PLANNING OF AGRICULTURAL PLANT WATERSHED MANAGEMENT BY HYDROLOGICAL REGIMEN SIMULATION

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Received December 15, 1979

Presented by Prof. Dr. I. V. Nagy

Economical production in up-to-date agricultural plants is conditioned by the realization or even increase of permanent, equalized high discharges. This is, however, significantly affected by the climatic factors. In the zone of continental climate, the scanty rainfall often causes difficulties while on other occasions, just the excessive rainfall endangers the cultivated plants. Therefore the engineering projects should be developed to be able both to retain the rainfall water and to drain the cultivated areas.

To be economical, mechanization requires to increase the size of the fields. As a matter of course, this affects the methods of planning the water management structures. Earlier, channels lining the plots of land sufficed. Furrows between plots, and the channel served for draining the detrimental waters. With the actual field sizes, as much rainwater as possible without damage has to be retained in the soil, the detrimental excess water has, however, to be drained off before causing a damage. Lowland fields, however, exhibit a slow surface runoff. Extended fields would retain the slowly moving water for a longer time than the tolerance time of plants grown.

This is why the methodology of the watershed management applied so far has to be revised.

Simulation of watershed management in the regimen investigation

The fundamentals of the hydrological regimen of the soil of agricultural lands have been worked out by *P. Salamin*. Although this work has been known since 1943, in lack of the actual highly developed computer technique this method could not be generalized. Its fundamentals, however, stating the surface runoff to depend on the actual amount and intensity of rainfall and on the soaking of the soil, are valid even today, inducing the Department of Water Management to deal with the methodology of watershed management.

The hydrological equation referring to the active soil layer of agricultural land is:

$$L = C - (B + P + T)$$

where:

L — surface runoff,
C — rainfall,
B — infiltration,
P — evaporation, and
T — storage in the soil surface layer.

Also the equation points out that the water retained on the surface depends on the amount of rainfall and the soaking of the soil, factors to be analysed in order to determine the real amount of water to be drained.

Rainfall investigation

Measurement of the amount of rainfall on a given area is a long standing practice, however, it is not sufficient to know the amount of the rainfall but also its variation with time is needed. Unfortunately, scarce measurements are available on the rainfall possible only in summer. Measuring the snowfall is rather difficult, and practically irrelevant to watershed management.

Rainfall measurement with rain recorder in Hungary have been dealt with by *J. Winter*, making use of available data from rain-gauge stations. Although hydrographs refer to short periods, they permit to conclude on unambiguous regularities such as:

1. The rainfalls of short duration in Hungary follow the same regularities, therefore the regional data may be combined.

2. The concept of average summer month may be introduced, permitting to increase the confidence of the combined data.

3. On the Hungarian territory, regularities of the summer rainfalls are identical in different regions. Therefore the rainfall and soil data referring to different regions can be utilized in the calculations.

Soil investigations

Determination of the soil parameters is imperative in hydrological regimen calculations. The water management properties of soils physically differing from each other are also highly different, therefore reliable results can only be obtained if water management parameters are exactly known. Water management parameters the most important for watershed management are the soil soaking infiltration rate and the permeability of the soil, studied by *Horton*. He established the following soil permeability equation (Fig. 1):

$$K = K_e + (K_0 - K_e)e^{-k_f t}$$

where:

K — intensity of water permeability at time t;
K_e — steady-state intensity of permeability;
K_0 — initial rate of infiltration;
e — natural logarithm (2.718);
k_f — soil constant;
t — time passed from beginning of investigation.

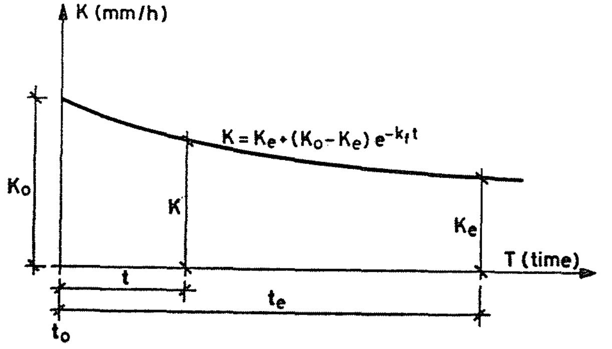

Fig. 1

Thus, the infiltration rate much depends on the amount of water stored in the soil.

The permeability of the saturated soil is a constant value. As a matter of course, it refers only to summer months, i.e., the growth season. The infiltration rate in winter is affected by numerous other factors (air temperature, soil and water temperature etc.), of uncertain interdependence. Thus, lack of data has prevented investigations in winter, off the growth season.

Obviously, the permeability of soils is also the function of the cohesion and chemical elements adsorbed. Thus, investigations always involved the physical and chemical properties of the soil.

These factors significantly change also along the depth of the soil section. Therefore the soil properties have been indicated across the depth.

In Figs 2 and 3, the water management characteristics and the permeability values, respectively, are presented. From the curve, the minimum permeability values appear to be at the boundary of cultivation, a feature common to most of the soils investigated. The compacting effect of cultivating implements, especially of the plough, results in the minimum permeability characteristic of the section, determining the water retention of the soil.

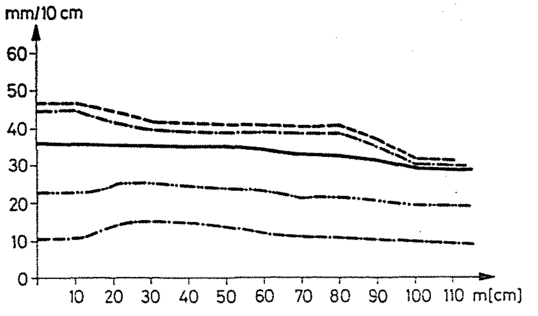

Fig. 2

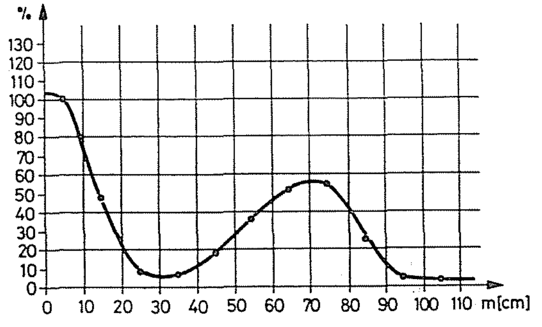

Fig. 3

Evaporation

The useful water resources of the soil decrease in the dry periods as a function of the evaporation rate. In the growth season, the evaporation rate depends on the soil, the cultivated plant species, as well as on the physical factors of evaporation temperature, wind, unsaturation. Even this enumeration shows the calculation of the evapo-transpiration to be rather difficult owing to the great number of parameters. This Department adopted *Thornthwaite*'s assumption for calculating the evaporation:

$$P = \frac{T - H_v}{V_k - H_v} \cdot P_0$$

where:

P — evaporation rate;
T — water resources in the soil;
V_k — water storage capacity of the soil;
H_v — water permanently bound in the soil; and
P_0 — possible evaporation.

The relationship points out that:

for $T < V_k$, $P = P_0$

for $T > V_k$,

$$P = \frac{T - H_v}{V_k - H_v} \cdot P_0$$

and

for $T = H_v$, $P = 0$.

This relationship apparently ignores the plant, thus, the calculation refers only to the physical evaporation. The calculated results have been compared with those measured in experimental catchment areas in Hungary, showing little difference between calculated and measured values. This may also be ascribed to the dew condensating on the ground in the growth season, not entering in the calculation as micro-rainfall, nevertheless offsetting the transpiration.

Mathematical simulation of the hydrological regimen

In knowledge of the parameters, the hydrological balance can be calculated. The value of the water resources $(T_n + 1)$ in the soil by the end of a given period depends on the initial value of the water resources T_n and on the effects during the period investigated:

$$T_{n+1} = T_n + C_n - P_n - L_n \pm E_n \quad \text{(mm)}$$

where:

C_n — rainfall during the period (mm);
P_n — evaporation during the same period (mm);
L_n — surface runoff value (mm);
E_n — amount of water permanently oozing through an infinitesimal cross section (mm).

The initial value of water storage T_n has either to be determined by direct measurement or estimated. In knowing the initial value, the calculation is continued by using the calculated T value. Thereafter the calculation follows the course of the regimen curve.

One hour has been chosen as time unit of investigation, however, in lack of some parameter values (e.g. evaporation) observed data referring to longer periods have been reckoned with.

The rainfall data refer to hourly intervals and so do both the surface runoff and the infiltration.

The computer program performs the following operations: printing out daily the water resources in the soil T, the daily amount of rainfall C, the daily evaporation value P, the surface water to be drained L and the infiltration to deeper soil strata E. The amount of water resources is plotted on the data sheet (Fig. 4).

Medium meadow solonetz
Soil layer thickness: 20 cm

Test period:
6. 1964

Day	C(MM)	P(MM)	L(MM)	E(MM)	T(MM)	100 110 120 130 140 150
						....0I....I....I....I....I....I
1	0.0	0.9	0.0	0.0	113.2	. *
2	0.0	0.9	0.0	0.0	112.3	. *
3	0.0	0.8	0.0	0.0	111.5	. *
4	0.0	0.8	0.0	0.0	110.8	. *
5	0.0	0.7	0.0	0.0	110.0	. *
6	0.0	0.7	0.0	0.0	109.4	. *
7	0.0	0.6	0.0	0.0	108.7	. *
8	0.0	0.6	0.0	0.0	108.1	. *
9	8.8	0.9	3.4	0.0	112.6	. *
10	0.2	0.8	0.0	0.0	112.0	. *
11	0.0	0.8	0.0	0.0	111.2	. *
12	0.0	0.7	0.0	0.0	110.5	. *
13	0.0	0.7	0.0	0.0	109.8	. *
14	0.0	0.7	0.0	0.0	109.1	. *
15	0.0	0.6	0.0	0.0	108.5	. *
16	0.0	0.6	0.0	0.0	107.9	. *
17	12.5	0.7	10.5	0.0	109.2	. *
18	10.4	0.9	6.4	0.0	112.3	. *
19	0.0	0.8	0.0	0.0	111.5	. *
20	0.5	0.8	0.0	0.0	111.2	. *
21	0.0	0.7	0.0	0.0	110.5	. *
22	0.0	0.7	0.0	0.0	109.8	. *
23	17.0	1.0	10.8	0.0	115.0	. *
24	6.5	1.1	4.0	0.0	116.4	. *
25	2.2	1.2	0.2	0.0	117.2	. *
26	0.0	1.1	0.0	0.0	116.1	. *
27	0.0	1.0	0.0	0.0	115.1	. *
28	0.0	1.0	0.0	0.0	114.1	. *
29	0.0	0.9	0.0	0.0	113.2	. *
30	1.0	0.9	0.0	0.0	113.3	. *

Fig. 4

Table 1

Soil section particulars of interest for the water management

Section No.	Sampling depth (cm)	Maximum — Permeability measured by the pipe method (mm/h)	Natural — Permeability measured by the sprinkling method (mm/h)	HV [mm]	Vk_{min} [mm]	DV [mm]	Vk_{cap} [mm]	Vk_{max} [mm]
7	0–10	318	18.0	11.0	36.5	25.5	45.0	47.0
	10–20	150		14.0	36.0	22.0	42.5	45.0
	20–30	20		15.5	36.0	20.5	40.0	42.5
	30–40	18		15.0	36.0	20.0	39.5	42.0
	40–50	60		14.0	35.5	21.5	39.5	41.5
	50–60	115		12.0	34.5	22.5	39.0	41.0
	60–70	160		11.0	33.0	20.0	39.0	40.5
	70–80	168		10.5	32.5	22.0	38.5	40.5
	80–90	75		10.0	31.5	21.5	35.0	37.0
	90–100	10		9.5	29.0	19.5	30.5	31.5
	100–110	8		9.0	28.5	19.5	30.0	31.0

Periods of harmful water accumulation

Under Hungarian conditions, harmful water accumulation causes damages in the agriculture mainly in the early spring and early summer months. The spring season of inland waters requires control interventions mainly in April and May. In places where the water table is in depths of 1 m or higher, also the capillary rise may cause damages. Therefore, in such regions the first task is to lower the water table. The initial assumption in the calculations is that the water table does not reach the soil layer of interest for the hydrological regimen, although also the water table is the highest in this period.

The early summer rainfalls in June and July commonly are heavy showers, of an intensity exceedings the soil permeability. According to the calculations the maximum runoff values occur during this period.

Obviously, the accuracy of calculations primarily depends on that of the input data. The results of calculations utilizing measured data are in good agreement with the practical results. The more accurate determination of the amount of detrimental waters during the growth season permits a safe dimensioning of drainage to fit the cultivated plant species and the soil type.

Evaluation

Hydraulic regimen calculations, as seen in Fig. 4, deliver the useful water resources in the soil and the amount of the detrimental waters on the surface. The calculation has been carried out with identical rainfall values but on different types of soil.

The amount of the water to be drained varies in wide ranges with the soil type. In certain regions of Hungary even in the occurrence of advantageous soil conditions, large amounts of detrimental surface waters are accumulated after rainfalls of high intensity.

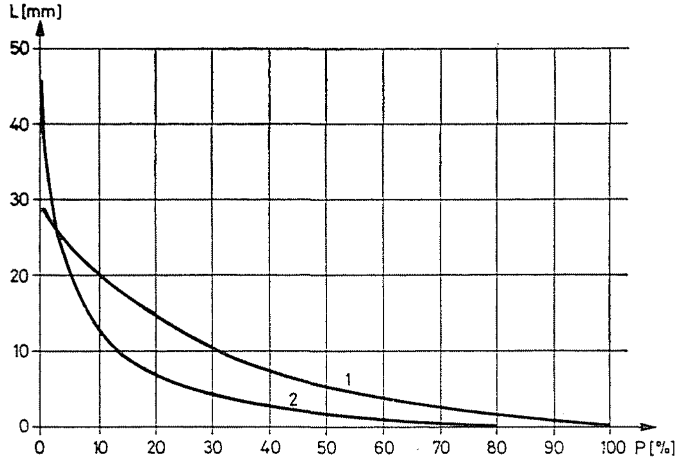

Fig. 5

On the basis of the daily hydrographs, the probability distribution curves of runoff values from two different soil types have been plotted in Fig. 5. Curves 1 and 2 refer to runoff values for a coherent meadow-type and a field-type, in the depth saline, soil, respectively. According to the figure, the mean runoff values of 20 percent probability are in the case of 15 mm equivalent to 174 lit/km^2 of water for soil type 1, and 7 mm, corresponding to an amount of water 81 lit/km^2 for soil type 2. These values are based on five years' frequency. Since the calculation reckoned with a one-day tolerance time, the results obtained mean the amount of water actually to be drained.

Knowledge of the calculation results permits the large agricultural plants to project division into large fields, and watershed management.

The fields must not be larger than to permit the daily accumulated water to be drained, in the case where only surface watershed management is planned. For larger fields, the construction of a subsurface drainage system becomes necessary. For poorly permeable soils, water soaking may be improved by filter drains, soil loosening, and occasionally, mole drainage.

Summary

An essential condition of planning up-to-date watershed management is the detailed study of the rainfall conditions and pedology of the area in question. The degree of elaboration and the field sizes have to be decided in accordance with the amount of the detrimental waters to be expected. The system of the watershed management should be decided on the basis of the amount of the detrimental waters, the hydrological regimen characteristics of the soil and the envisaged size of fields.

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