REFLECTIONS ON HYDROLOGICAL SUPPORT OF SOIL PROTECTIVE CONTOUR AGRICULTURE

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The Soil Protective Contour Agriculture (SPCA) put into practice throughout the Central Russian Plains (CRP) consists of forest shelter belts, soil ridges, dykes and terraces which contoured the peculiarities of local relief. The SPCA-measures are developed to regulate surface runoff and to prevent soil erosion on agriculture lands of the prairie zone. Special field investigations for determining their efficiency were carried out on five small watersheds of the Institute for Soil Protection near the town of Kursk in the CRP area. Experimental watersheds are located on hilly plain with typical clayey *Chernozem* soils with ravines and forested dells. The SPCA elements at several watersheds are various (**Table 1**) with varied spacing *S* of the elements. Hydrological investigations were consisted of the following:

1) scope of the information about the local climate, soils, geo-hydrology, etc.;
2) correction for measured precipitation against the wind-related errors;
3) spatial averaging of the SWEs with allowance for the landscape structure;
4) evaluating evapotranspiration by using meteorological and soil moisture data;
5) estimation of possible replenishment of ground water resources due to SPCA.

Climate conditions and the water cycle elements for the study site are uniquely representative of the area located at the "forest – steppe" zone boundary. Energy budget and wetness are in an equilibrium so the Budyko's climatic index defined as the ratio of the net radiation to the latent heat flux R/LP is practically equal to one. Normal precipitation amount P = 615 mm, evapotranspiration E = 470 mm and runoff Y = 145 mm. Mean air temperatures are –8.7°C for January to 19.8°C for July. Such conditions are food productive as yielding cereals in about 5.5 ton a hectare and optimal to grassland productivity, which can yield hay up to 24 ton a hectare.

General outcomes from the study:

A. Quite appreciable influence of the SPCA takes place on the snow accumulation, in particular, it was clearly found that the forest shelter belts in combination with soil ridges (the 4th variance of SPCA) given the best snow retention capacity (**Table**).
B. Decreasing spring runoff and peak flow depth has been discovered in comparison with that runoff from intact watershed and runoff depth specific for the given area (**Fig. 1**).
C. Differences in evapotranspiration rates have been found for crops (**Fig. 2**) that have been taken into account by using the Heat- and Water balance (HWB) method (Shutov, 1998).
D. Ground water regime (observed at 5 wells) of the Chalk age aquifers has not been affected.

Snow accumulation

Snow surveys were carried out to obtain the Snow Water Equivalent (SWE) at the snow courses traversed forest belts and terraces. Separately, the snow accumulation was studied in ravines and dells. Snow depth profiles were to detect snow drifts and blowing snow at both upwind and lee sides of the man-made obstacles. As the most suitable criterion for estimating the snow retention, the so-called Local Snow Accumulation Coefficient (LSAC) has been used defined as the ratio:

$$K_{í} = H/(P_{cr} - E - M) \quad (1)$$

Where H is local SWE (mm), P_{cr} is corrected precipitation, $Å$ is snow evaporation calculated, M is snowmelt rate determined by the degree day factor which was found there 4.1 mm/degree.

Spatially averaged SWE was evaluated as weighed mean with taken the partial areas of open slopes, ravines and forests into account. The output data are represented in **Table**.

Table. Snow accumulation characteristics for the SPCA watersheds (H_a – averaged SWE, H_f – SWE at open field, H_r – SWE in dells, K_H – the local snow accumulation coefficient)

##	Variances of SPCA practice	Area (F), km^2	H_a, mm	H_f, mm	H/H_f	H_r/H_f	K_H
1	Soil ridges with S = 100 m	0.41	76	54	1,41	2,04	1,03
2	Soil ridges with S = 200 m	0.50	55	53	1,04	1,89	0,75
3	Control watershed (without SPCA)	0.42	54	51	1,06	2,16	0,73
4	Forest belts & soil ridges with S = 100 m	0.92	79	51	1,55	1,16	1,07
5	Forest belts with S = 200 m	0.46	71	53	1,34	1,75	0,96

Comments to the **Table**: The K_H value wholly indicate the snow retention capacity of the examined practice. The presented data show that K_H = 0.73 for control watershed, and K_H = 1.07 for the most efficient variance. That is snow is generally blown off the control watershed (No. 3) into ravine network (H_r/H_f = 2.16), but there are an evident snow retention over the 4-th watershed so, the respective SWE exceeds (P – E).

Snowmelt runoff

Flow discharges from each watershed were measured with the use of duplicated flumes, one for small discharges another for high flood levels. Runoff data were then analyzed in comparison with the discharges observed at the *Devitsa* river basin chosen as the regional analogue.

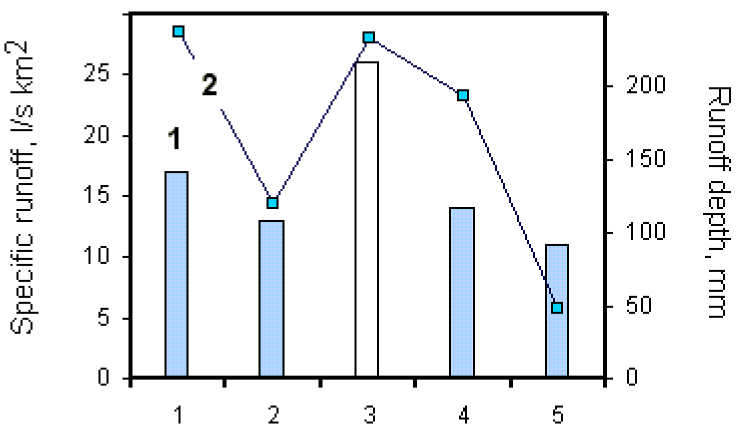

Fig. 1. Snowmelt runoff characteristics for the five SPCA watersheds
1 – spring runoff depth, 2 – maximal (peak) specific runoff

Observed runoff discharges from the control watershed (No. 3) were found of nearly 40% probability, i.e. the unregulated flow is a bit higher than its median value appropriated to the given region and the basin attributes (drainage area, mean slope, etc.). In opposite, two most "powerful" SPCA variances widespread on watersheds No. 4 and No. 5 gave lower runoff values which were found of 75% to 90% exceedance probability.

Evapotranspiration from crop plants together with soil moisture storage is a necessary data to reliably estimate the SPCA effectiveness. Evaporation was calculated by using the meteorological variables observed at the weather station *Petrinka* (some 25 km off the site) and the soil moisture measured on the watersheds. Accepted was the following equation (Shutov, 1998):

$$E = \beta\, E_0\, W_{av}/(FC - WP) \qquad (2)$$

where β is empirical factor changing by plant growth, E_0 is potential evaporation (defined either by Penman or another way), W_{av} is soil moisture content (mm) within top 1-meter soil layer averaged for a time interval (usually 10 day). The values obtained are shown in **Fig. 2**.

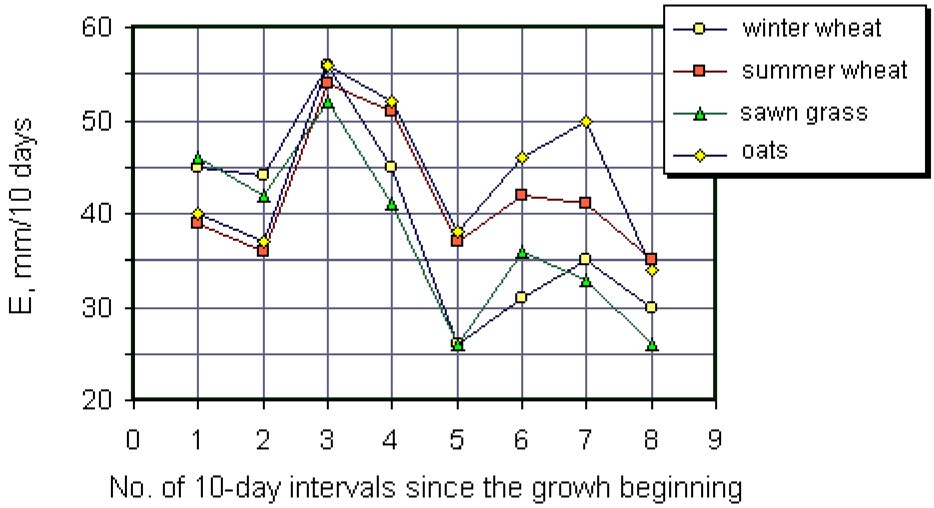

Fig. 2. Evapotranspiration rates calculated using the observed soil moisture for different crops. One drought and two more wet periods can easily be seen at the diagram, as well as divergent values of evaporation from watersheds during the second half of the growing season.

Inferences and suggestions

- Likely hydrological support allows to extend those results obtained on small experimental watersheds to a large scale basin to make this results more usable for both agricultural and hydrological purposes. As the agricultural ecology problems have steadily increased due to deregulated land management for the last two decades, there is a need to undertake a special study to evaluate the impact of land management practices by changing climate and agricultural economy.
- One of the main problems of water protection is how to decrease the contaminants from agricultural lands (Coleman and Ingham, 1988), from the so-called non-point sources. The magnitude of their impact

on inland water bodies may be extended throughout large-scale watersheds and existed for a long time as the continual factor affecting fresh water quality.

- The water protective SPCA transforms the soil texture and permeability that also reduces overland flow and can decrease the removal of contaminants from non-point sources. Also, there appears another fundamental problem of how to prevent possible pollution of the ground water.
- When having the purposes of the flood prevention, one must pay attention to runoff, but when studying drought, one should not omit the evapotranspiration and soil moisture measurements. As the lysimetric measurements cannot allow for satisfactory spatial data, one should recourse to the profile and Bowen ratio methods along with evaluating the spatially varied soil properties conditioned non-uniform heat and vapor fluxes (Doran *et.al*, 1995, Shutov, 2003).
- Field studies should be enforced by processing the long-term observation data at surrounding sites. Their results can testify both progressive trends in precipitation and runoff depth, and the series of various wetness. These series are of a number of years running and they may promote for progressive changes in agricultural benefits. The common frequency analysis is not a satisfactory way to predict how frequent such dry and wet series will return. Hence, another approach is needed based, for instance, on models of discrete events (Storch and Zwiers, 1999)
- Field investigations should obligatory be complemented with simulations by using models such as the APEX (Williams *et.al*., 1998) which are applicable for the field-scale water balance simulations. To be more useful in Russia, this model should be updated by information on soil physical properties and improved through description of the snow accumulation and snowmelt (Shutov, 2000a) into account, which seems to be absolutely necessary.
- To produce most common inferences, one must implant into the model the spatially distributed input variables such as precipitation distribution by using the weather radar data and special indicators (Shutov, 2000b) convenient to hydrology, in particular, the spatial rainfall coverages.
- Finally, the regional frequency analysis of extreme events both extreme rainfalls and severe droughts should be carried out by using up-to-date statistical tools (Stedinger *et.al*., 1992).

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