaporation and drainage respectively.

Case Studies

A. Upper Betwa River Basin Madhya Pradesh

The importance of soil cover in determining the amounts of runoff, infiltration and aquifer recharge in a catchment is generally underestimated and often ignored completely. The recharge to an unconfined aquifer has to pass through the soil before reaching the water table and the rate and amount of recharge is, therefore, largely governed by the hydraulic properties of the soil. The amount of timing of runoff from a catchment is also consderably influenced by the hydraulic properties of the soil particularly the immediate surface layer. The soil moisture studies in the Betwa Catchment were, therefore, largely aimed at providing detailed physical information on the role of the soil moisture reservoir in controlling recharge to groundwater through soil. The soil moisture study in the basin was carried between May 1977 and February 1980 by the Central Water Board under Indo-British Betwa Ground Water Project.

2. Selection and Description of Study areas

A rapid soil reconnaissance was carried out during May 1977, in order to deleniate different soil types. The soils developed on the outcrops of Vindhyan sandstones are normally very thin and consist of medium to fine sand with gravel and cobble of weathered sand stone. Although large depths for soil may occur in occasional oracks and fissures and along the standstone/basalt, soil depths rarely exceed 0.30 m and large area may be entirely devoid of soil cover.

The soils derived from sandstone are therefore unimportant in terms of soil moisture storage and are of little agricultural importance. They support only scrub and open dry jungle vegetation.

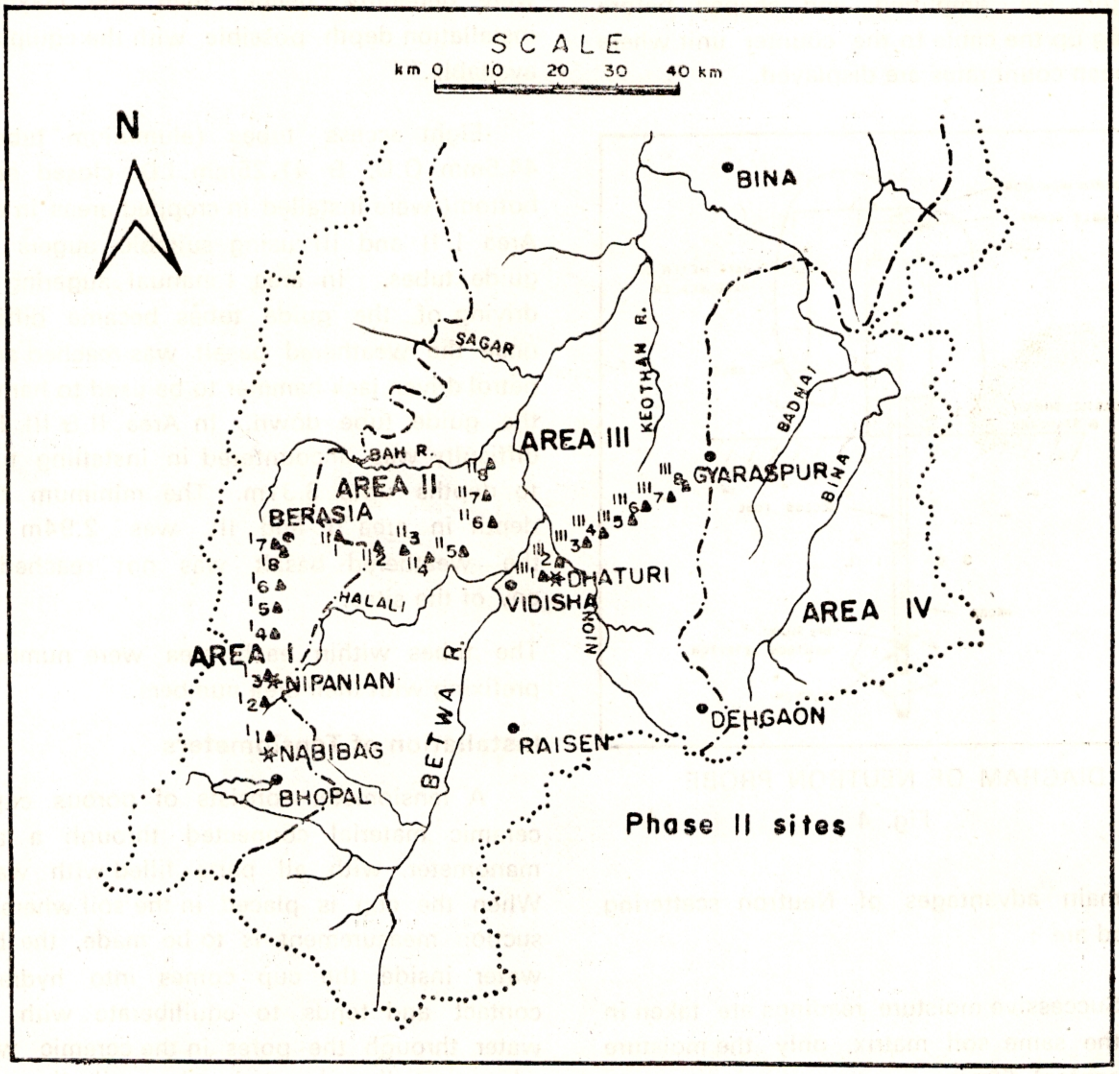
The soil derived from the Deccan trap basalts are predominantly dark coloured, often very deep, silty swelling clays which are popularly known as "black cotton soils". The study was concentrated on the black cotton soils as they are most importent in terms of soil moisture storage and are the major agriculture soils of the catchments.

Four areas were selected for soil moisture studies mainly on the basis of topography, soil depth and to some extent, soil colour. The areas were numbered I and IV and are shown in Fjgure No. 3.

3. Instrumentation

Neutron Soil Moisture Probe

The Neutron Soil Moisture Probe (Fig. No. 4) contains a radioactive source (Americium-Berilium of 30-100m Ci. of very long half-life 450 years) which emits fast neutrons into



MAP SHOWING LOCATIONS OF SOIL AREAS
AND ACCESS TUBE SITES
UPPER BETWA RIVER BASIN, MADHYA PRADESH

Fig. 3

the surrounding soil. Collision with the nuclei of the hydrogen atoms in the soil water, causes the neutrons to scatter, to slow and to lose energy. When they have slowed to the so called 'thermal' energy level they are absorbed by the other nuclear reactions. Thus a 'cloud' of slow neutrons is generated within the soil around the source. The density of this cloud, which is largely a function of the soil water content, is sampled by a slow neutron detector in the probe. The electrical pulses from the detector are amplified and shaped before passing up tne cable to the counter unit where the mean count rates are displayed.

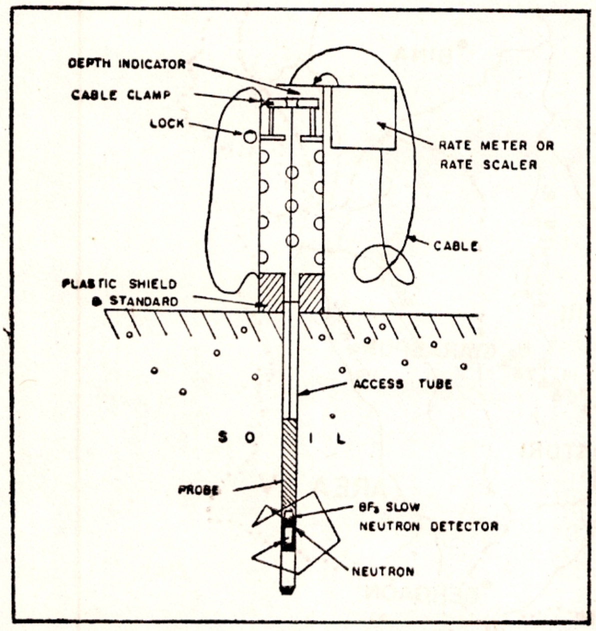


DIAGRAM OF NEUTRON PROBE

Fig. 4

The main advantages of Neutron scattering method are :

(1) Successive moisture readings are taken in the same soil matrix, only the moisture content difrers.

(2) Background errors are constant and moisture differences thus can be measured very accurately.

Installation of Access Tubes

The sites for installation of access tubes were distributed among the main crops in each area in approximate proporation to the area under each rabi crop and sites were widely spread in order to take account of a revl variations of soil characteristics within each area. In area I sites were also distributed with regard to different depths of soil. This was not an important factor in area II and III as the soils were generally deeper than the maximum installation depth possible with the equipment available.

Eight access tubes (aluminium tube of 44.5mm O.D, & 41,25mm I.D. closed at the bottom(were installed in cropped areas in each Area I, II and III using suitable augers and guide tubes. In area I manual augering and driving of the guide tubes became difficult once the weathered basalt was reached and a petrol driven jack hammer to be used to hammer the guide tube down. In Area II & III little difficulty was encountered in installing tubes to depths upto 3.31m. The minimum tube depth in area II and III was 2.94m and the weathered basalt was not reached at any of the sites.

The tubes within each area were numbered prefixing with their area numbers.

Installation of Tensiometers

A tensiometer consists of porous cup of ceramic material connected through a tube manometer, with all parts filled with water. When the cup is placed in the soil where the suction measurement is to be made, the bulk water inside the cup comes into hydraulic contact and tends to equiliberate with soil water through the pores in the ceramic wells when initially placed in the soil, the water contained in the tensiometer is generally at atmospheric pressure. This pressure is indicated by a manometer, which may be mercury filled U-tube. The use of several tensiometers at different depths can allow calculations of the hydraulic gradients in the soil profile. Tensiometers were installed at 3 selected sites i.e. Nipania, Nabibagh and Dhaturi.

4. Soil Moisture Storage

Observations

Water content observations were made down access tube at approximately weekly intervals using Neutron soil moisture Probe. Readings were taken at 0.20 metre depth intervals from 0.20m below the surface down to the bottom of the tube with 16 Seconds counting time.

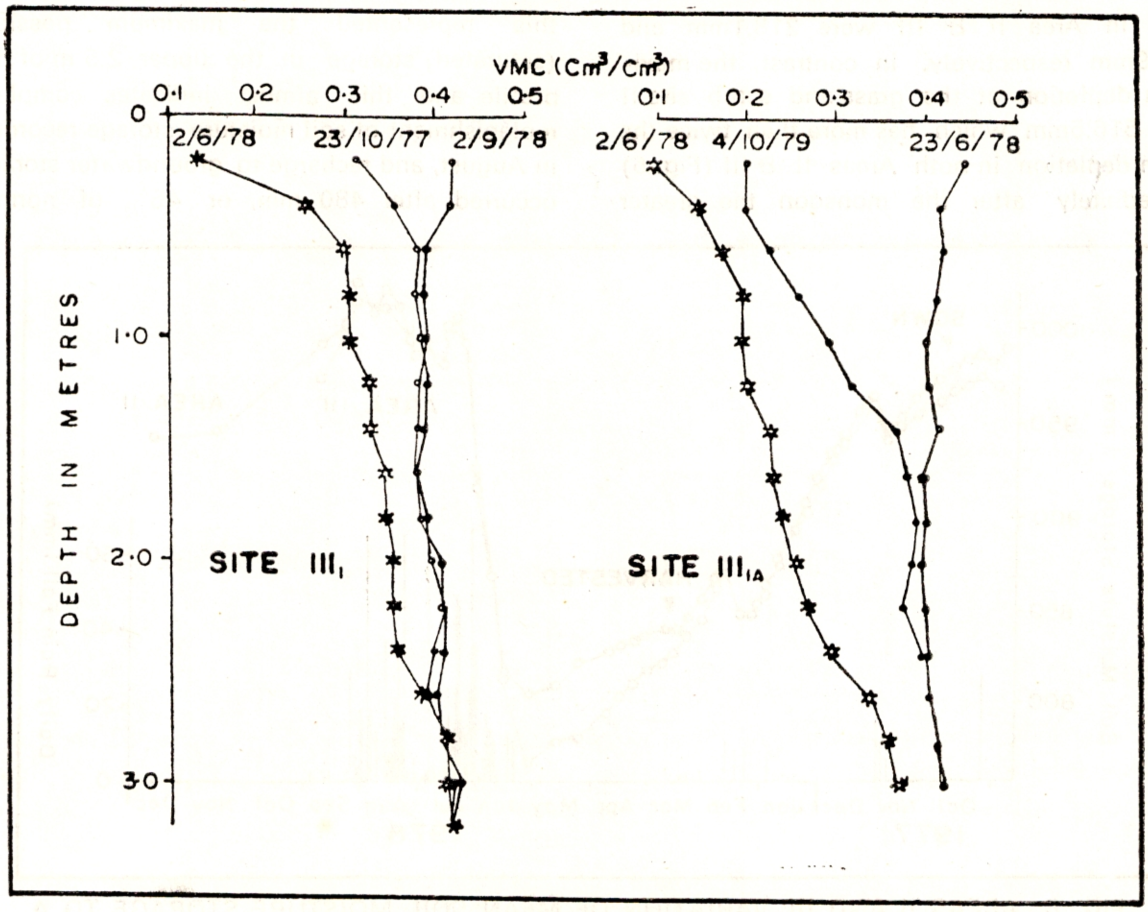
Data Processing

The count rate data measure in the field were converted to volumetric moisture content (V.M.C.) using the calibration equation. The moisture content measured at each depth in the profile in assumed to represent the moisture content of a layer extending midway to the adjacent measuring depths. The amount of water stored in each layer in mm. is the product of the layer length and the V.M.C.

Variability of moisture content with depth of selected sites in area III for the following three differcnt stages is given below and shown in Fig. 5.

(a) When the soil is wettest, at the end of the monson.

(b) When the water table has fallen below the measured profile (usually late October, shortly after the crops are sown).



AREA III SOIL MOISTURE PROFILES

Fig. 5

(c) When the soil is driest, immediately prior to the onset of the monsoon.

Depletion Patterns

In figure the area between driest profile (2 june 1978) and the wettest (2 sept. 78) represents the amount of water gained by each soil profile. The soil return to an almost idential moisture content each monson (except possibly in extremely deficient monsoon). Thus the amount of water gained also represents the depletion.

Cycle of Soil Moisture Storage Variation

The maximum depletions in Area II & III in the upper 2.5 m of the profiles ranged from 161,0mm at site II to 332.5mm at site III and the mean maximum depletions for the cultivated sites in Area II & III were 218.1mm and 246.9mm respectively. In contrast, the maximum depletion at the grass and scrub site II was 516.5mm which has more than twice the mean depletion in both Areas II & III (Fig. 6) Immediately after the monsoon the greater depletion rate in area III may have been due to more rapid fall of water table and hence more rapid drainage than in area II, but after the crops were sown the depletion rate increased more rapidly in Area II and the depletion rates in both areas coincided after the end of November.

Replenishment of moisture storage in Area II and III was extremely rapid after the onset of the 1978 monsoon and in both areas more than 90% of the storage had a been repienished within a month or the start or the monsoon. The fluctuations or storage in Area III were sightly smaller than in Area II where the range of fluctuation was 40mm.

In Area III the maximum measured storage in the 1976 monsoon occurred when the water table was almost at fhe grovnd surface as that this represented the maximum possible (saturated) storage in the upper 2.5 m of the profile and this almost indicates complete replenishment of soil moisture storage recorded in August, and recharge to groundwater storagc occurred after 480 mm, or 45% of normal

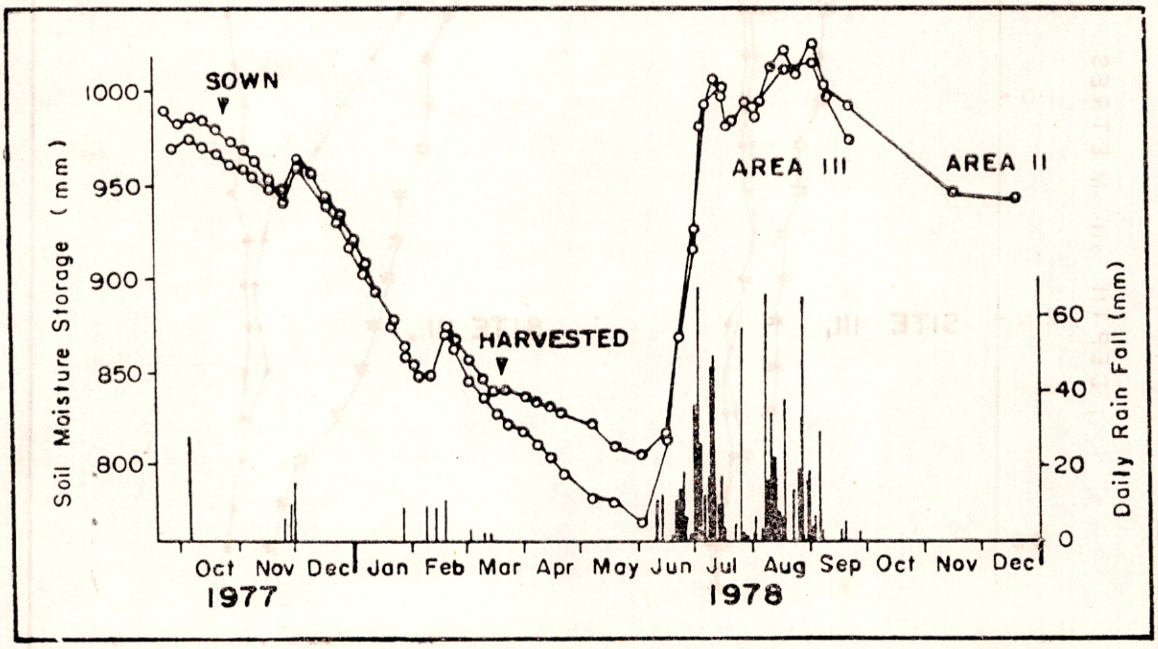


FIG. 6 AREAS II AND III VARIATION OF MEAN SOIL MOISTURE STORAGE TO A DEPTH OF 2.5 m

monsoon rainfall had fallen in both areas. This means that the soil moisture reservoir will he full replenished even in very deficient monsoon.

Water Balance of the Soil Zones

The water balance of the soil profile (to a depth of 2.5m), is described by the equation.

$$\pm \triangle S = R - Qs - E - D$$

where $\triangle S$ is the increase of soi! moisture storage in the profile.

R is the rainfall

Qs is the surface runoff

B is the evapotranspiration from the soils/crops

D is the drainage from the profile.

In the above equation (R—Qs) represents the net input of water to the profile and (E + D) the total losses of water from the profile, as the '$\triangle$S' is simply the balance between input and losses.

The separate situations arise when estimating the drainage from the profile.

Case I, When the water table is within the measured profile (to 2.5 m bgl). In this case the drainage loss from the measured profile is due to ground water loss as discharge to the streams, and this may be regarded as equal to the baseflow.

Case II. When it is below the measured profile. In this case the drainage loss from the profile is due to flow in the unsaturated zone This cannot be estimated ftom the baseflow because this comprises the sum of the unsaturated drainage contributions from both the measured profile and the zone beneath it, plus groundwater discharge due to the falling water table. In this situation baseflow measurements can only be used set an upper limit to the unsaturated drainage losses.

The results of water balance of the soil zone upto 2.5m depth in the Non sub-basin for the depletion period 14th October 77 to 2nd June 1978 are given below :

Rainfall (R)	=	116.4mm
Change in soil moisture		
storage ($\triangle$S)	=	— 201.2mm
Drainage (D)	=	10.5mm
Surface Runoff (Qs)		
	=	0
E	=	R—Qs—$\triangle$S—D
(Actual)	=	116.4—0+201.2—10.5
	=	307.1mm

The potential evapotranspiration calculated for the same period is 998.7mm indicating that the actual evapotranspiration was about 31% of potcntial evapotranspiration. Thus, the use of potential losses from the soil could lead to serous over estimation.

Estimation of Specific Yield using Soil Moisture Data

In area III during the monsoon the water table may rise to the ground surface. Between 7th July and 24th October estimates of ground water storage based on specific yield multiplied by the change in water table depth included in the measurements of soil moisture storage. This 'double counting arises because the neutron probe measures all the water present, not distinguishing between saturated and unsaturated conditions. The maximum amount of 'double counting' is represented by the difference in the measured profile water content between the wettest unsaturated and wettest saturated profiles. These occured on 7th only and 2nd September respectively when the differences was 22mm. This is equivalent to a mean specific yjeld of 0.86% for the entire soil more structured than the lower part, due to cracking and root action, the specific yield within this zone will be greater at the surface and will decrease with depths.

Soil moisture depletion following the 1978 monsoon began after 2nd September and depletion was initially rapid although there was 33mm of rainfall on 4th and 5th September. Between 2nd 8th September there was 25.9mm of runoff but the base flow component of this could not be seprrated to determine the drainage loss frcm the profile. However, during this time the water table fell from 0.30m to 0.55m and the loss of saturated storage measured by Neutron Probe is 3.4 mm. Betbeen 8th September and 24th October, the water table declined to 2.5m and the baseflow in the Nion river i.e. the ground water drainage contribution to the depletion amounted to 14mm.

Total saturated storage in) = 14.0+3.4

Measured (to 2.5m) profile) = 17.4mm

This is in good agreement with the figure of 22mm derived solely from the neutron probe measurements.

Based on the decline in water table and drainage during the period 2nd September to 24th October, specific yield of different depth zones in area II & III was estimated below Table No. 1

This shows the rapid decline in the rate of groundwater drainage, as the water table fell after the monsoon, which reflects the decrease in specific yield with depth.

5. Hydraulic Conductivity of Soil

The measurement of soil water content is not sufficient to provide a description of the state of soil water. To obtain such a description the evaluation of soil moisture potential or suction is necessary.

Experimental Procedure

A site is selected and neutron probe access tubes and manometer tensiometers are installed at 0.2m depth intervals to a depth of 2.4m at Nabibagh and Dhaturi and at 0.15m intervals to 1.35 m at Nipanian. At the Nabibagh and Nipanian sites, gypsum resistance blocks were also installed on open plots to measure soil metric potential. Once the soil has been

Table 1

Estimation of Specific Yield using Soil Moisture data Area II & III

Period	Drainage (mm)	Drainage rate (mm/day)	Water table decline (m)	Specific yield of layer (%)
2-8 Sept.	3.4 (Difference in soil moisture storage)	0.56	0.30-0.55	1.36
8-21 Sept.	8.1 (Baseflow)	0.62	0.55-1.49	0.86
21-30 Sept.	2.9 (,, ,,)	0.32	1.49-1.87	0.76
30 Sept./Oct.	3.0 (,, ,,) 17.4	0.13	1.87-2.50	0.48

wetted to near saturation during the monsoon the ground surface of one plot at each of the sites was covered with a 5m x 5m black plastic sheet and tent to prevent rainwater collecting on the plastic sheet and to reduce thermal effects on the tensiometers. The open plots were cultivated and wedded at the same times as these operations were carded out in the surroonding cultivated areas.

Results and Discussions

(i) The main features of the conductivity, characteristics observed for the Nabibagh and Dhaturi sites are,

(i) At Dhaturi & Nabibagh sites there is a rapid decrease of conductivity below 1.5m seem to be relatively uniform with depth and very low.

(2) Very small change in water content accompany very large change in conductivity.

The potential gradients within the profiles also became very small, often less than 0.05 cm, H_2O/cm depth, making them difficult to determine accurately.

The above observations indicate that the hydraulic conductivity of the soil decreases progressively with depth reaching very low values below the structured upper 1.5m of the profile.

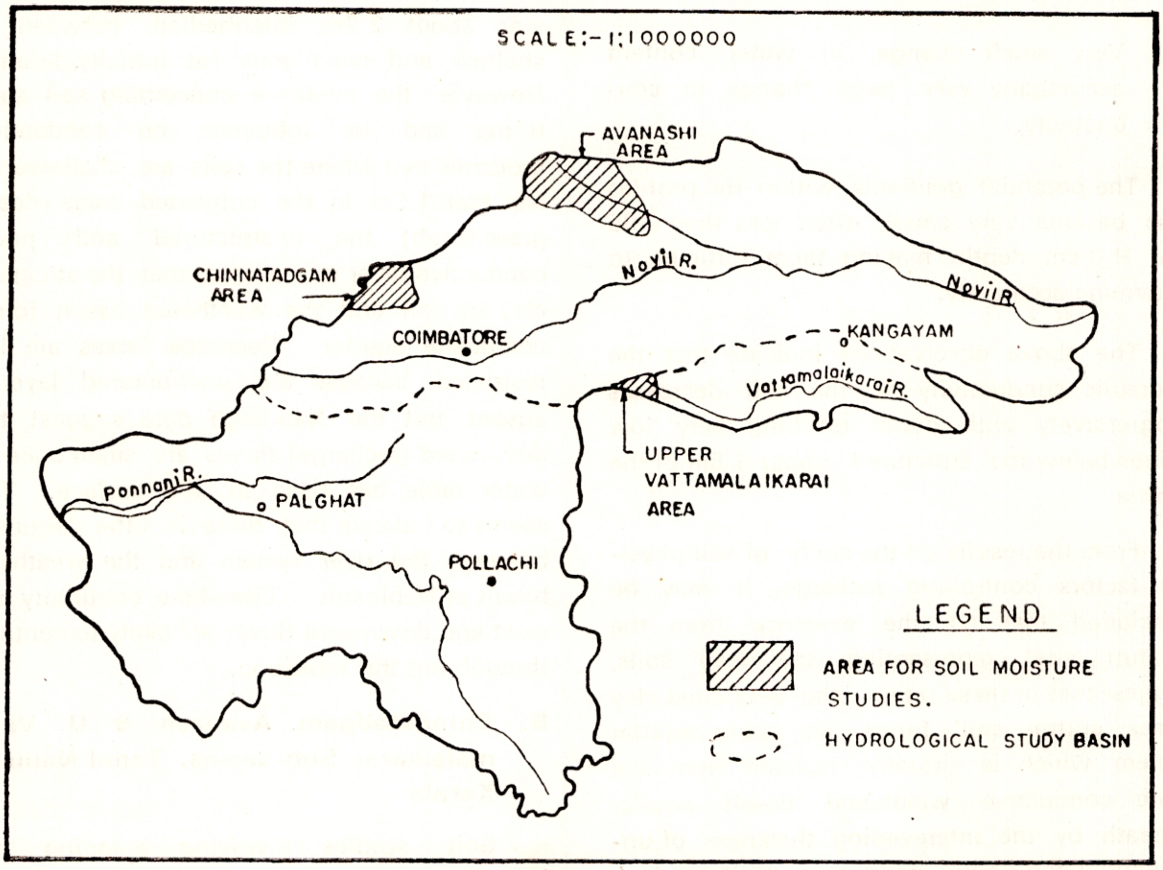
From the results on the study of soil physical factors controlling recharge, It may be concluded that (i) the evidence from the Dhaturi site, representing the deep soils, suggest that in these areas, the structured clay 'black cotton soil' forms an apper aquifer system which is virtually isolated from the more conductive weathered basalt aquifer beneath by the interevening thickness of unstructured and poorly conductive 'yellow clay'. During the monsoon, downward fluxes constituting recharge through the base of the structured soil layer appear to be very small indeed. but are nevertheless sufficient to restore the profile beneath to saturation. The cultivated deep soils can therefore be modelled as a tank with an almost non leaking base, and a capacity of about 280mm (varying somewhat with crop). The tank overflows when full to produce surface runoff. which includes a component of interflow through the macrostructures into ephermarel drainage channels, The interflow probably drains only the capacity of the macrustructures (less than 2% of the upper 1.5m of the profile) which would yield a postmonsoon baseflow of not more than 30 mm. The predominent mechanism of water loss fram the soil tank is evaporation.

The situation in the shallow soils is very different. The Nabibagh evidence was not entirely conclusive because the profile depth was about 2.2m, intermediate between the shallow and deep soils (as initially defined), However the evidence concerning soil structuring and its influence on conductivity indicates that where the soils are shallower i.e. less than 1.5m in the cultivated areas (deeper grass/scrub) the unstructured and poorly conductive layer is absent so that the structured clay/silt soil and the weathered basalt form a composite aquifer. Recharge fluxes are loss restricted because the unstructured layer is absent; but the Nabibagh data suggest that downward (recharge) fluxes are small once the water table has risen to the surface. This seems to indicate that there is little continuity between the river system and the weathered basalt at Nabibagh. Elsewhere continuity may exist and downward fluxes are likely to continue through out the monsoon.

B. Chinnatadgam. Avanashi & U. Vatta malaikarai Sub-basins, Tamil Nadu & Kerala

Soil studies involving mapping and hydrological classification of soils based on soil type, texture, drainage conditions, and properties of infiltration capacity, permeability, water retention and run-off potential of the upper 1m soil layer, covering the Noyil, Ponnani and Amravathi river basins in Tamil Nadu & Kerala were undertaken by the Central Ground Water Board under the SIDA assisted Ground water Project, Detailed soil moisture studies and soil physical investigations have been carried out in 3 smaller sub-basins (Fig. 7) is Chinnatadagam (67 sq. kms) Avanassi (140 sq, cms) and upper vattamalaikarni (10 sq. kms.) to understand to phenomena of ground water recharge into hard rock basins and to develop a base for optimum utilisation and management of water for agricultural purposes in these areas. Soil water data collected in these areas made possible the water balance calculations, estimation of specific yields of soil aquifers, rates of infiltration and water use by different crops.

Soil water measurements were started in the area in Sept. 1976 and continued till March 1979. In each sub-basin, 5 stations were set up and at each stations 3 or 4 access tubes were installed for taking soil moisture measurements using Neutron Probe. The depth intervals has been 10 cm throughout and the total depth of measurements has varied from 80 to 270 cm depending on prevailing depths of loose soil at the site. The measurement period varied from 10-15 days. Moisture retention of soils at different seasons was measured using pressure tension plate apparatus Soil samples were collected from selected sites and were subjected to analysis such as particle size, bulk denslty, porosity, hydraulic conductivity, etc. In most cases, the location of soil water stations concides with raingauge sites, as access to relevant rainfall and other meteo-



SIDA ASSISTED GROUND WATER PROJECT
LOCATION OF AREAS FOR MOISTURE STUDIES IN THE PROJECT AREA

logical data greatly facilitates the correct interpretation of the soil water data collected with the neutron gauge.

In chinnatadagam sub basin the soils are of colluvial origin consistuing of hill washed material (weathered rock material) and in the Central part of the Valley soils are calcareous. The soils in case of Avanashi sub basin belong to two different groups, a central black soil region surrounded by medium deep red non-calcereous soils. The soils of the upper Vattamalai Karai Sub-basin are Black cotton type soils.

Changes in water content during various measurement periods have been compiled for the three sub-basins based on the data from neutron probe moisture measurements and the variation in the soil water content with time a space in the three sub-basins was analysed and studied, The results clearly indicate that the soil profiles become saturated in November–December due to the NE monsoon and then water is transmitted to the sub-surface layers below to the root zone.

Infiltration studies with the double ring infiltrometer have been conducted inside the project area at 22 sites with different land use and different soil cover. The final rate of infiltration varied from 5 to 150 mm/hr for Black soils, 40 to 150 mm/hr ror Red insitu soils, and 20 to 390mm/hr for colluvial and alluvial soils. The infiltration capacities of different soils varied quite a lot. The most interesting results are the results from the areas where tank silt or black soil has been added to the original soil. The decrease of the infiltration capacity from 160mm/hr to about 10 mm/hrs is remarkable. The type of manipulation with the top soil is very common in the project area as this has two advantages i.e. decreased infiltration and permeability of the soil which gives less seepage under irrigated conditions and increased water holding capacity of the soil.

Assessment of specific yield of soil aquifers

Using neutron moisture measurements an assessment of specific yield of the soil aquifer at the Eruthampathy farm was made. Neutron moisture measurements were mada below the water table in the access tubes that penetrates into the saturated portion of the aquifer. A nearby well is pumped to dewater the zone of the aquifer in which the tube are placed. Neutron moisture measurements are made again and the difference in the water content before and after drainage, expressed as a percent of the total volume of the aquifer zone is the measured specific yield. Ths specific yield values estimated by this method are given in Table No. 2, the estimated average specific yield value at this site is about 15%.

Assessment of Actual Evapotranspiration

One of the few valid methods available for determining the actual evapotranspiration rate from an area is by means of soil water balance method. The equation for this can be written as follows.

$$ET = P - R - I - \triangle S$$

where ET Actual Evapotranspiration

P = Precipitation

R = Runoff

I = Infiltration Percolation

$\triangle S$ = Soil water change in the root zone.

Deep percolation and changes in the deeper ground water storage are not included since these factors do not have any bearing on the actual evapotranspiration.

During the periods when the flow parameters (P, R and I) are nil and the horizontal flow of soil water can be neglected, the atual evapotranspiration can be estimaled as the change of soil water in the root zone. These conditions are applicable during 7-8 months of the year for the major part of the project area.

TABLE 2

The Specific yield of Soil Layers as Measured by the Neutron Soil Moisture Probe at Eruthampathy Farm.

Tube No.	Depth (cms)	Average specific yield (% by vol.)	Remarks :
42	48 to 80	10.0	Probably a soil layer with increasing clay content.
42	80 to 140	6.2	Probably a soil with a high ciay content.
42	140 to 160	19.0	Probably a soil layer with a sandy type of texture.
59	20 to 110	17.0	Probably a soil layer with a sandytype of texture.
59	110 to 140	10.0	Probably a soil layer with increasing clay content.
59	140 to 200	8.0	Probably a soil layer wlth a high clay content.
59	200 to 900	10.5	Probably a soil layer with an increasing sand content.

Using tha soil weter balance method described above, the evapotranspiration rates have been estimated for 1977–78 for the 3 sub-basins. A root depth of 90cm has been considered for all the stations. The results indicated that the average actual evapotronspiration in the Chinnathadagam. Avanashi and upper Vattamalai Karai Sub-basins is 0.71mm/day, 0.79mm/day and 0.55mm/day respectively.

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