Chapter 5

Technical Efficiency of the Subsurface Drainage on Agricultural Lands in the Moldova River Meadow

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Abstract

This study aims to investigate the technical efficiency of different subsurface drainage variants, in terms of the depth of the tile drains, spacing between the drain lines, type and thickness of the drain + filter complex, and the improvement procedures. Within the four variants, the discharge rate of the soil moisture excess was studied. In variants A and D, the spacing between drains is 20 m, and in the variants B and E, the spacing is 15 m. The depth of the tile drains is 0.8 m in variants D and E and 1.0 m in variants A and B. In variant A, tile drainage was combined with land shaping in the bedding system with top of ridges and furrows. Soil moisture was determined on checkpoints placed on drain cross section, at 2 m from drain lines, and of the middle of the drain spacing. In the version with land shaping, the drain lines located under the furrows favor the excess moisture removal. A similar technical efficiency was recorded in unimproved variant but with spacing between drains of 15 m. Best efficiency at removing excess water was registered in variant of the filtering material from ballast associated with flax strains.

Keywords: moisture excess, tile drainage, land shaping, technical efficiency

1. Introduction

Soil quality is more or less affected by one or more conditions, such as drought, periodic excess water, soil erosion, landslides, etc. [1, 2]. Their harmful influences are reflected by the degradation of soil characteristics and functions, of soil bio-productive capacity, affecting yields and food safety, with consequences on human life quality [3–5]. These conditions are determined either by natural factors [6–8] or by agricultural and industrial activities that might have a negative synergic action [9, 10].

Some of the main limiting factors of crop production in Suceava County are excess water, floods, low infiltration rate and soil compaction, soil erosion, and landslides. Waterlogging is a complex process determined by water supply, retention, movement, and discharge in the sub-adjacent rock-soil system [11, 12]. Water excess (rainfall water and/or groundwater) gets manifest under different forms and intensities, both in case of flat and slope lands [13–15]. Natural conditions of the Baia Piedmont Plain favor the occurrence and maintenance of waterlogging. The Moldova River meadow and terraces platform in the form of stripes with an average width of 1.5 km, almost parallel to Moldova River bed, oriented from North West to South East, of gentle slope (1–5%), with flat-horizontal areas and a lot of micro-depressions, facilitating water storage. Because of the humid climate in the Radaseni-Fantana Mare-Baia depression, at low evapotranspiration, the 1–5 days of consecutive heavy rainfall are the main source of water excess in the poorly permeable soils. Furthermore, the hydrographic network represented by the Somuzul Baii runlet, which crosses the mid-area of Radaseni-Fantana Mare-Baia, with a riverbed of about 0.3–0.6 m depth and shallow at some sectors, is a permanent cause of excessive humidity, prone to flooding nearby agricultural lands during heavy rains. Groundwater is stored in permeable deposits of sands with gravel and rocks, and its level is generally free, yet in meadow and low terrace areas, at highest levels, it flows under pressure, causing rising of the water table.

Experimental drainage fields were organized to explore the wide range of causes conducive to excessive water, the complexity of natural conditions hosting the phenomenon, and the multitude of its forms of manifestation. Study results are the base for solutions applied in implementing planning projects of the said areas and, by extrapolation, they were the basic materials for spreading technical solutions in natural homogenous conditions, concretized in the elaboration of design and use standards, instructions, or recommendations.

2. Material and method

Based on the pedo-climatic conditions of the wet area of Suceava County (**Figure 1**) and from the humid area of the meadow and terrace platform of the Moldova, respectively, subsurface drainage experimental fields were organized as a main mean of rainfall excess removal, locally associated to different land improvement works.

The pilot experimental agricultural drainage field of Baia was organized in 1978 by the National Society for Land Improvements—Suceava branch—in collaboration with the Agronomical University of Iasi, on a pseudo-gley glosic albic luvisol, used in natural pastures and hayfields with periodic excessive humidity from precipitations.

The hydro-technical scheme of the Baia experimental drainage field (**Figure 2**) comprises a surface of 3.00 ha, organized by subdivided lots, with two repetitions of three variants each, distinguished by distance between drain lines (12; 15; 20 m), average depth of the pipe drains is 0.8–1.0 m, type and diameter of drain pipes, type and thickness of filtering materials (**Table 1**).

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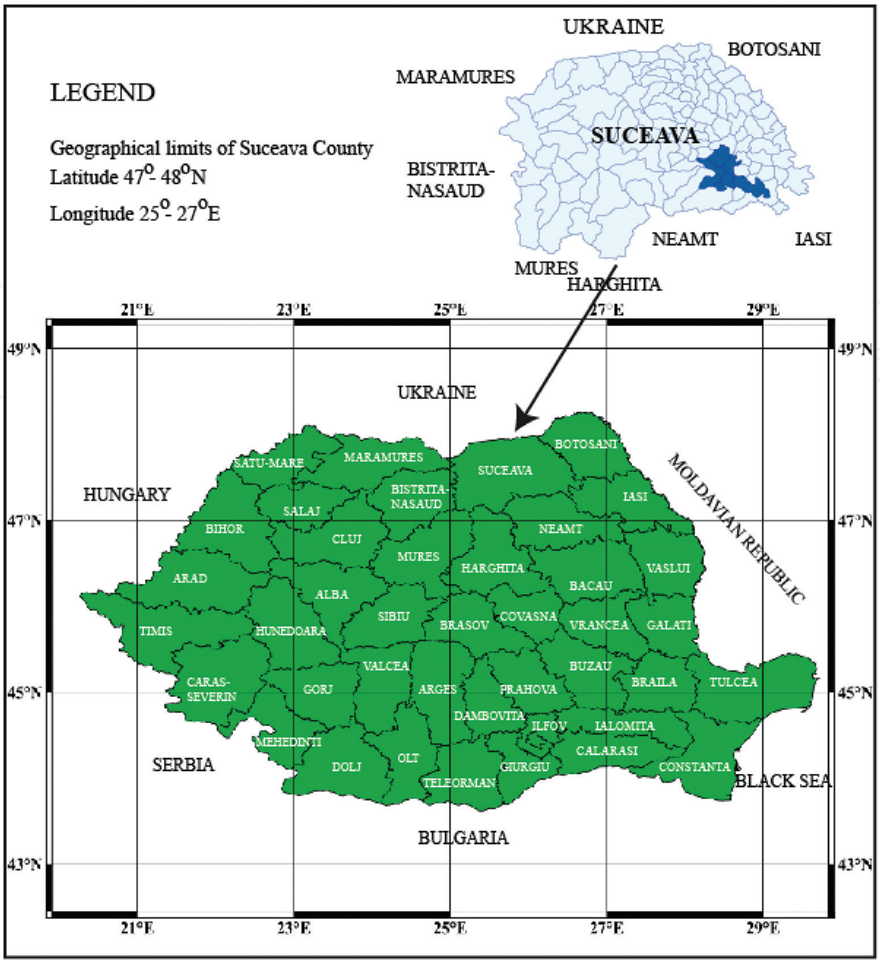

Figure 1. Map of Romania and the geographical position of the Baia drainage field.

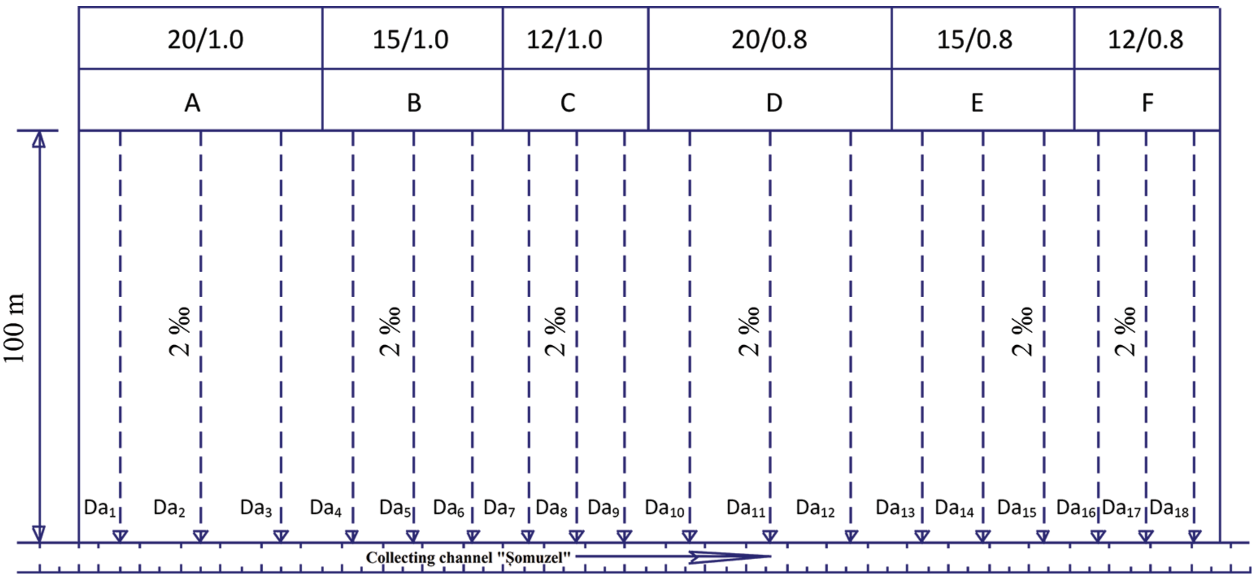

Figure 2. Baia experimental drainage field.

Tile drainage variant	Spacing between drain lines/depth drain (m)	Drain line number	Pipe type and diameter (mm)	Type and thickness of the drain + filter complex (cm)
A	20/1.0	1	Tile Ø 70	Ballast (20) + flax stems (50)
		2	Tile Ø 125	Ballast (70) + green sods
		3*	Tile Ø 70	Ballast (20) + green sods
B	15/1.0	4	Tile Ø 70	Flax strains (30)
		5*	Tile Ø 70	Ballast (12) + flax stems (20)
		6	Tile Ø 70	Ballast (15) + green sods
C	12/1.0	7	Corrugated plastic Ø 65	Ballast (12) + green sods
		8	Smooth plastic Ø 63	Ballast (12) + green sods
		9	Tile Ø 70	Ballast (15) + green sods
D	20/0.8	10	Corrugated plastic Ø 65	Ballast (20) + flax stems (40)
		11	Smooth plastic Ø 110	Ballast (60) + green sods
		12*	Tile Ø 70	Ballast (20) + green sods
E	15/0.8	13*	Tile Ø 70	Flax strains (30)
		14*	Tile Ø 70	Ballast (12) + flax stems (20)
		15*	Tile Ø 70	Ballast (15) + green sods
F	12/0.8	16	Corrugated plastic Ø 65	Ballast (12) + green sods
		17	Smooth plastic Ø 63	Ballast (12) + green sods
		18	Tile Ø 70	Ballast (15) + green sods

*Studied drain lines/variants.

Table 1. Constructive elements of drains from the Baia experimental drainage field.

To improve the production capacities of agricultural lands and mostly of farm fields, surface and subsurface drainage system, banking, watercourse regulation, soil erosion control, and other such works were conducted. According to data from the National Association for Land Improvement, in Suceava County, there is an area of 44,904 ha with surface drainage works, of which 27,455 ha were completed with underground drainage works. The drainage ditches are of 1875 km in length, while the subsurface drainage network has a total length of 11,909 km.

Based on results from the Baia agricultural drainages experimental field, technical solutions for the Moldova River meadow depletion-drainage planning were established. Rotopanesti-Radaseni-Fantana Mare, Dragoiesti-Berchisesti, Bogdanesti-Baia, and Baisesti-Dumbrava surface and subsurface drainage systems comprise a total surface of 8761 ha, of which underground drainage covered an area of 3059 ha (**Figure 3**).

The surface drainage ditch network with a total length of 126.85 km is made of collecting, disposal and interception channels, and so on. To discharge excessive soil moisture, an underground drainage network was organized, made of tile drains with a total length of 1575.12 km, based on the nature and intensity of excessive water.

The Baia agricultural experimental drainage field is placed in the northern part of the Rotopanesti-Radaseni-Fantana Mare depletion-drainage system, on a platform of the upper terrace, on the left side of the Moldova River, located North West from the Baia depression. In the natural conditions of this wetland, the albic stagnant-lossic luvisol is used as a natural pasture.

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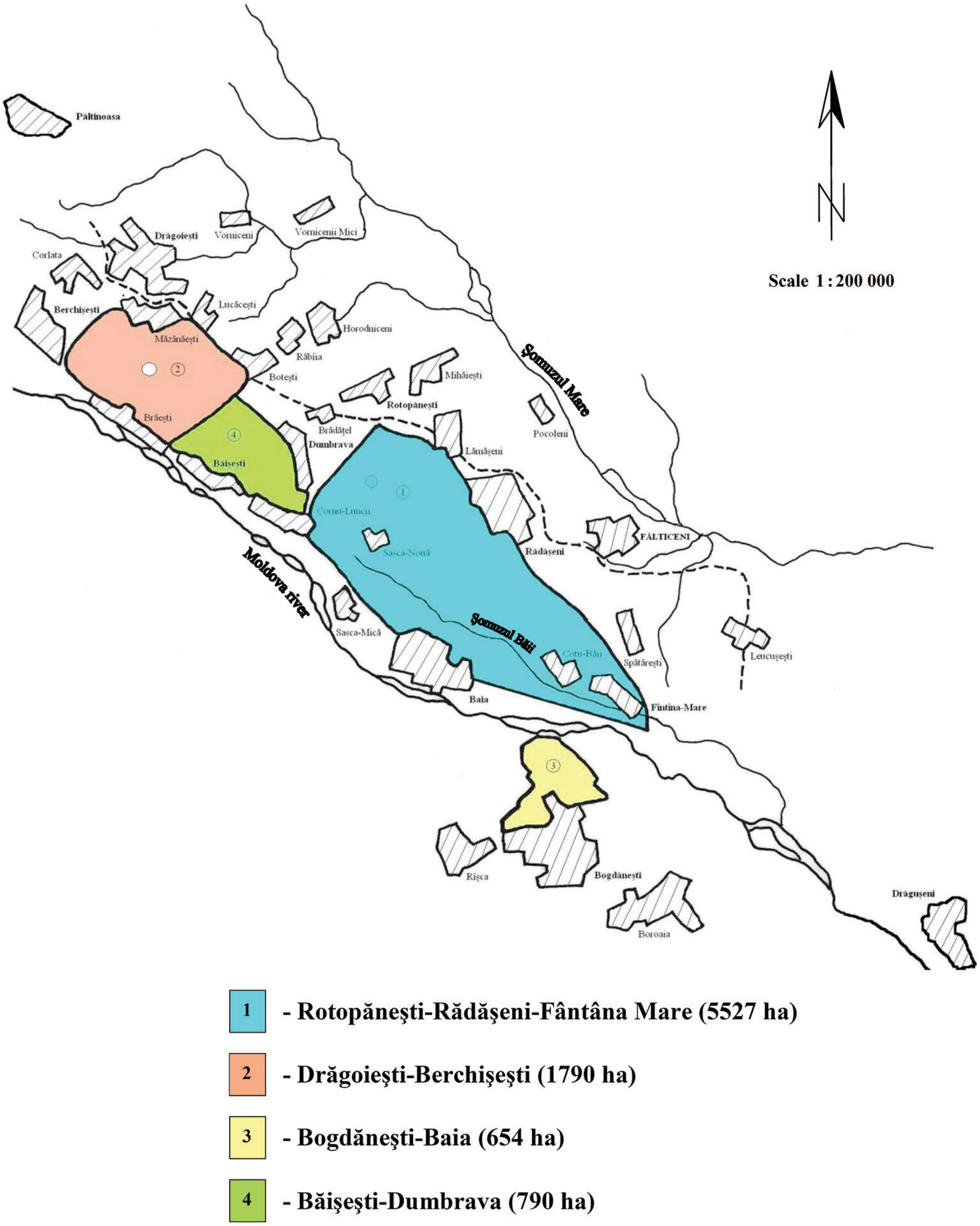

Figure 3. Surface and subsurface drainage systems of Moldova River meadow.

The surface and subsurface drainage systems, as a measure of moisture control, were associated to works of land shaping in the bedding system (**Figure 4**), deep soil loosening, mole drainage, amendments, and so on. After implementing improvement procedures, their operation and behavior are of high importance.

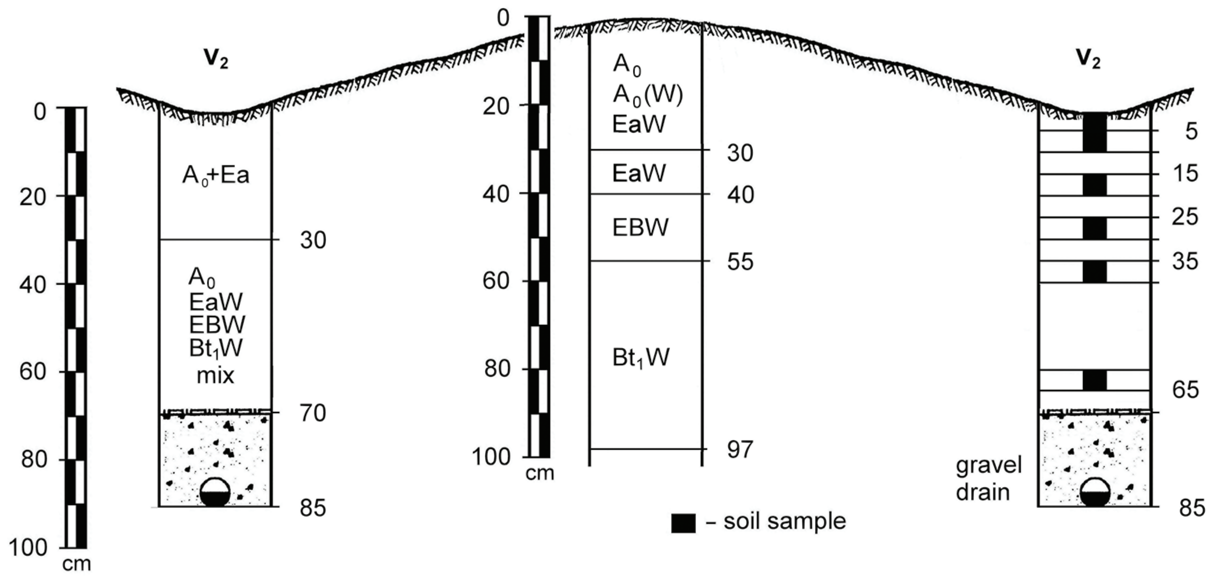

Figure 4. Tile drainage combined with the bedding system variant: top of ridges and furrow.

In order to evaluate the operative behavior of drainage technical solutions, after 36 years soil samples were collected to establish soil moisture in layers with thickness of 10 cm each, up to a depth of 0.8 m and 1.0 m, depending on the depth of the tile drains, at 2 and 5 days, respectively, after the rainfalls. Control points were placed on the drain line, 2.00 m from it and mid-distance between drain lines.

Soil samples were collected from the area served by D_5, D_{13}, D_{14}, and D_{15} drains, placed 15 m apart and laid at 0.8 m (D_{13}, D_{14}, D_{15}) and, respectively, laid at 1.0 m depth from D_5 drain and from the area served by D_3 and D_{12} drains which are 20 m apart, but laid at different depths, 0.8 m the D_{12} drain and 1.0 m the D_3 drain, with a ridge-and-furrow land surface.

3. Results and discussions

The analysis of soil moisture values at 10 cm depth, 2 days after cumulative rainfall of 40 mm, on the variants with the spacing between drains of 15 m, shows that in case of control points placed 2.0 m from the drain line and at mid-distance between drains, the moisture level got to the depth of 30–40 cm, where the poorer permeable layer is located and decreased (**Figure 5**). As for D_3 tile (distance between drain lines 20 m and depth of the pipe drains 1.0 m), with the land shaping in the bedding system with top of ridges and furrows, the soil moisture at control points located 2.0 m from the drain line and mid-distance between drains (10.0 m) got to the depth of 40–50 cm, due to the harsher material placed when the ridge-and-furrow system was created, which implicitly increased the depth of the poorer permeable layer (**Figure 6**). In all cases, at the control point located on the drain line, soil moisture values 2 days after rainfall generally increase as depth increases, as the water flow is directed to the drain line and the permeability of the filtering layer got poorer over the 36-year operating period.

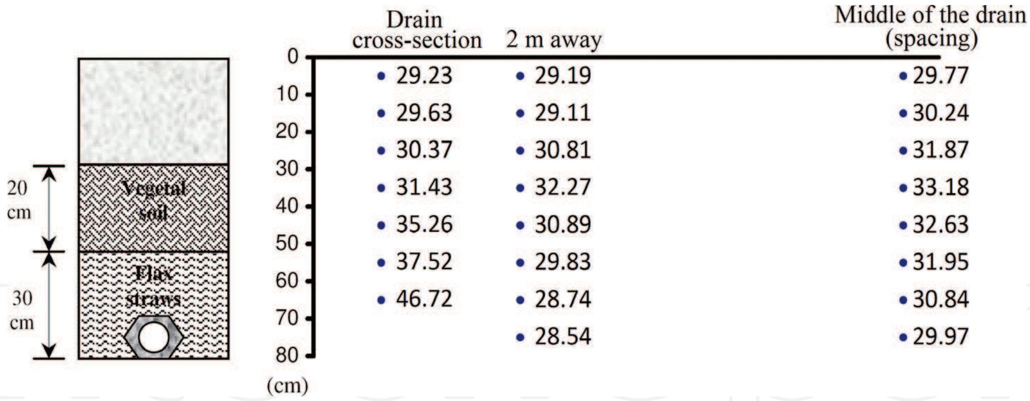

Figure 5. Soil water content in the area served by the tile drain D_{13}, 2 days after rainfall.

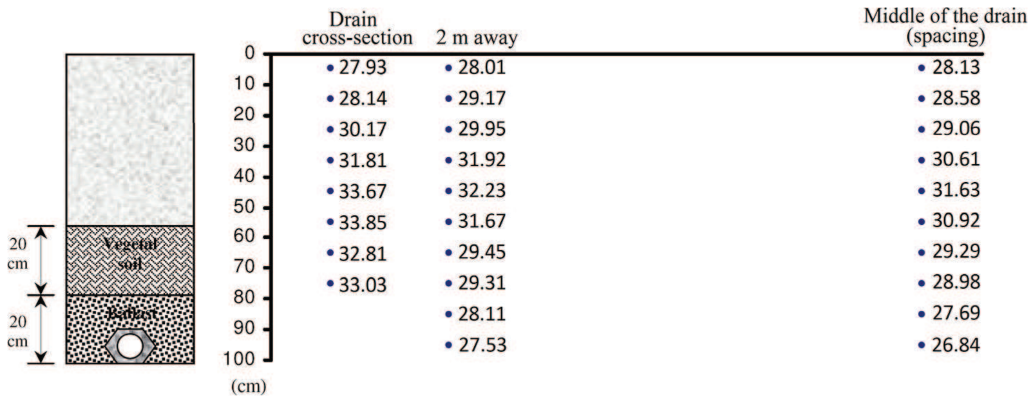

Figure 6. Soil water content in the area served by the tile drain D_3, 2 days after rainfall.

After 5 days from rainfall, soil moisture at control points of D_5, D_{12}, D_{13}, D_{14}, and D_{15} drains located at 2.0 m from the drain line and the middle of the drain spacing generally increases from a 10–20 cm depth to a 40–50 cm depth; then it slightly decreases because of the poorer permeable layer (**Figure 7**). Higher moisture in the superficial soil layer is due to water storage by organic material from the discontinuous celery layer, as the drained surface is used as pasture.

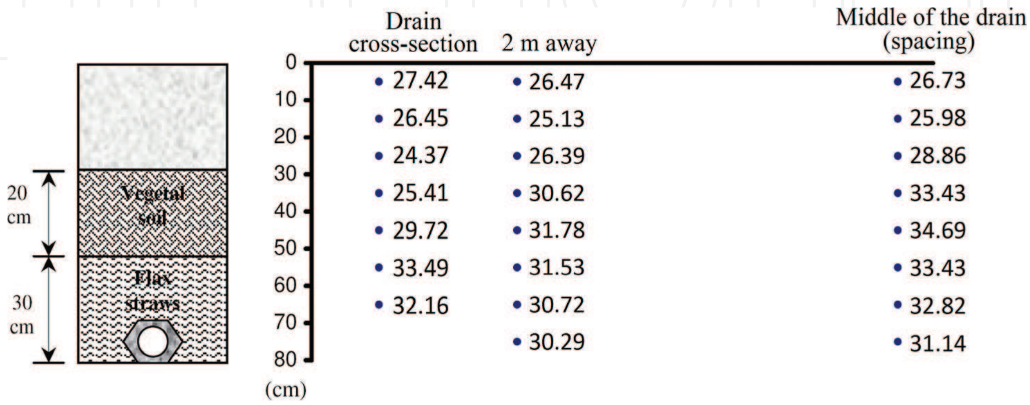

Figure 7. Soil moisture in the area served by the tile drain D_{13}, 5 days after rainfall.

At D_3 drain with ridge-and-furrow system, soil moisture values have the same dynamics; the only difference being that the depth where the greatest moisture is recorded increases from 50 to 60 cm for the control point located at 2.0 m from the drainage ditch to 60–70 cm mid-distance between drains, due to water excess elimination and water consumption by plants (**Figure 8**).

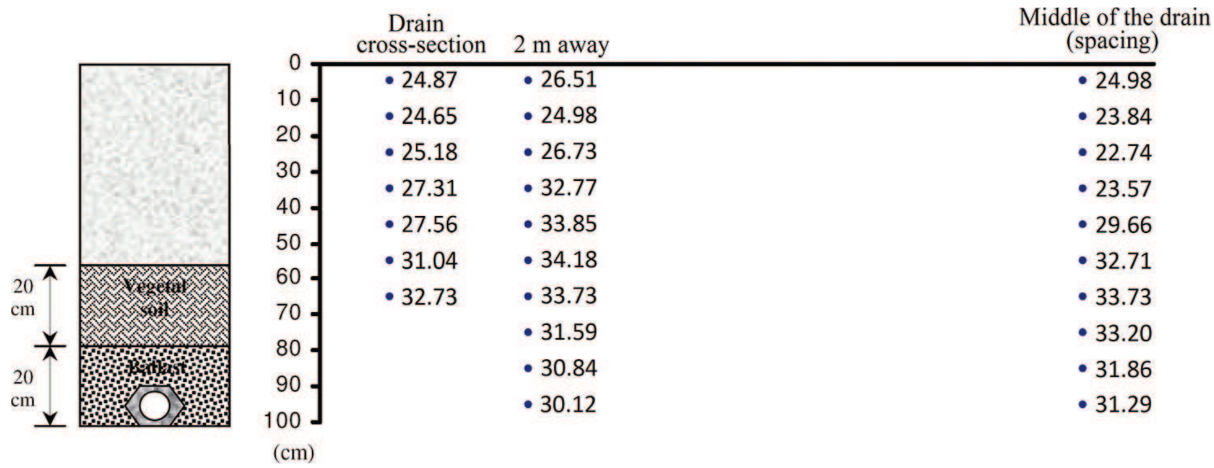

Figure 8. Soil water content in the area served by the tile drain D_3, 5 days after rainfall.

At the drain line, soil moisture values generally decrease to the depth of 20–30 cm, and then they increase thanks to the water flow directed to the drain filter during the operating period. For the first 20 cm, moisture values are higher because of the plant root system, which is better developed on the drain cross section.

The analysis of the values of the average content of soil water by control points, established 3 days from rainfalls, shows that at the drains placed at 15 m one from another, the lowest value is recorded at the control point located 2.0 m from the drain line, while the highest value is recorded on the drainage cross section (**Figure 9**).

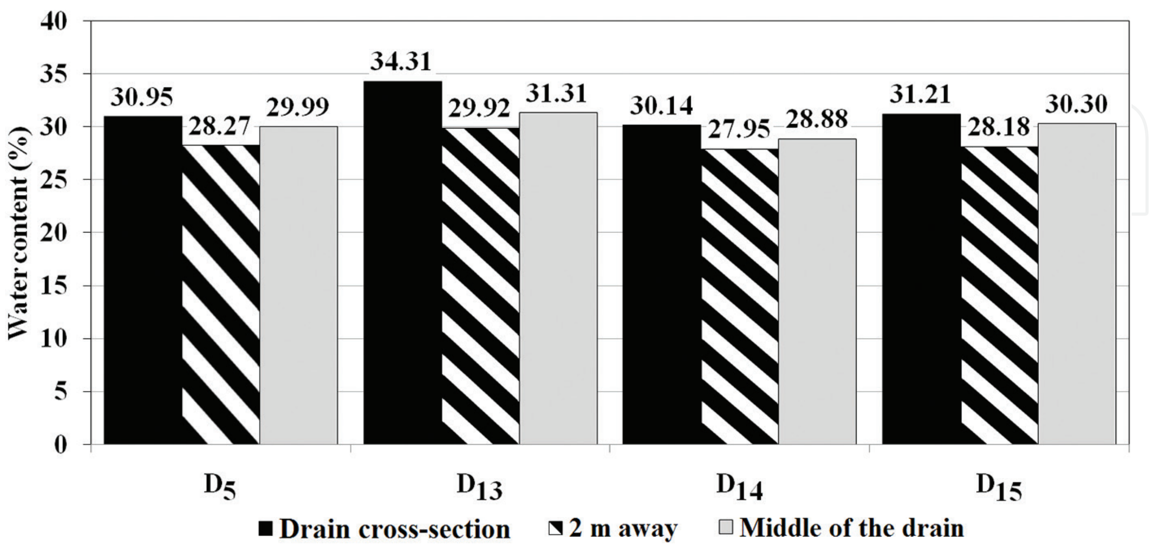

Figure 9. Average soil moisture at control points, after 2 days, in variant with spacing between drains of 15 m.

At D_3 drain with distance between drain lines of 20 m and with ridges and furrow, the highest value is also registered on the drainage ditch, but the lowest value was obtained at the control point located mid-distance between drain lines, due to the water flow directed to the drain filter and runoffs toward the drain line produced during heavy rainfalls (**Figure 10**).

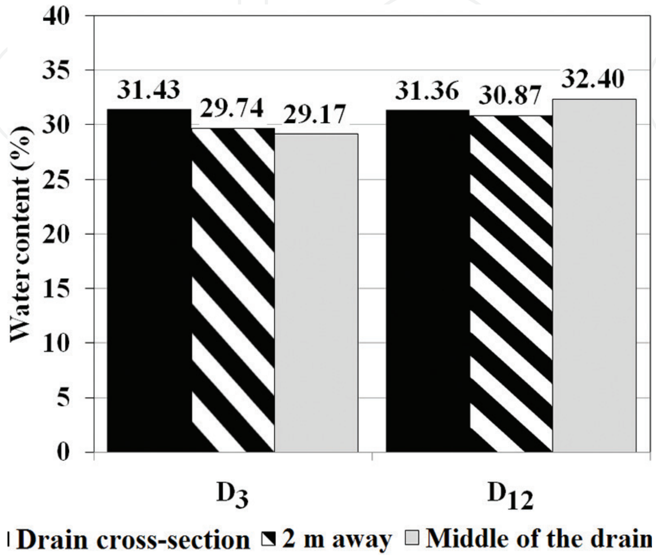

Figure 10. Average soil moisture at control points, after 2 days, in variant with spacing between drains of 20 m.

Runoff control toward the drain line in case of D_3 drain with a ridge-and-furrow land surface is also shown in the analysis of the average soil moisture recorded at D_{12} drain, with the distance between drain lines of 20 m, but with the non-modeled land surface, where the highest value was obtained for the control point located mid-distance between drains (**Figure 10**).

After 5 days, the last precipitations, the average moisture reaches the highest peak at the control point located mid-distance between drain lines, while the lowest value is registered for the drain cross section, except for D_3 drain (**Figures 11** and **12**). The decreasing values of average soil moisture water at mid-distance between drains to the drain line show drain system operation after 36 years of activity.

For the D_3 drain with ridges and furrow, the lowest value of the average moisture is also recorded at the drain line, yet the value obtained at the control point mid-distance between drains (on ridge) is 1.77% lower than the value at the control point 2.0 m away from the drain line, due to any runoff control to the drain line and to having added harsher material when the ridges were created. For such material, hydro-physical indices (fading coefficient, field water capacity) are lower than those of finer textured material (with high clay content).

The analysis of soil moisture content in the control section, 2 days and 5 days from the rainfall recording, of the studied drains (**Figure 13**), shows that the efficiency of water excess removal may be assessed by using different drainage technical solutions after 36 years of operation.

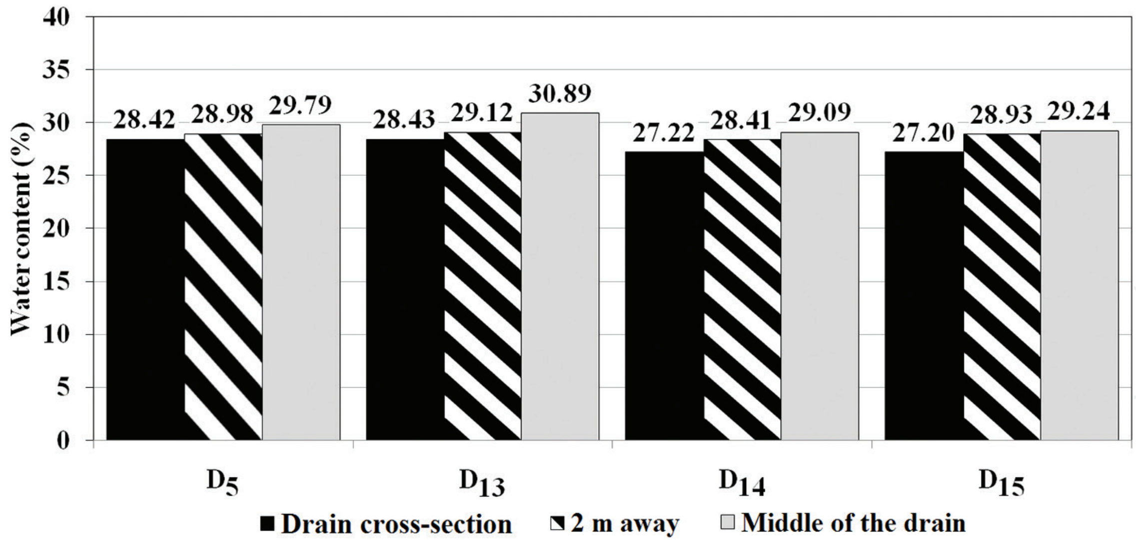

Figure 11. Average soil moisture at control points, after 5 days, in variant with spacing between drains of 15 m.

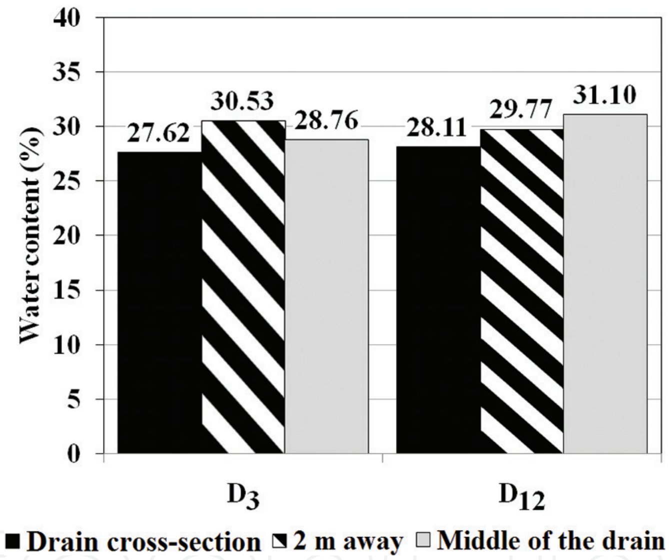

Figure 12. Average soil moisture at control points, after 5 days, in variant with spacing between drains of 20 m.

For D_{13}, D_{14}, and D_{15} tile drains laid at the same depth (0.8 m) and distance between drain lines of 15 m and with different filtering materials, the lowest average moisture values on the control section, in both soil sampling stages, were obtained for D_{14} drain. The use of a ballast layer of 12 cm thick and of a flax stalk layer of 20 cm as filtering material at D_{14} drain favored the discharge of excessive humidity for the serviced area, obtaining an average moisture of 28.99% every 2 days, respectively, and 28.24% every 5 days from rainfall recording, values which are by 0.91%, respectively, and 0.22% lower than those obtained at D_{15} drain, where the only ballast layer used was 15 cm thick.

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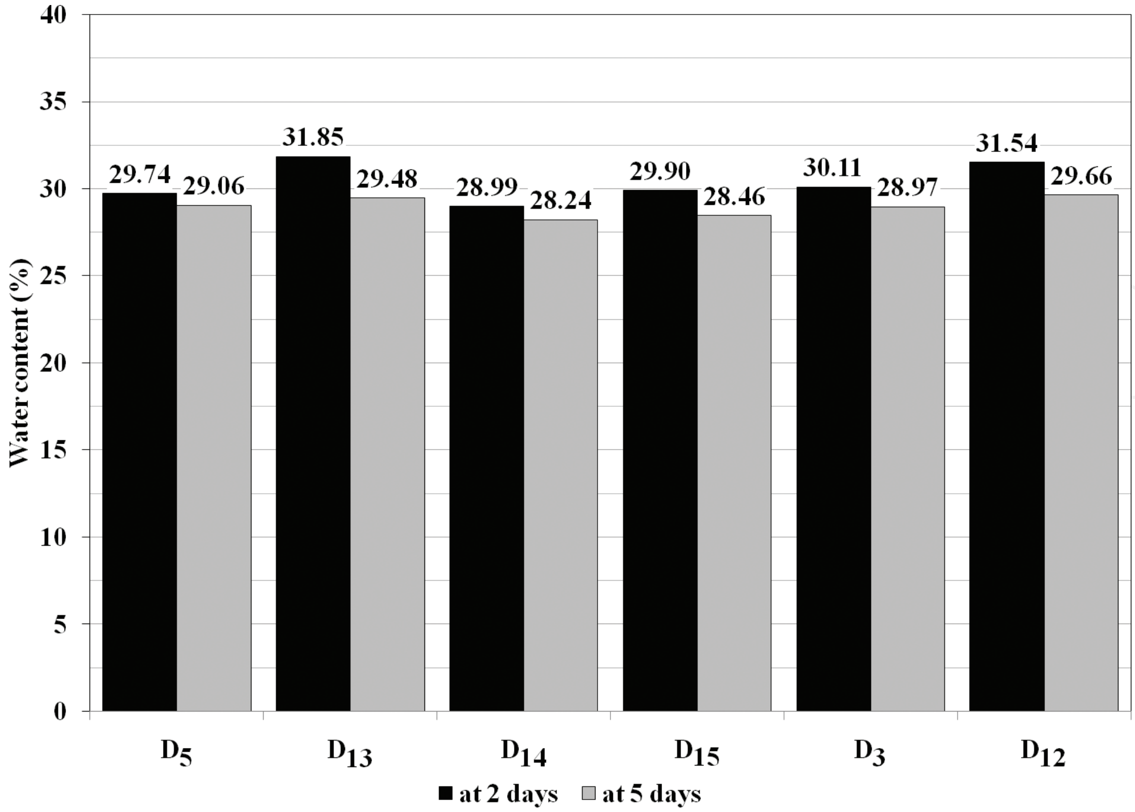

Figure 13. Average soil moisture on control section, at 2 and 5 days, respectively, after the rainfalls.

At D_{13} drain with a filtering layer made of 30 cm thick flax stalks, after 36 years of operation, they turned into organic matter, prone to poorer permeability around the drain pipe and water flow to the drain, recording 2 days from rain the highest average soil moisture at the control section of 31.85% and 5 days after the value of 29.48%. At the same drain, 2 days after the last rainfall, the greatest amplitude of the soil moisture of 4.39% per control points was achieved.

Maintaining the distance of 15 m between drains, the same filtering material (ballast layer of 12 cm thick and flax stalk layer of 20 cm thick) and increasing the laying depth from 0.8 m (D_{14}) to 1.0 m as for D_5 drain, there is an increase of average soil moisture for the control section, from 28.99 to 29.74% (29.94% calculated at 0.8 m depth) during the first soil sample collecting stage. Five days after rain recording, the average soil moisture for control section of D_5 drain increased by 0.82% (0.94% calculated at 0.8 m depth) in comparison with soil moisture determined by D_{14} drain.

At D_{12} drain laid at 0.8 m depth, when the distance between drain lines is of 20 m, high soil moisture values are recorded. After 2 days of rainfall, average soil moisture is 31.54%, by 2.55% higher than D_{14} drain, where the lowest value was recorded. During the second stage of sample collection, this drain registered the highest value of 29.66%, 1.42% higher than the value obtained in D_{14} drain.

By increasing the laying depth to 1.0 m, maintaining the distance of 20 m between drain lines and land shaping in the bedding system with top of ridges and furrow as in D_3 drain variant, a better discharge of excessive water is achieved, yielding an average soil moisture of 30.11%, respectively, and of 28.97% for the control section, values that are relatively close to those determined in case of the drains placed every 15 m, except the D_{13} drain.

4. Conclusions

- In case of subsurface drainage systems from the Moldova River meadow, the predominant spacing between drains is 20 m, and the depth of the tile drains is 1.0 m in the terrace area.
- For an efficient water excess removal, it is advisable improvement procedure as land shaping in the bedding system with ridges and furrows in order to ensure a good drainage.
- Ridge-and-furrow system favors the discharge of water excess, as the runoffs are led to drain lines, obtaining a better water collection and discharge during the first hours and days from excessive water incidence.
- The average soil moisture content of 2 days following the rainfall has the smallest value close to the drain lines, due to the water afflux toward the drains and of the decrease of the permeability of the filtering layer, in time.
- The use of the flax stalks only as filtering material, regardless of the thickness of the layer, is not recommended because of permeability diminishing. However, it was observed that their association with ballast ensures the best discharge of the moisture excess even after 35 years of operation.

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References

[1] Burja C., Burja V., 2013, Sustainable development of rural areas: a challenge for Romania, *Environmental Engineering and Management Journal*, 14(8), 861–1871.

[2] Hornbuckle J.W., Christen E.W., Faulkner R.D., 2007, Evaluating a multi-level subsurface drainage system for improved drainage water quality, *Agricultural Water Management*, 89(3), 208–216, http://dx.doi.org/10.1016/j.agwat.2007.01.004

[3] Mirsal A.I., 2004. Soil Pollution. Origin, Monitoring and Remediation. Springer: Berlin.

[4] Walker W.R., 1989. Guidelines for Designing and Evaluating Surface Irrigation Systems. Irrigation and Drainage Paper 45. FAO Rome, Italy.

[5] Valipour M., 2014. Comparison of different drainage systems usable for solution of environmental crises. In Soil. Proc. 1st International Conf. on Environmental Crises and Its Solutions, Kish Island, Iran, 8 pages.

[6] Troeh F.R., Thomson L.M., 2005. Soils and Soil Fertility. Blackwell Publisher: Iowa.

[7] Lukianas A., Vaikasas S., Malisauskas A., 2006, Water management tasks in the summer polders of the Nemunas Lowland, *Irrigation and Drainage*, 55(2), 145–156. John Wiley & Sons. DOI: 10.1002/ird.230.

[8] Lin D.G., Hung S.H., Ku C.Y., Chan H.C., 2016, Evaluating the efficiency of subsurface drainages for Li-Shan landslide in Taiwan, *Natural Hazards and Earth System Science*, Copernicus Publications, Göttingen, Germany, 1–22, DOI: 10.5194/nhess-2015–309.

[9] Irwin R.W., 1997. Handbook of Drainage Principles. Publication 73, RP-01-97-500. Ontario Ministry of Agriculture, Food and Rural Affairs (*OMAFRA*), Toronto, Canada.

[10] Townend J., Reeve M.J., Carter A., 2001. Water release characteristics. In Soil and Environmental Analysis: Physical Methods, (2nd edn), Smith K.A., Mullins C.E. (eds). Marcel Dekker, Inc.: New York.

[11] Kovács G., 1981. Seepage Hydraulics. Developments in Water Science vol. 10. Elsevier Science Publishers: Amsterdam.

[12] Singh V., Frevert D., Rieker J., Leverson V., Meyer S., Meyer S., 2006, Hydrologic modeling inventory: cooperative research effort, *Journal of Irrigation and Drainage Engineering*, 132(2), 98–103. DOI: 10.1061/ASCE

[13] Valipour M., 2013. Scrutiny of inflow to the drains applicable for improvement of soil environmental conditions. In Proc. 1st Int. Conf. on Environmental Crises and Its Solutions, At Kish Island, Iran, 12 pages.

[14] Tang Z., Shi C., Bi K., 2013, Impacts of land cover change and socioeconomic development on ecosystem service values, *Environmental Engineering and Management Journal*, 14(10), 2697–2705.

[15] Ritzema H.P., Kselik R.A.L., Chanduvi F., 1996. Drainage of Irrigated Lands: a Manual. Irrigation Water Management Training Manual. FAO: Rome.