Erosion Processes Due to Sprinkler Irrigation

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Abstract

The study and analyses of erosion have shown that the main factors determining erosion processes under equal soil and climatic conditions are the intensity and structure of artificial rain and the ground slope. The main factor, artificial rain intensity, depends mainly on the soil infiltration rate. In sprinkle irrigation, the soil infiltration is preceded by interaction between the soil and the rainfall drops. Failure to observe this interaction has often caused irrigation erosion problems due to the impact drops on the soil. It has been proved that the bigger are rainfall drops and their intensity, the bigger are the damages to soil structure. The most important factors on which depends the degree of erosion are erosion resistance and slope of the soil surface. Bulgarian soils are classified in a seven-degree scale, based on $Q_{critical}$ - erosion-safety discharge.

This paper deals with the feasibility to choose irrigation equipment suitable for agricultural crops and having appropriate characteristics of the irrigation sprinklers in dependence of soil resistance and land slope. Both analytical and experimental approaches have been used in solving the problem.

Nomograms, aiming at determining the required parameters of irrigation equipment in order to prevent soil erosion, are presented. They are created on the base of experimental approaches for sprinkler equipment characteristics. The intensity and structure of the artificial rain in relation to the nozzle and the working pressure head of the sprinklers, on one side, and the soil erosion stability in relation to the difference in the land slope and rain intensity, on the other, have been studied.

The analysis of nomograms allows following conclusions about the application of three classes irrigation equipment in the erosive-safe area of land with high slope:

- High pressure sprinklers set with the appropriate blendes are to be applied to terrains of soils with medium to high degree of erosion resistance regardless of the slope. In the set with nozzles the field of application is the same as by 2-3 degree of erosion resistance, but the limit of the slope is 7 %.
- The erosion-safe area of medium pressure sprinklers application is wider as they can be used in soils of low erosion resistance (1-2 and 2) by limiting the slope to 3-5 %. For soils with moderate resistance (2-3) the slope limit is 3-7 %, and for soils with high resistance (above 3), the sprinklers are applicable on steep slopes.

Key words: irrigation, irrigation technologies, irrigation equipment, soil erosion, environment

Introduction

The most important role in the protection of the lands in irrigation systems plays the protection of the key elements of irrigation landscape, such as water, soil and environmental well-being, which determine the efficiency of irrigation and drainage. The appearance of irrigation erosion due to improper irrigation deteriorates the situation of the environment in the areas. This problem is particularly pronounced in all countries with developed irrigation network, especially where irrigated areas are on slopes.

About 34 per cent of the total irrigated areas in Bulgaria are eroded, among them 40 per cent are slightly eroded, 14 per have slight to medium degree of erosion and 28 per cent have high degree of erosion. 3.5 million hectares of the sprinkler-irrigated lands are located on sloped terrain (Rousseva, et. al., 2010). Therefore the problems related to soil conservation are of great interest.

Materials and Methods

In order to protect soil from erosion due to sprinkler irrigation is necessary to analyze and evaluate the factors, which determine the erosions process. The analysis of the research up to date indicates that in terrains with the same soil and climatic conditions the main factors, which determine the amount of irrigation erosion, are the intensity and the structure of the fed artificial rain. The slope of the terrain is of secondary influence, but spraying of crops, located on steep slopes, and raises the conditions for further deterioration of the areas.

The intensity of rain, which is a major factor for the erosion process, is directly dependent on the absorbing capacity of the soil.

If the rain intensity is greater than the absorbing capacity of the soil, in flat terrains is observed the appearance of puddles. In slope terrains under the same conditions is observed seepage. This seepage depends as well on the average intensity of the rain as on its momentary intensity, which by the high pressure sprinklers is higher as the average.

The Bulgarian soils are classified in a seven-degree scale, based on Qcritical - erosion-safety discharge (Krusteva et. al., 1990). This paper deals with the feasibility to choose suitable irrigation equipment for agricultural crops with suitable characteristics of irrigation sprinklers in dependence of the soil resistance and the land slope). Both analytical and experimental approaches have been used for solving the problem.

Nomograms for determining the required parameters of irrigation equipment in order to prevent soil erosion are presented. They are created on the base of experimental approaches for sprinkler equipment characteristics, received by author's investigations (Gadjalska, 1988), (Petrova, 1994), (Simeonova, et al., 1994a), (Simeonova, et al.,1994 b) and other researchers: (Petrov, et al., 1980), (Petkov et. al., 2007). The used data for the soil erosion stability in relation to the difference in the land slope and rain intensity were reported in the study of (Krusteva et al., 1990). The intensity and structure of the artificial rain in relation to the nozzle and the working pressure of the sprinklers on one side and the soil erosion stability in relation to the difference in the land slope and rain intensity on the other have been studied.

Results and Discussion

The nomograms are shown in (figs.1, 2 and 3).

The right side of the nomograms displays in a graphic form the relationship between the permissible average intensity of rain and the resistance class of the soil, under a relevant terrain slope. The zones of the relevant additional anti-erosion measures are given (A - competitive agriculture; B – construction of flow stopping furrows; C – replacement of usual sprinkling with pulse or periodical sprinkling). Determining factor in deciding on the nature of these measures is the slope of the terrain.

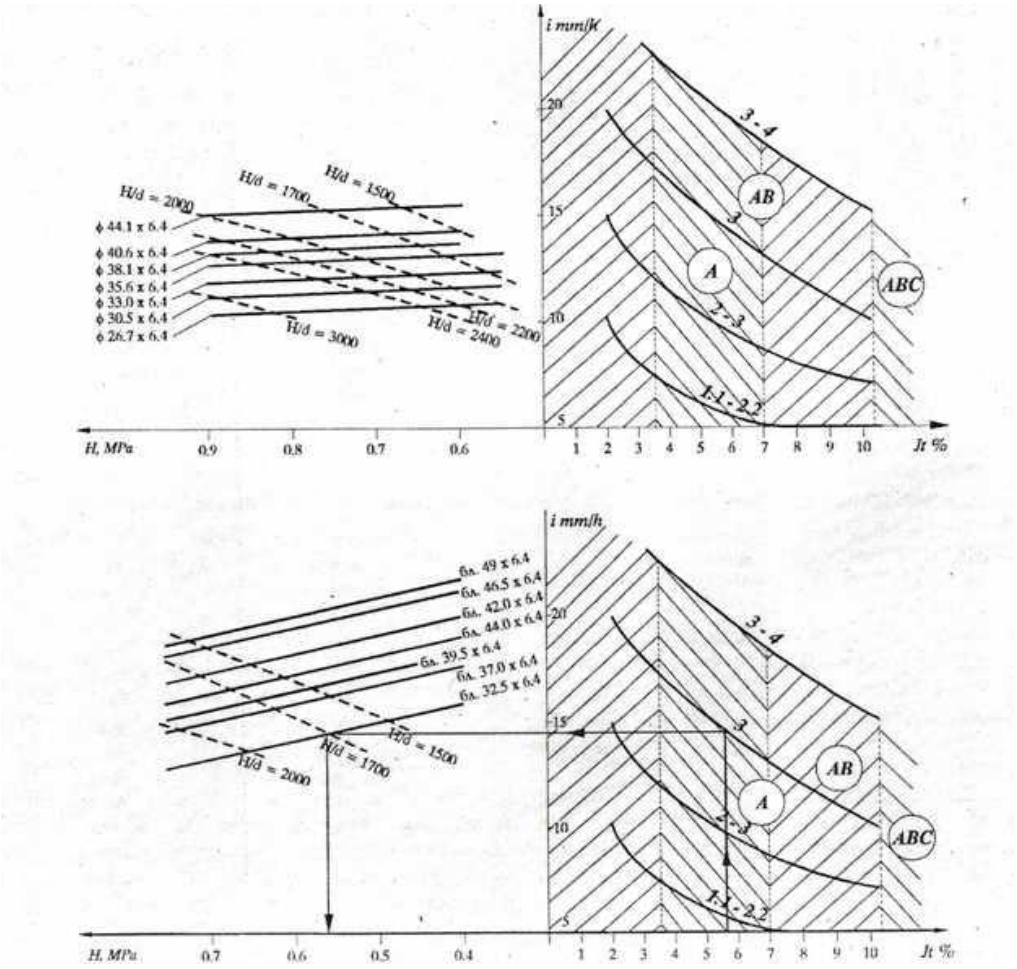

Fig. 1. *High pressure sprinklers –variants with nozzle and blende*

The left side of the nomogram shows the relationship between the technical parameters of the sprinkler head, such as working pressure and middle intensity of rain of the respective nozzle and the schedule of work.

Due to the lack of experimental data on the structure of rain for the individual sprinklers that is appreciated by criteria known H / d.

The nomogram shows that it is feasible to adjust the parameters of the sprinkler (sprinkler head and nozzle (blende)), when knowing the structure and the intensity of the artificial rain, in accordance to the erosion resistance of soil and the slope and in this way to avoid irrigation erosion.

Example of fig.1 shows that by slope of the terrain I = 5, 5 % and by third degree of erosion resistance of the soil (average sustained), the allowable average intensity of rain is 14 mm / h. By this intensity H / d = 1700 (particle size of rain drops, suitable for watering plants with good root system), sprinklers must have a blend 32.5 x6, 4 mm and to operate at pressure 0.57 MPa.

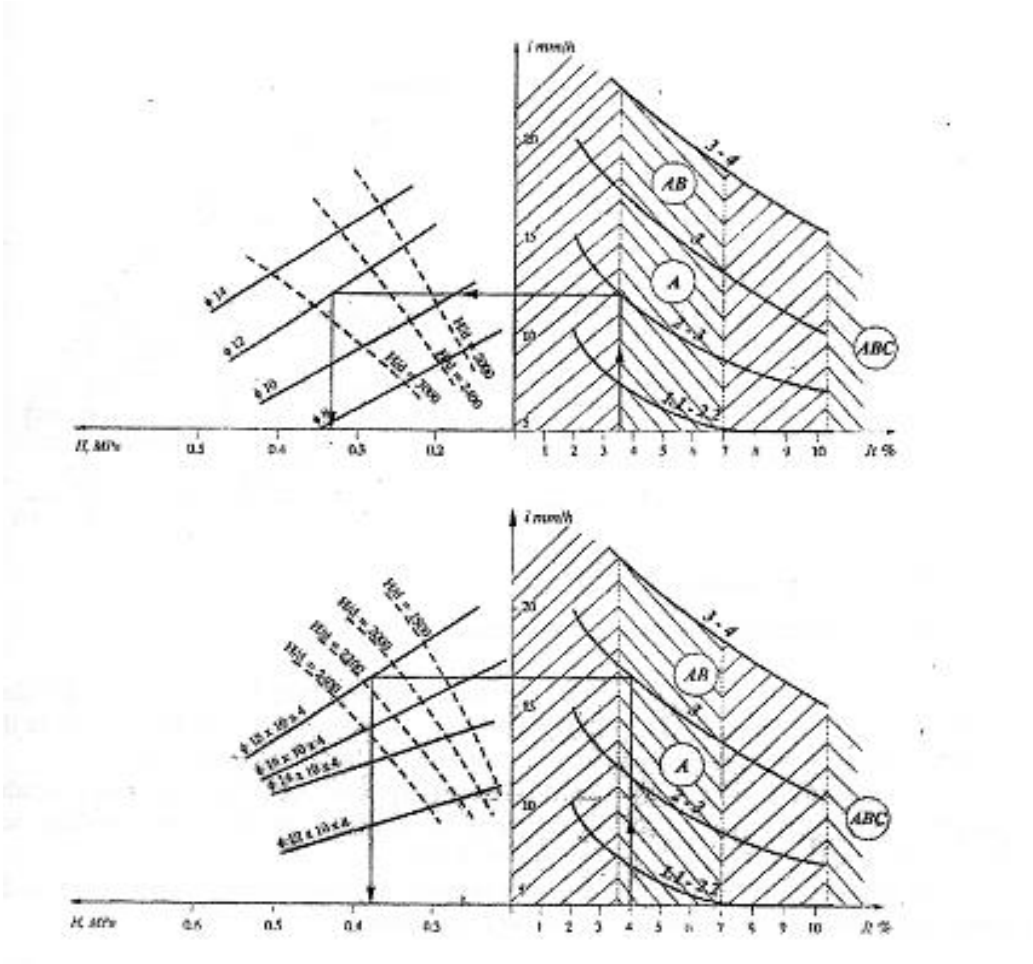

Fig. 2. *Middle pressure sprinklers*

For the middle pressure sprinklers, when the slope of the terrain is 3-5 % and soils have low erosion resistance (1-2 and 2), the allowable intensity of rain is 8 mm / h and the sprinkler must have a nozzle 16x3.5 mm. For soils with moderate resistance (2-3) and slope of the terrain 3-7 %, the allowable intensity of rain is 12-13 mm/h and a sprinkler must have a nozzle 12 mm. For soils with high resistance (above 3) the allowable intensity of rain is 16 mm / h and the sprinkler must have a nozzle 18x10x4 mm (also applicable on steep slopes).

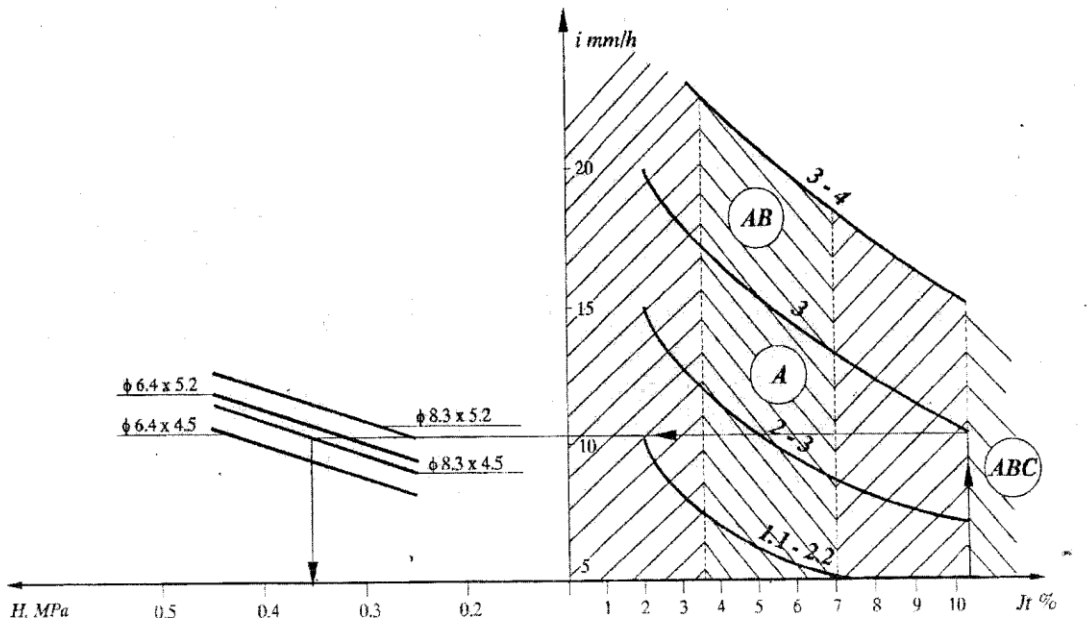

Fig. 3. *Low pressure sprinklers*

For low pressure sprinkler (fig. 3.), slope of the terrain I = 3, 5 % and 2-3 degree of erosion resistance of the soil, the allowable average intensity of rain is 12 mm / h. In this case it is recommended to use a nozzle 8.3 x 5, 2 mm in working pressure 0.42 MPa.

In the nomogram are composed all three types of sprinkler equipment produced in Bulgaria - lower, middle and high pressure sprinklers and the most used working schemas, which ensure uniformity rate of irrigation above 70 %.

In coupling the sprinklers to the installations and machinery it is necessary to do additional studies in case of the change of the working schemes.

Conclusion

The analysis of the nomogram allows following conclusions about application of the three classes of irrigation equipment for irrigation in the erosive-safe area of land with high slope:

1. High pressure sprinklers (P-90C and P-50C) set with the appropriate blende are to be applied on terrains with soils with medium and high degree of erosion resistance (from 3 to 4) regardless of the slope and also on soils with low to moderate (2-3) resistance with slopes from 3.5 to 5 %. In set with nozzles the field of application is the same as by 2-3 degree of erosion resistance, but the limit of the slope is 7 %.

2. The erosion-safe area of application of middle pressure sprinklers is wider as they can be used in soils with low erosion resistance (1-2 and 2) by limit of the slope 3-5 %. For soils with moderate resistance (2-3) the slope limit is 3-7 %, and for soils with high resistance (above 3), the sprinkler are applicable on steep slopes.

3. For low pressure sprinklers the environmentally scope varies between 5 and 9 % slope in soils with moderate resistance (2-3) and 2-3 % in soils with low resistance (1.1 to 2). For all other cases there is no limit.

In conclusion it can be said, that the proposed graphics can be used for:

• Selection of appropriate irrigation equipment in the design of irrigation fields, giving its parameters depending on soil type and slope;

• Assessment of built irrigation fields with particular consideration of the environmental performance of the equipment, used in sprinkler irrigation, before all in areas with higher slopes;

The proper complex of anti-erosion sizing parameters of irrigation equipment, in accordance to the erosion resistance of soils, allows the implementation of environmentally friendly irrigation in areas with high slope without additional investment.

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