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Tile Drainage on Agricultural Lands from North-East Romania - Experimental Variants and Technical Efficiency

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1. Introduction

Romania is situated in geographical center of Europe (south-east of Central Europe) at north of Balkan Peninsula at the half of distance between Atlantic Coast and The Urals, inside and outside the Carpathians Arch, on the Danube lower course and has exit to the Black Sea. Otherwise, parallel 45°N with the meridian 25°E intersects near the geometrical center of the country, 100 km N-V of the country capital, Bucharest. Romania is the twelfth country of Europe, having an area of 238,391 km².

Romania's relief consists of three major levels: the highest one in the Carpathians, the middle one which corresponds to the Sub-Carpathians, to the hills and to the plateaus and the lowest one in plains, meadows and Danube Delta.

Romania's climate is temperate-continental of transition, with oceanic influences from the West, Mediterranean ones from South-West and continental-excessive ones from the East. Multiannual average temperature is latitudinally different, 8°C in the North and over 11°C in the South, and altitudinally, with values of -2.5°C in the mountain floor and 11.6°C in the plain.

Yearly precipitations decrease in intensity from west to east, from over 600 mm to less 500 mm in the East Romanian Plain, under 450 mm in Dobrogea and about 350 mm by seaside, in the mountainous areas they reach 1000-1500 mm.

Romanian running waters are radially displayed, most of them having the springs in the Carpathians. Their main collector is the Danube river, which crosses the country in the south on 1075 km length and flows into the Black Sea (Romanian Statistical Yearbook, 2010).

Maps of Excess of moisture show the geographic occurrence, at national and district level, and intensity of the three kinds of excess of moisture: from groundwater, rainfall and by floods. The classes are defined according to intensity and the subclasses according to the nature (source) of the excess moisture (Munteanu et al., 2004).

Drainage systems reduces the volume of drainage water leaving a field by 20-30% on average; however, outflow varies widely depending on soil type, rainfall, type of drainage system and management intensity (Ramoska et al., 2011).

The impact of drainage on yields is variable. Long-term computer simulations indicate that the average annual yield increase is less than 5%, but it could be substantial in some years depending on annual precipitation variability and regional climatic characteristics as well (Cooke et al., 2002, Troeh et al, 2005).

Drainage systems must cost-effectively manage flooding, control streambank erosion, and protect water quality (Lukianas et al., 2006). To do this, designers must integrate conventional flood control strategies for large, infrequent storms with three basic stormwater quality control strategies for small, frequent storms: infiltrate runoff into the soil, retain/detain runoff for later release, and convey runoff slowly through vegetation (Ritzema et al., 1996, Singh et al., 2006).

Integrated flood control/stormwater quality control designs must meet a variety of engineering, horticultural, aesthetic, functional, economic, and safety standards (Townend et al., 2001, Walker et al., 1989).

The preservation and sustainable use of soil resources include also the differentiate application of hydro-ameliorative works depending of the limiting factors of soil fertility.

Monitoring within Romania has revealed that there are approximately 4.0 million ha of farmland that have suitable soil resources, 3.7 million ha of which are arable lands, capable of sustaining competitive agriculture (Dumitru et al., 2004).

According to the *Romanian Statistical Yearbook* from 2008, the area of agricultural land categories affected by various limiting factors of productive capacity included: frequent droughts - 7,100 thousand ha; periodic excess moisture in the soil - 3,800 thousand ha; soil erosion and landslide - 7,000 thousand ha; soil compaction - 6,500 thousand ha; high and moderate acidity - 3,400 thousand ha; small and very small reserves of humus in soil - 7,500 thousand ha; low and very low concentration of mobile phosphorus - 6,300 thousand ha.

According to the data highlighted by Man et al., 2002, based on specialized studies carried out in the counties of Timis, Arad, Bihor and Maramures, there was estimated an agricultural area of 958,000 ha affected by excessive moisture. On these agricultural lands having excess moisture, there were carried out drainages for 854,925 ha, of which an area of 18,159 ha was drained with tile and plastic drains.

The spatial distribution of the ecosystemic territorial units in north-east of Romania, respectively, in Suceava County, showed a percent of soil with excess moisture ranging between 30% and 40% of the considered area, with an extension from south to north and from east to west. According to data estimated by Moca et al., 1988, 2001, the permanent and / or temporary excess moisture has been present over time on a area of more than 100,000 ha. Among the hydro-ameliorative improvements performed on agricultural lands with excess moisture in the extra-Carpathian region of Suceava County, there can be mentioned the drainage systems with open canals, and in some areas includes also subsurface drainage provided with ceramic and/or plastic pipes. The management of soil resources having excess moisture and a high risk of suitability for agricultural use requires the use of photogrammetric products as images and digital data files.

Suceava County is situated in the north part of Romania and is included, together with other five counties, in the North-Eastern Development Region. Having a total area of 855,350 ha, Suceava County is the second largest county of Romania, representing 3.6% of the country

surface. By land use, Suceava County has 349,544 hectares agricultural land, representing 41 % of the total surface, and 505,806 ha, i.e. 59 %, non-agricultural land (Jitareanu et al., 2009).

The resources of agricultural land of Suceava County are limited both by the size of the contained area, and by production capacity. With the aim of normal use of soil resources, a series of hydro-ameliorative works have been done over time. The goal of performing these works was to combat the following soil agricultural capacity limiting factors: excess moisture, flooding risk, soil erosion, unstable slopes and others.

Among the first works to eliminate the water excess, which were applied on the agricultural land with excess moisture in Bucovina can be mentioned: surface water drainage channels between the parcels of different owners; land forming in the bedding system with ridges and furrows; canals for water evacuation and others. Documents from that time show that the first ameliorative works associated with drainage works were performed in the late nineteenth century and early twentieth century in Radauti Depression, by the Agricultural Society of Vienna, who executed both, subsurface drainage and small regularization of rivers. Starting with 1895 and then between 1903 and 1910, was done a series of important tile drainage works in Radauti Depression.

The drainage and subsurface drainage works included several development stages, which took place, particularly between 1950 and 1990. In the first stages, from 1950 to 1975, were designed drainage systems and river regularization with dikes. In the second period that ranges between 1976 and 1990, some older systems were improved and resized. Also, in some hydrographic basins were executed new works, which included the hydro-ameliorative systems with canal drainage and subsurface drainage.

In the social and economical context of Romania after 1990, which led to a substantial decline of investments, land improvements were, also diminished. At this stage, was done only maintenance work and completion of existing improvements. Among the specific works carried out during 1990-2010 can be mentioned: the maintenance of drainage ditch networks, pipe and tile drains and flood prevention works.

In Suceava County, surface drainage systems were set up on 55,100 ha, tile drainage networks on 26,300 ha and systems of embanking and protection against floods on 7,400 ha between 1960 - 1990 to remove this excess moisture.

The structure of land use types from Suceava County, which includes a share of agricultural land of 41 % and 53 % for forests and forest plantations, is relatively balanced for a territory belonging to the *Carpathian orogeny* and the plateaus unit.

Highest soil resources belong to the *class of Luvosols*, which has a share of 25.3 % from the effectively charted area and among the soil types, can be, and noted the *faeoziom* with 18 %.

The distribution of soil resources on the five quality categories indicates that most of them are included in the *III-rd class* (35 %) of soils with average fertility, and in the *IV-th class* (30 %) of soils with low fertility.

The main limiting factors for soil quality are as follows: excess moisture affecting 185,316 ha, water erosion and land sliding, compaction, acidity and nutrients deficiency.

2. Surface and pipe drainage systems

Natural drainage of the soil is represented by all conditions of terrain, soil and hydrogeology of an area which causes gravity circulation of water located at a point in excess of the land surface or on soil profile (Mirsal et al., 2004).

In terms of hydroameliorative works, the drainage is all that apply to land surface or underground, from which excess water is eliminated.

Surface drainage works is the ensemble of hydro-ameliorative works which removes excess water from rainfall, land surface or accumulated stagnant at the top of the soil profile, above the hard permeable horizons.

From surface drainage category of works are highlighted the following:

- *land shaping in slope* that is done, usually with a continuous slope of the land surface after one or more inclined planes, to a gutter or nearest canal drainage network. The purpose of levelling land drainage works is to avoid stagnation of rainwater on the surface of local depressions without drainage.
- *land shaping in the bedding system with ridges and furrows* is the realization of the greatest slope of the terrain of ridges with widths of 15 to 40 min length from 100 to 500 m and cross slope of 1-3%. These strips are ridges separated by shallow channels with large slopes, easily traversed by agricultural machinery.
- *mole drainage* consists of galleries of 8 to 14 cm diameter, located at a depth of 0.4 to 0.8 m below surface, and is achieved through a special device. The purpose of these underground galleries is to remove excess water from the upper soil profile derived from precipitation.
- *deep loosening* of soil profile at depth of 0.4 to 0.8 m is achieved either by plowing or scarifying, to increase the permeability of poorly permeable horizons and infiltration of water into deeper layers of soil profile. In addition to the categories of works mentioned above, surface drainage is completed through a hydropower scheme including collection network channels, outlet channels and all related construction.
- *ridge ditch* issued for the collection and removal of water from precipitation which is in excess of the land surface.
- *drainage ditch* is a channel that takes discharged water from the network channels and transports it to the nearest outlet channel being carried long distances between them, from 200 to 500 m.
- *evacuation channel* is the channel that takes drained water from discharged channels and transports it to the nearest outlet higher point channel or direct in the emissary.
- *emissary* (*water course*) is a natural watercourse, in which the drainage system discharges its drained water volume either by gravity or by pumping.

Pipe drainage systems with pipes is represented by all hydro-ameliorative works used for lowering groundwater levels at the depth required by the grown plants, respectively, of climate and soil conditions (Mejia et al., 1998). In this category of work is a contained tubular drain of different sizes, network channels and exhaust collection related construction, filled sometimes with surface drainage.

2.1 The causes of excess moisture on agricultural land

The main water sources and factors that determine the formation of excess soil moisture conditions in Romania are the following:

- *precipitation* is directly or indirectly, the main source of excess water in the soil for most agricultural land. In natural conditions of various climatic zones are recorded variations of rainfall, both from a calendar year to another, and in the same year from one season to another. Thus, in the same climate area 800-1000 mm annual rainfall can be recorded in rainy years and only 350-450 mm in dry years. However, large amounts of precipitation are recorded in short intervals. Thus, in intervals from 1 to 5 consecutive days, rainfall totals from 50 to 150 mm and sometimes even more. Excess moisture coming from rainwater accumulates in the roots of crops, and sometimes as a layer on top of pedophreatic soil profile. Depending on local natural conditions, excess moisture coming from precipitation is associated with lower slopes and/or local minor unevenness respectively, with clay soils, poorly permeable.
- *high water table* fed by precipitation, infiltration from river sand other sources contribute to excess moisture on the land of meadows, plain sand low terraces. Excess moisture is manifested by increasing the water table, flooding the area of plant roots as well as small swamps in depression areas. On this land, ground water is usually located at depths between 1 and 5 m, which during rainy or high levels in rivers, lakes and other sources increases almost to the ground surface.
- *the heavy rainfall and high ground water level, easy accessional*, fuelled by one or more of the above sources, also contribute to the formation of excess moisture on the clay soils, hardly permeable. Excess moisture in the form of swamps and/or caused by precipitation of pedophreatic layer, respectively, as a high ground water level, the result of association between water sources said.
- *river water* formed by the outpouring of excess moisture and flooding over the sides of valleys without mills. Floods are recorded normally during winter due to snow melting and in summer after heavy rainfall. Duration and frequency of flooding on local conditions vary from one stream to another, very different durations of time. Typically, floods are more frequent and shorter periods on the rivers of Romania and have a longer character and are less frequently in the Danube meadow. However, low lands are flooded from surface water runoff from higher areas of the surrounding land.
- *the landscape* favours the formation of excess moisture in the soil so the small slopes of the terrain and the local minor unevenness elements which make the water flow and natural drainage of the soil characteristic. These areas are specific areas of meadow and low plains and sometimes on the terraces. Excessive wetting of the soil favours swampiness of the land, especially in humid and subhumid climates.
- *the illuvial clay soil with low permeability* from wet climate and sub-humid areas are also challenging conditions for gravity circulation of water in the profile. The presence of textural horizon, illuvial clay, hard permeable, at a depth of 60-80 cm from ground surface contributes to the accumulation of excess water in the upper horizons of the soil profile.

2.2 Soil water balance

Agricultural land drainage fitting sizes, in general, for non-permanent or permanent regime, depending on soil water balance, respectively, of the elements considered for calculation of specific flow discharged through drains network.

Depending on the causes of formation of excess moisture in the soil which were previously presented, the most representative and most common cases encountered in practice of drainage work are.

-   *Temporarily excess moisture with stagnant nature, caused by precipitation*, is specific to farm land with small slopes and local unevenness in humid and subhumid climates with clayey soils hardly permeable. The water balance during periods of excess moisture has the following form:

$$P - ET > S + I + W_{max}$$

where:

P - average annual rainfall;
ET - average annual evapotranspiration;
S - surface water drainage of land;
I - the amount of water infiltrated in the soil profile, below the plant roots;
W_{max} - the maximum amount of water that can accumulate in the soil in the plants root zone.

In practical terms, this formula in a simplified form of soil water balance equation is complete in terms of knowledge of natural factors causing excess moisture in the soil and established necessary drainage work.

In this case, **the excess water volume (Ve)** can be expressed by the relationship:

$$Ve = P - Et - S - I - W_{max}$$

Specific agricultural land of humid and sub-humid climates are located on terraces, high and piedmont plains, highlands and hills: Banat, Crisana, Maramures, Transylvania and the northern Oltenia and Muntenia. However, large areas have been reported in the sub-Carpathian hills of Moldova and in the hard permeable soils of Romanian.

-   *Excess moisture caused by free level ground water*, fed from precipitation, infiltration from rivers, lakes, fish ponds, rice facilities, leaking underground and sometimes loss of irrigation water.

Water balance during periods of excess moisture relation is expressed as:

$$P + Inf + Ir - Et > S + I + W_{max}$$

where:

P - average annual rainfall;
Inf - infiltration from rivers, lakes and other sources;
Ir - loss of water from irrigation systems;
ET - average annual evapotranspiration;
S - surface water drainage of land;
I - the amount of water infiltrated in the soil profile, below the plant roots;
W_{max} - the maximum amount of water that a soil can accumulate in the plants root zone.

In this case, **the excess water volume (Ve)** is the appropriate minimum amount of porosity of aeration required for normal respiration of plant roots, respectively, of aerobic microorganisms.

Agricultural land with excess moisture from the category of soil water balance are commonly encountered in the irrigated or unirrigated territories from the Romanian Plain, more specific soils with good permeability (K> 0.5 m/day). These soils are formed on loess and sandy deposits where the water table is located at medium depths, less than 2-4 m.

- *Excess humidity caused by rain and ground water with high, slightly ascending level*, supplied from precipitation, infiltration from rivers, lakes, fish ponds, rice facilities, underground leaking and others, in low permeable clay soil conditions. Water balance during periods of excess moisture is obtained by the relation:

$$P + Af - Et > S + I + W_{max}$$

where:

P - average annual rainfall;
Af - water intake from the phreatic layer under pressure;
ET - average annual evapotranspiration;
S - surface water drainage of land;
I - the amount of water infiltrated in the soil profile, below the plant roots;
W_{max} - the maximum amount of water that soil can accumulate in the plants root zone.

The agricultural land with this type of moisture excess is common on low land in the Banat, Crisana and Maramures, in internal river meadows and some areas in the Danube.

After the estimated forecast by *National Meteorological Administration* in the coming years is likely to increase the size of the droughts that will occur in alternation with periods of intense rainfall. During relatively short periods of heavy rainfall, flooding will occur quickly in river meadows with different intensities inside and manifestation of excess moisture in the soil.

The effect of increasing average temperatures predicted for the coming years is considered to be more pronounced in areas of the Romanian Plain and less significant in sub-mountainous and mountainous areas of the Carpathian chain.

3. Experimental drainage site - Baia depression

Water excess in soil is a complex process that is determined by some factors like water uptake, circulation and removal in the system soil-subjacent rock. For removing water excess from soil profile, drainage systems were planned for improving soil aeration regime and field cultivation.

For knowing the long-term effect of hydro-ameliorative and soil-ameliorative works, applied under conditions of soil from drainage fields arranged in Baia, was determined the evolution of main eco-soil indicators of unimproved and improved soils.

3.1 Soil genetic conditions

The Baia Depression is located in the Sub-Carpathian Basin of the Moldova River, which is located in Suceava County, Romania. The total area of the Baia Depression is approximately 15,000 ha, 5,000 ha of which have excess soil moisture owing to rainfall or groundwater capillary rise.

The Baia Drain Field has an area of 3 ha and is located on a terrace platform of the Moldova River. The area bends slightly to the southeast and has a longitudinal slope of 2 - 5% and a height of 393 m. The parental material is silty clay with a thickness of 10 - 15 m. As a result, the natural drainage of the soil is weak to very weak. In addition, the groundwater is situated at a mean depth of 9 - 10 m, and the perched water table is located at a mean depth of 0.2 - 0.5 m.

The climate of the study area is continental temperate, with great thermal amplitude and rainfall that occurs primarily in the vegetative season. The rainfall in the study area is generally spread non-uniformly and usually torrential. The mean multiannual temperature from 1978 - 2008 was 7.9 °C, the average rainfall was 806 mm and the average evapotranspiration was 599 mm, with an average water excess of 207 mm.

The vegetation in the study area was composed of a hygrophilous environment that contained an association of *Agrostis tenuis* and a sub-association of *Deschampsia caespitosa*, *Juncus effuzus*, and *Carex sp.*

Evaluation of the study location revealed that the area was characterized by albic stagnic - glossic Luvosol under the *Romanian System of Soil Taxonomy* (Florea et al., 2003) or albeluvisol under the *World Reference Base for Soil Resources* (WRB, 2006).

3.2 Tile drainage experimental variants

To optimize the air and water regime of soil in the area, an experimental field containing a tile drainage system designed to remove excess water was constructed in 1978.

During the study period (1978 - 2010), six different tiles drainage systems (A, B, C, D, E, F) were installed and the effect of the removal of excess moisture from the soil by these systems was evaluated (Figure 1).
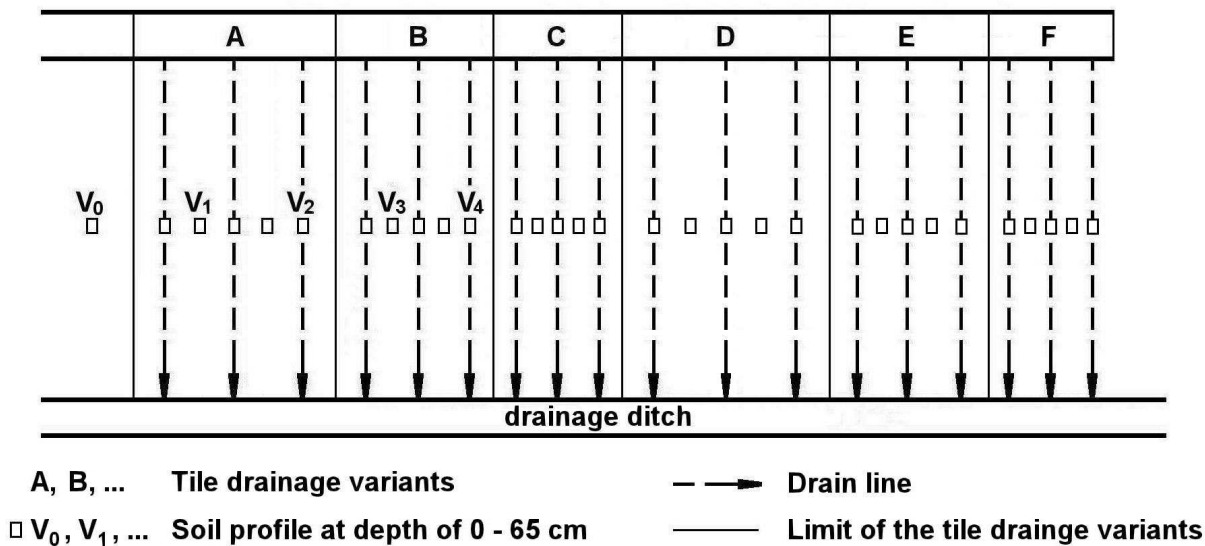

Fig. 1. Hydrotechnical scheme of the Baia drainage experimental site.

Moreover, in variant A, the tile drainage was combined with the land forming in the bedding system with ridges and furrows. In this variant, furrows were constructed upon tile drains with spacing at 20 m. The bedding turning furrows to the middle of a cut to form a ridge that gradually slopes toward deep furrows to ensure good drainage.

Each drainage variant includes three drain lines. The length of each drain was 100 m and the slope of the drain lines was 0.2%.

In variants A, B and C the depth of the tile drains is 1.0 m. The spacing between drains is 20 m in variant A, 15 m in B variant and 12 m in C variant. In variants D, E and F, the depth of the tile drains is 0.8 m. The spacing of the drains is 20 m in variant D, 15 m in variant E and 12 m in variant F.

Hydrotechnical scheme of the Baia drainage experimental site (Figure 1) was sized to optimize the basic design elements, used routinely in the design of tiles drainage systems (Table 1).

Tile drainage variant	Spacing between drain lines /depth drain (m)	Drain line number	Pipe type and diameter (mm)	Type and thickness of complex drain + filter (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

Table 1. Materials used for construction of the Baia drainage experimental site.

- *Spacing between drain lines:* 20 m (variants A and D), 15 m (variants B and E) and 12 m (variants C and F) were determined assuming a non-permanent flow regime.
  In terms of functional efficiency, the spacing between drain lines, should allow lowering the groundwater level from the maximum height to optimum height, within

3-5 days. This lowering of groundwater level in time guaranteed certain plant root zone aeration.

- *The depth of the tile drains:* **1.0 m** (A, B and C variants), **0.8 m** (variants D, E and F) was sized taking into account the horizontal position of the hard permeable soil profile. If the soil is albic stagnic - glossic Luvosol, the Bt_1W textural horizon is located at a depth of 0.9 to 1.0 m.
- *Pipe type and diameter* that was used for the construction of all 18 drain lines included the following materials: *tile drain* (pipe are from ceramic) with inner diameter of 70 mm and 125 mm, tube length of 33 cm with circular inner section and outer section of hexagonal form, *smooth plastic drain* with external diameter of 63 and 110 mm; *corrugated plastic drains* with linear waves and external diameter of 65 mm.
- *Filter material* that was put on top and around the drainage tube consisted of the following: river ballast, and, for some certain drain lines Ballast with flax strains and vegetal soil on the form of green sods.

Under Romania natural conditions the ballast from the river inland meadows is considered al widely used material as a filter in tube drainage works. Filter layer of Ballast has very good drainage effect because of the maintenance of its permeability over the period of operation of the drainage system. Ballast placed around and above the drainage pipes does not compact under soil conditions; it is not degraded by microorganisms in the soil or groundwater chemical action.

Implementation of drainage tubes was performed using E.T.T. 202-A equipment, a mechanic system that performed: digging trenches with a width of 50 cm, variable depth of 0.8 – 1.5 m and laying Tile drainage pipes and / or plastic.

After estimating the cost value of the lei / ha, on the time of implementation of drainage experimental variations has resulted some differentiate constructive solutions. For drain lines: 11/variant D, 2/variant A was the highest assessed values of the cost. Lower cost price values were obtained for the drains: 13/variant E and 12/variant D, depending on dimensional elements and building materials used.

3.3 Improvement procedures

After installation of the tile drainage system, the study area was used for farming.

The drained soil was then improved by applying the three following experimental cycles:

- *Cycle 1* (1978-1986): superficial land forming, cultivation of virgin hygrophilous meadow, deep loosening to a depth of 0 - 70 cm, amendment by the application of 10 - 12 t·ha^{-1} limestone with a content of 95 - 100% $CaCO_3$, organic fertilizing with 40 t·ha^{-1} manure (in variants A, B, C, D, E and F), land forming in the bedding system with a ridge and furrow (only in variant A) once a cycle and annual mineral fertilization (in all variants);
- *Cycle 2* (1987 - 1997): deep re-loosening at the useful depth of 0 - 70 cm, re-amendment of the soil with 7 - 8 t·ha^{-1} limestone, organic refertilization with 40 t·ha^{-1} manure once a cycle and annual mineral fertilization;
- *Cycle 3* (1998 - 2010): no application of soil improvement and/or cropping works.

Crop rotations and plants were cultivated in the following three experimental cycles:

- *Cycle 1*, crop rotation I: maize-two-row barley-potato-flax fibers (1979 - 1982); crop rotation II: (wheat + rye), (maize + potato), maize - potato (1983 - 1986);
- *Cycle 2*, mixture of seeded perennial grasses (70%) and legumes (30%) (1987 - 1990); mixture of perennial grasses (70%) and overseeded legumes (30%) (1990 - 1997);
- *Cycle 3*, overseeded natural meadow (1997 - 2010).

To quantify the changes in the major physical and chemical characteristics of the improved soil in response to the following variations of the drainage treatments described above (Figure 1), at the end of each cycle soil samples from the following treatments were analysed:

V_0 - control variant, natural unimproved meadow (Figure 2);
V_1 - tile drainage combined with land forming in the bedding system variant: top of ridges (Figure 3);
V_2 - tile drainage combined with land forming in the bedding system variant: drain line - furrow cross-section (Figure 3);
V_3 - tile drainage variant: middle of the drain lines (Figure 4);
V_4 - tile drainage variant: drain line cross-section (Figure 4).
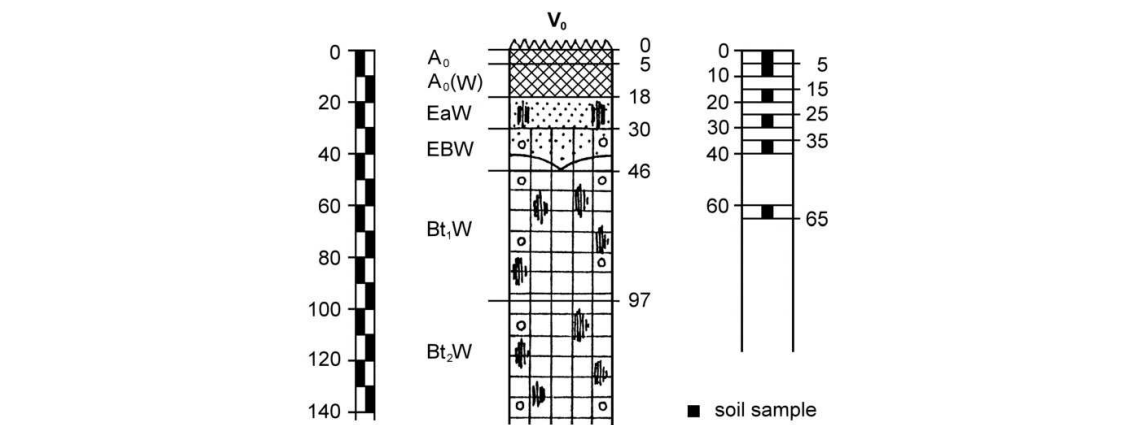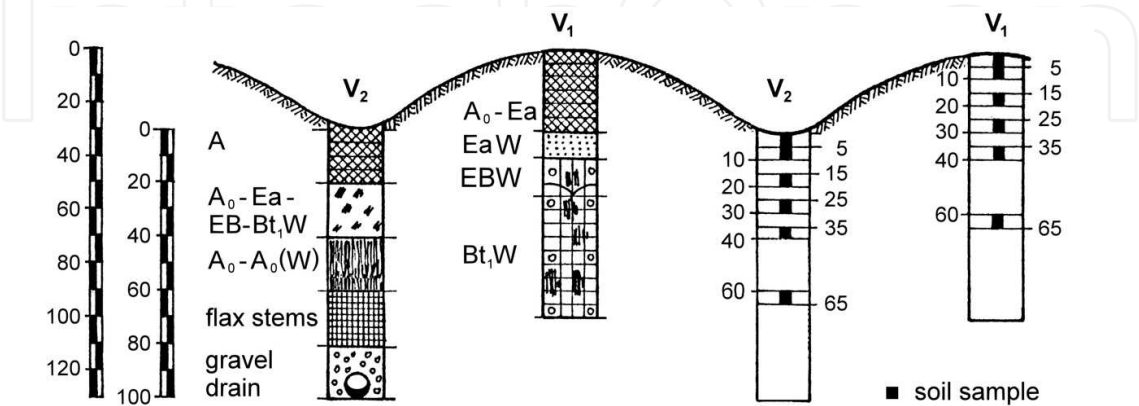

Fig. 2. Soil sampling in the control variant (V_0).

Fig. 3. Tile drainage combined with the bedding system variant - top of ridges (V_1) / furrow (V_2).

The evolution of some physical and chemical features under the influence of the improvements was also analyzed in the three experimental cycles. To accomplish this, soil samples were collected from the ploughed stratum (0 - 20 cm) and the horizon below this layer (20 - 40 cm). Soil samples were collected using an agrochemical drill at the end of each experimental cycle in 1986, 1997 and 2010 from the entire surface of the experimental variants (V_0, V_1 and V_3).
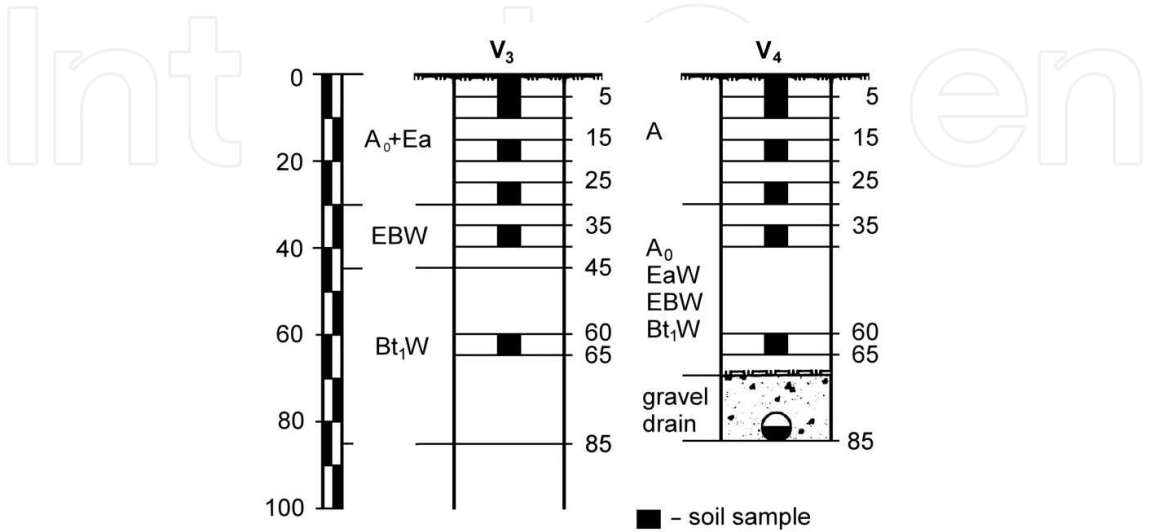

Fig. 4. Tile drainage variant - middle of the drain spacing (V_3) and drain cross-section (V_4).

In the natural conditions of this wetland, the albic stagnic - glossic Luvosol, which is used as a natural pasture, presented the following morphological features in the horizon succession (Figure 2):

A_0 0 - 5 cm - strongly unreclaimed stratum; silt loam; very dark brown grey 10 YR 4/2 (wet) and light grey 10 YR 7/2 (dry); small polyhedral angular structure, moderately developed; very friable in wet state, quite hard in dry state; weakly plastic; weakly adherent; very frequent roots.

A_0 (W)   5 - 18 cm - silt loam; dark greyish brown 10YR 4/2 (wet) and light greyish brown 10YR 6/2 (dry); small polyhedral angular structure, moderately developed, friable in wet state and easily compacted when dry; weakly plastic; weakly adherent; frequent coarse and medium pores; thin and very thin frequent roots; clear contact with the horizon below.

E_aW 18 - 30 cm - silt loam; light olive colour 7.5Y 6/2 with small yellowish brown spots 10 YR 6/6 (wet) and white 7.5 Y 8/2 with yellowish brown mottles 10 YR 6/8 (dry); small polyhedral angular up to lamellar structure, weakly developed, friable in wet state and easily compacted when dry; weakly plastic; weakly adherent; frequent medium pores; rare very thin roots; diffuse irregular contact with the horizon below.

$E+BW$ 30 - 46 cm - clayey loam; greenish gray 5GY 6/1 with small and medium frequent mottles, light yellowish brown 10 YR 6/4 (dry) and white 7.5 Y 8/1 with brown yellowish spots 10 YR 6/6 (dry); medium polyhedral angular structure, moderately developed; clay films on the faces of structural aggregates; small and medium ferromanganese spots and concretions; tough when wet and compacted in dry state; plastic; adherent; frequent pores; diffuse irregular contact with the horizon below.

Bt$_1$W   46 - 97 cm - loamy clay, greenish gray 5GY 6/1 with frequent large yellowish brown mottles 10 YR 5/6 (wet) and light gray 7.5 Y 7/1 with light yellowish brown 10 YR 6/4 and brown-yellowish 10 YR 6/6 mottles (dry); large prismatic structure, moderately developed; coarse clay films on the faces of the structural aggregates; medium ferromanganese spots and concretions; hard in wet state and very compacted when dry; plastic; adherent.

Following placement of the tile drainage system, land was forming in the bedding system and then the soil was cultivated for the first time. In consequence, a mixture between the upper genetic horizons of the soil profile was observed. After the first experimental cycle (1978-1986), the soil from the surface formed in the bedding system presented the following horizon succession (Figure 2 and Figure 3):

A$_0$ + A$_0$ (W) + E$_a$W - (0-30 cm): silt loam;
EaW - 30-40 cm: silt loam;
Ea+BW - 40 - 55 cm: clayey loam;
Bt$_1$W - 55 - 97cm: loamy clay.

In the new conditions of the improved soil, the active physiological depth was greater than that in the unimproved soil. The succession of the horizon morphology revealed that the Bt$_1$W textural horizon is situated at a higher depth when compared to the unimproved soil.

The experimental parcels from the space between the drain lines also showed a mixture of the soil profile upper horizons. The changes inferred were signalled in the depth of the ploughed horizon (0 - 30 cm), and occurred due to the agricultural cultivation works and the deep loosening from the first two experimental cycles (1978 - 1986 and 1987 - 1996). The space between the tile drain lines resulted in the following horizon succession (Figure 4):

(A$_0$ + E$_a$)p - 0 - 30 cm: silt loam;
Ea+BW - 30 - 46 cm: clayey loam;
Bt$_1$W - 46-97 cm: loam clay.

The analysed physical and chemical characteristics of soil sampled in 2010 were determined according to the norms of the *Methodology of soil studies elaboration - National Institute of Research and Development in Soil Science, Agrochemistry and Environment Bucharest* - 1987 and to the *Romanian System of Soil Taxonomy* - 2003.

3.4 Hydrometeorological balance of field drainage pipes

Depending on **annual precipitation (P)** and **annual water consumption by evapotranspiration (ET)** was expressed, on the basis of made observations during the experiment, the annual hydrometeorological balance **(± ΔP = P - ET)**.

- *Annual rainfall regime* (P) was the main source of excess water from the ground, being based on alternation between periods of intense rainfall and, respectively, dry periods in May. Database of observations made on annual rainfall were extracted for the case study examples, from a rainy year (1981), respectively, a dry year (1982).

For wet weather conditions area of north-eastern Romania, was considered as rainy year, 1981, with an annual rainfall of 968 mm fallen (statistical insurance 5%) and the dry year, 1982, with annual rainfall of 742 mm insurance and 80% (Table 2).

The average volume distribution of 855 mm from the years 1981-1982 was 541 mm (63 %) in summer and 314 mm (27 %) in winter.

Year	Annual rainfall (P mm)	Season rainfall distribution (mm)	
		Warm season months (V-X)	Cold season months (XI-IV)
1981	968	592	376
1982	742	489	253
Average	855	541	314

Table 2. Annual rainfall and seasonal distribution in 1981-1982.

- *Average multi-annual rainfall* throughout the period examined in the years 1978-2010 recorded an annual average value of 806 mm (50% assurance).

In terms of annual rainfall distribution and intensity of growing seasons, months and calendar time intervals from one day up to 5 consecutive days of the years 1978-2010 have been reported following characteristics:

- In the hot season (V-X) the annual average year, rainfall was recorded 549 mm (68%), and in winter (XI-IV), 257 mm (32%).
- Average and maximum monthly rainfall recorded multi-annual, usually, recorded the largest amounts of water in June and July and lowest in January-March.
- Rainfall in periods of 1-5 consecutive days were characterized, throughout the study period, by the size and distribution on everyday, 2 days, 3 days and 5 days, depending on the overall progress of the climatic conditions (Table 3).

Month of the year	Monthly precipitation (mm)		Rainfall in consecutive intervals of 1-5 days (mm)							
			1 day		2 days		3 days		5 days	
	average	max.	average	max.	average	max.	average	max.	average	max.
I	33	69.3	12	25.7	16	31.3	18	36.5	20	49.2
II	34	80.2	11	18.9	14	23.2	16	30.0	18	33.5
III	33	63.0	11	25.1	12	25.1	14	25.1	16	28.3
IV	80	12.3	26	41.3	33	53.6	38	65.5	45	79.9
V	97	199.1	32	95.1	43	95.1	46	97.5	50	97.5
VI	133	193.2	49	72.0	65	96.5	78	140.8	89	153.8
VII	133	236.5	40	89.1	51	100.7	54	109.6	62	137.0
VIII	82	186.2	32	43.6	39	81.8	45	118.5	53	158.7
IX	63	125.8	21	37.5	28	59.8	30	59.8	35	66.5
X	41	127.5	16	39.5	21	73.4	21	75.8	24	98.2
XI	41	105.1	18	38.5	23	59.4	24	61.4	26	62.2
XII	36	103.8	12	25.6	16	39.9	17	41.0	20	43.7
Annual	806	-	280	-	361	-	401	-	458	-

Table 3. Multiannual precipitation (1978-2010), average and maximum, monthly and on intervals of 1-5 consecutive days.

- *Annual evapotranspiration regime* (*ET*), ranged between the limits of normal distribution of the wet weather conditions. For the two characteristic years of the climate conditions (1981 and 1982), annual evapotranspiration was 559 mm (1981) and 580 mm (1982), with an average of 569 mm. Distribution of mean annual evapotranspiration for the two growing seasons of the year difference between the value of 517 mm (91%) in the warm season, respectively, 52 mm (9%) in cold season of the year (Table 4).

Year	Annual evapotranspiration (Et mm)	Seasonal distribution of evapotranspiration (mm)	
		Warm season month (V-X)	Cold season month (XI-IV)
1981	559	505	54
1982	580	529	51
Average	569	517	52

Table 4. Annual and seasonal evapotranspiration in years 1981 - 1982.

- *Average annual evapotranspiration regime* throughout the period examined in the years 1978-2010 recorded an average of 599 mm per year which varied in size according to the general trend of climatic factors and the use of agricultural land.
- Distribution of average annual evapotranspiration (1978-2010) on the two growing seasons, differentiate significantly separately. In the warm season (V-X), which corresponded to wet land with vegetation period of crops, has developed a water consumption of 481 mm, which means 80% of annual average. In winter (XI-IV), evapotranspiration recorded in terms of annual average, water consumption of 118 mm, which is 20%.
- Average monthly evapotranspiration was characterized by maximum values during the months of summer season with a 90-142 mm consumption, small to medium in the months of spring - autumn, with a consumption of 1-76 mm and negligible values months of winter.
- Evapotranspiration and diurnal periods of up to 3-5 consecutive days, was typically, below the rainfalls in these intervals, which resulted in a surplus in the hydrometeorological water balance.
- The amount of excess water with other natural factors contributed to the formation and maintenance of the soil profile or on the land of excess rainfall from moisture.
- *Annual hydrometeorological regime balance* ($\pm \Delta P = P - Et$) registered in terms of the years 1981 to 1982 an average surplus of 286 mm, 162 mm annual distribution in 1982 and 409 mm in 1981 (Table 5) .

Year	Annual hydro-meteorological balance				Warm season months (V-X)				Cold season months (XI-IV)			
	P (mm)	Et (mm)	$\pm \Delta P$ (mm)		P (mm)	Et (mm)	$\pm \Delta P$ (mm)		P (mm)	Et (mm)	$\pm \Delta P$ (mm)	
			+	-			+	-			+	-
1981	968	559	409	-	592	505	87	-	376	54	322	-
1982	742	580	162	-	489	529	-	40	253	51	202	-
Average	855	569	286	-	541	517	44	20	314	52	262	-

Table 5. Annual hydro-meteorological balance and seasonal distribution in 1981-1982.

Distribution of surplus and/or water deficit equation from annual hydrometeorological balance individualized only by excess water in 1981, respectively by excess and water deficit in 1982. The distribution of the two seasons average surplus of 286 mm to 262 mm difference between the value (92%) in winter and 24 mm (8%) in summer.

- *Hydrometeorological annual average regime balance* of the period under review (1978-2010) recorded a surplus of 207 mm water, characterized by the following features on the seasons, months and characteristic times of the year.
- Distribution of the two growing seasons of the year differed between 139 mm (67%), in the hot season of the year annual average and 68 mm (33%) in winter.
- Annual distribution of water surplus resulted from the hydrometeorological balance was characterized in terms of environment, positive in almost all months of the year.
- The average values of the determined period were employed between 0-11 mm minimum quantities, made in July, September and October and 31-40 mm maximum on the other months of the year, except August.
- In terms of climate, we can say that the August register, usually an average deficit of 11-20 mm, offset by reserves of water stored in soil in winter. In this context, water scarcity may be an example of 40 mm was recorded in August of 1982, considered a dry year.

3.5 Technical efficiency of the experimental drainage variants

3.5.1 Periods of drainage system operation

In periods of drainage operation with non-permanent flow regime, rainfalls volume (P) exceeded the water consumption by evapotranspiration (Et), deep infiltration (I) and drain the land surface (S). In periods of excess water removal (ΔP), drained soil is working functionally as a reservoir, which records under the effect of heavy rains filling, respectively, depletion under the effect of drainage.

To characterize evolution of climatic factors that determine the hydro-meteorological balance and proper functioning of pipe drainage are presented the observations from the operation of drainage tubes in the years 1981-1982 (Table 6).

- Hydrometeorological balance, that helped triggering the operation of the drainage system with pipes, had on given weather conditions between 1981-1982, the following significant issues:
- Excess water (ΔP) derived from annual hydrometeorological balance recorded 625 mm in 1981 and 401 mm in 1982. This water surplus caused the total filling of the lacunar space of soil, which led to its discharge in the drainage tubes system.
- Dynamics of water surplus recorded in intervals of drainage operation was located, under review conditions, between the minimum values of 1-4 mm and maximum of 102-113 mm.
- The functioning duration of drainage pipes of periods with water surplus totaled from 2 days to 20 consecutive days, as determined by the volume, duration and intensity of rainfalls.

3.5.2 Specific drainage flows

To characterize the dynamics of drainage specific flows, first were analyzed the observations from climatic conditions in 1981 and 1982. In periods of operation of drainage mentioned in

Year	Drainage period	Number of days	Hydrometeorological balance		
			P (mm)	Et (mm)	+ΔP (mm)
1981	3-17 II	14	70	1	69
	9-29 III	20	100	10	90
	27-30 IV	3	22	7	15
	6-18 V	12	135	22	113
	21-24 V	3	18	6	12
	10-19 VII	9	90	38	52
	21-25 VII	4	22	18	4
	27-31 VII	4	53	16	37
	1-4 VIII	4	47	18	29
	16-19 IX	3	60	6	54
	21-30 XI	9	105	3	102
	7-15 XII	8	20	-	20
	16-31 XII	15	28	-	28
	Annual	108	770	145	625
1982	12-31 III	20	122	10	112
	1-5 IV	4	3	2	1
	19-24 IV	5	20	5	15
	28-30 IV	2	40	3	37
	1-5 V	5	20	4	16
	15-22 VI	7	108	25	83
	25-29 VI	4	22	14	8
	1-3 VII	2	24	8	16
	11-22 VII	11	95	46	49
	23-25 VII	2	21	10	11
	26-31 VII	6	56	21	35
	1-10 VIII	9	50	32	18
	Annual	77	581	180	401

Table 6. Operating periods of drainage tubes in the years 1981 - 1982.

the previous paragraph, specific drainage flows (q) expressed in l/s and ha for each drain line were characterized, generally, depending on specific factors.

Specific flow drainage dynamics was analyzed depending on the size of the excess rainwater and drainage lines efficiency, respectively, on the average assessed for the six experimental drainage variants (A, B, C, D, E and F). Also, tube drainage operation was highlighted both in terms of association with land shaping in the bedding system with ridges and furrows (variant A) and, respectively, aeration soil to a depth of 50-60 cm on average (variants B, C, D, E and F). In the early hours of operating periods of pipes drains were measured, typically, maximum flow, which measure on the evolution of precipitation increases and/or continuity of the excess volume of water till minimum values.

Specific flow regime of pipe drains drainage tubes was characterized on the base of volumetric flows measured 2-3 times daily, on the discharge place of each drain, in drainage operation during the years 1981 and 1982 (Table 7).

Variant and spacing between drain lines /depth drain (m)	Drain line number	Specific drainage flow q (l·s⁻¹·ha⁻¹)								
		Maximum extreme flows			Annual maximum average flows			Annual average flows		
		1981	1982	Average	1981	1982	Average	1981	1982	Average
A 20/1.0	1	5.17	4.87	5.02	1.89	1.25	1.57	0.63	0.31	0.47
	2	5.77	5.17	5.47	1.55	1.37	1.46	0.49	0.32	0.41
	3	5.00	4.84	4.92	1.46	1.21	1.34	0.48	0.30	0.39
	Average	5.31	4.96	5.14	1.63	1.28	1.46	0.53	0.31	0.42
B 15/1.0	4	2.98	4.44	3.71	0.95	1.27	1.11	0.36	0.33	0.35
	5	2.90	3.92	3.41	0.99	1.25	1.12	0.36	0.32	0.34
	6	2.86	4.26	3.56	1.02	1.30	1.16	0.36	0.32	0.34
	Average	2.91	4.21	3.56	0.99	1.27	1.13	0.36	0.32	0.34
C 12/1.0	7	3.85	6.25	5.05	1.30	1.80	1.55	0.48	0.41	0.45
	8	3.97	5.95	4.96	1.39	1.74	1.57	0.48	0.42	0.45
	9	4.17	6.58	5.38	1.38	1.66	1.52	0.48	0.46	0.47
	Average	4.00	6.26	5.13	1.36	1.73	1.55	0.48	0.43	0.46
D 20/0.8	10	2.50	4.17	3.34	0.87	1.24	1.06	0.31	0.29	0.30
	11	3.13	3.49	3.31	0.95	1.15	1.05	0.33	0.28	0.31
	12	2.94	3.20	3.07	0.96	1.01	0.99	0.33	0.27	0.30
	Average	2.86	3.62	3.24	0.93	1.13	1.03	0.32	0.28	0.30
E 15/0.8	13	4.00	5.41	4.71	1.23	1.69	1.46	0.44	0.41	0.43
	14	3.33	5.71	4.52	1.22	1.51	1.37	0.42	0.40	0.41
	15	4.00	5.13	4.57	1.32	1.59	1.46	0.45	0.37	0.41
	Average	3.78	5.42	4.60	1.26	1.60	1.43	0.44	0.39	0.42
F 12/0.8	16	4.55	6.10	5.33	1.48	1.80	1.64	0.54	0.43	0.49
	17	4.55	6.76	5.66	1.61	1.93	1.77	0.60	0.46	0.53
	18	4.17	6.07	5.12	1.31	1.73	1.52	0.53	0.40	0.47
	Average	4.42	6.31	5.37	1.47	1.82	1.64	0.56	0.43	0.50

Table 7. The specific drainage flows in 1981-1982.

- *The maximum extreme flows*, measured in the first functioning hours of drainage under the conditions of the 18 drains lines showed obvious differences. In terms of the year 1981, measured flows were hierarchized between 2.50 l· s⁻¹ and ha (drain 10/variant D) and 5.77 l· s⁻¹ and ha (drain 2/variant A), and in 1982 from 3.20 l· s⁻¹ and ha (drain 12/variant D) and 6.76 l· s⁻¹ and ha (drain 17/variant F).

- *Annual maximum average flows* were individualized on the 18 line pipe drains between the minimum value of 0.87 l· s⁻¹·ha (drain 10/variant D) and a maximum of 1.89 l· s⁻¹·ha (drain 1/variant A), during operation of drainage in 1981. There is a similar dynamic in terms of 1982, with a variation of this flow from 1.01 l· s⁻¹·ha (drain 12/variant D) and up to 1.93 l· s⁻¹·ha (drain 17/variant F).

- *Annual average flows,* that were expressed on the basis of all measurements from the 108 days in 1981 and 77 days in 1982 showed also, functional technical efficiency of solutions designed in the 18 lines of drainage.

Mean annual specific drainage flows were correlated with the size of maximum flow and maximum annual extreme, both for individual conditions of drains, and also for the estimated average experimental version of drainage lines consisted of three drains lines. Thus, in 1981 the annual average flows ranged from 0.31· s⁻¹·ha (drain 10/variant D) and 0.63 · s⁻¹·ha (drain 1/variant A) and in 1982, from 0.27· s⁻¹·ha (drain 12/variant D) and 0.46· s⁻¹·ha (drain 17/variant F).

- *Technical efficiency of drainage variants*, depending on the size of the specific flows highlighted the following issues relevant to the experimental cycle:
- The size of discharged flows showed a higher efficiency of drains to the distance between them 12 m and average depth of 0.8 m and 1.0 m (F and C variants), who drained a 20% to 70% more, compared to variants with distance between drains of 15 m and 20 m.
- Association of the pipe drainage with the soil shaping combined with the bedding system at the same distance of 20 m (variant A) provided a capture and efficient evacuation of excess water, comparable to the distance between drains variant F 12 m and average depth of 0.8 m.
- The usage of a filter layer as a prism with dimensions of 20 x 70 cm was achieved from Ballast and flax strains on drained 1/A, and from ballast on drain 2/A, ballast layer with a thickness of 20 cm, on drained 3/A did not show a high functional efficiency.
- The increase of the distance between the drains or drain depth settlement resulted in a reduction of debts discharged, except association of pipe drainage tubes with land shaping in the bedding system with ridges and furrows (variant A).

3.5.3 Drained water volumes

Depending on the size of specific drainage daily flow of the area served by the drainage lines (1-18) and experimental drainage variants (A-F) volumes of drained water were calculated, expressed in mm or m³·ha⁻¹. To calculate the volume of drained water areas were used areas of 0.60 ha (variants A and D), 0.45 ha (variants B and E), and 0.36 ha (variants C and F).

- *Average annual volumes of drained water* (Table 8), in the excess water conditions during 1981 and 1982 showed a differentiated technical efficiency, first drain lines respectively arranged on the six variants, as follows:
- The individual efficiency of the component drains of the network drainage was illustrated by the size of drained water volumes, which ranged from 232 mm (2320 m³/ha) for drain 12 / D and maximum of 406 mm (4 060 m³/ha) for drain 1 / A, associated with land shaping in the bedding system with ridges and furrows.
- Operational efficiency of the experimental variants, depending on the size of individual volumes of component drains was noted by a reduced capacity for variant D (20/0.8 m) with a drain rate of 245 mm (2450 m³·ha⁻¹) and better under variant F (12/0.8 m), which achieved a 368 mm drained rate (3680 m³·ha⁻¹).
- *Technical efficiency of drainage variants*, depending on the size of the drained water volumes was materialized through the following significant features:
- Operating mode of the drains lines is dependent on seasonal rainfall distribution and consumption of water by evapotranspiration.

Spacing between drain lines /depth drain (m)	Drain line number	The annual volume of drained water (mm)			Seasonal distribution of drained water volumes (mm)					
					Warm season (V-X)			Cold season (XI-IV)		
		1981	1982	Average	1981	1982	Average	1981	1982	Average
A 20/1,0	1	583	229	406	202	102	152	381	127	254
	2	469	211	340	185	110	147	284	101	192
	3	395	178	287	166	82	124	229	96	163
	Average	482	206	344	184	98	141	298	108	203
B 15/1,0	4	359	207	283	143	114	128	216	93	155
	5	360	205	283	142	111	126	218	94	156
	6	352	192	272	144	98	121	208	94	151
	Average	357	201	279	143	107	125	214	94	154
C 12/1,0	7	456	273	364	177	142	159	279	131	205
	8	453	273	363	175	139	157	278	134	206
	9	433	248	341	164	117	140	269	131	200
	Average	447	265	356	172	133	152	275	132	204
D 20/0,8	10	310	189	249	125	100	112	185	89	137
	11	327	183	255	128	100	114	199	83	141
	12	324	139	232	134	69	101	190	70	130
	Average	320	170	245	129	90	109	191	80	136
E 15/0,8	13	432	258	345	171	137	154	261	121	191
	14	440	240	340	177	118	148	263	122	193
	15	430	239	335	169	122	145	261	117	189
	Average	434	246	340	172	126	149	262	120	191
F 12/0,8	16	457	279	368	182	148	165	275	131	203
	17	482	296	389	196	155	176	286	141	214
	18	428	265	347	171	136	154	257	129	193
	Average	456	280	368	183	146	165	273	134	203

Table 8. Drained water volumes regime in 1981-1982.

- Maintenance of the same spacing between the drain lines of 12 m or 15 m and increase of the depth of drains from 0.8 m to 1.0 m contribute in reducing the excess capacity of water interception by an average of 3% for a distance of 12 m (variant F to variant C) and 22 % for distance of 15 m (variant E to variant B).
- Drained soil aeration to an average depth of 50-60 cm resulted in an improvement in rainfall interception excess water by about 2-9%, according to the first two lines of drains (B, C, D, E, F variants) than the unaerated surface soil of the third drain.
- Average volumes of drained water from the corresponding size of the excess moisture from rainfall from 1981 and 1982, on the 6 variant were distributed among the 48% efficiency (variant D) and up to 72% (variant F).
- Drained water volumes were found in large quantities during the cold season (XI -IV) and lower in the warm season of the year (V -X).
- The exploitation behaviour of the drainage lines of the experimental variants, showed an increase in water drained in variants when the distance between drains variants was 12 m and average depth of 0.8 m or 1.0 m.

3.5.4 The capture capacity of drain pipes

The excess stagnant water from the surface of the field and/or as pedophreatic water in the upper part of the soil structure must be evacuated in a relatively optimal period of time.

Before the descendent water current from the soil structure gets into the drain pipe it encounters a series of resistances that in general depend of the following natural factors and arrangement conditions:

- the permeability of the soil arranged with pipe drainage works;
- the permeability of the soil in the cross-sections of drain lines;
- the type and thickness of complex drain + filter;
- the pipe type and diameter;
- the distribution and the surface of the joints / perforations that allow the water to enter into the drain pipes.

According to *van Someren (1964)*, the total energy losses in pipes (Δh) that are due to the resistances that appear when the water enters the drain pipe and that is measured at the middle of the distance between the drains, can be divided into the following three categories.

- *Horizontal energy losses (Δh_0)* that are to the resistances encountered by the water current at the passage through the soil, up to approximately 1.0 m away from the drain pipe.
- *Radial energy losses (Δh_r)* that is due to the convergence of the water current lines, from the immediate area of the drain pipe.
- *Entrance energy losses (Δh_i)* that are determined by the resistances encountered by the water current when entering into the drain pipe.

For the water current to enter into the drain pipe, the total energy losses *(Δh)* from the middle of the spacing between the drain lines must be higher than the sum of the partial energy losses:

$$\Delta h > \Delta h_0 + \Delta h_r + \Delta h_i$$

The studies made on the *total energy losses (Δh)*, under the conditions of a non-permanent regime were analyzed in the hypothesis of knowing the period of time (t days) in which the water level must be lowered from the maximum height (h_0) to the minimum height (h_t).

The effect of the total energy losses ($\Delta h = h_0 - h_t$) was followed in the piezometric pipe situated at the middle of the spacing between the drain pipes, with the distance between them of 12 m and the medium depth of 0.8 m. At different periods of time (t), the total energy loss was represented, in general, by the decrease of the excess water level at the maximum height of the depression curve of 60 - 70 cm, the best height of 15 - 20 cm. At the same periods of time (t) the drained flows decreased from 9 - 10 l/minute to 0.1 l/minute.

- *the factor of the draining intensity* ($a = \dfrac{1}{J}$) was determined in the base of the measured

   levels in the piezometer from the middle of the spacing between the drain lines, at the beginning and the end of the draining's functioning periods, with the help of the following relation:

$$a = \frac{1}{J} = \frac{2.3\left(\log h_o - \log h_t\right)}{t}$$

where:
a - factor of the draining intensity (days^{-1})
h_o - maximum height of the pedophreatic water level
h_t - minimum height of the pedophreatic water level
t - period of time (days).

Depending of the amount of rain that fell, that in periods of 3 - 5 consecutive days, registered values of up to 60 - 140 mm, there were differentiated as well the values of the intensity draining factors. So, depending of the *total energy losses* (Δh), after the previously mentioned rains, the values of the draining intensity were of 4 - 6 days, during the hot season, and of 6 - 14 days, during the cold season (Table 9).

Time (t)	The height of the depression curve at the middle of the spacing between the drain pipes		Total energy losses	Factor $a = \frac{1}{J}$	Coefficient $J = \frac{1}{a}$
days	h_0 (mm)	h_t (mm)	Δh (mm)	days $^{-1}$	-
5	690	300	390	0.167	6.0
7	660	200	460	0.171	5.8
5	620	290	330	0.152	6.6
4	620	270	350	0.208	4.8
5	620	190	430	0.236	4.2
11	520	240	280	0.070	14.3
2	380	250	130	0.209	4.8
4	320	200	120	0.117	8.5

Table 9. The draining intensity factor depending of the total energy loss.

- *the filtration coefficient (K)* was characterized by a very good permeability, in the arable layer of 0 - 25 cm (K = 3.2 m·day^{-1}), fact that assured the high degree of efficiency of the process of draining the excess water. In the case of the underlying horizon that was analyzed for the depth of 25 - 65 cm, the permeability was lower (k = 0.2 m·day^{-1}), fact that determined the execution and the periodical renewal of the soil loosening process until the necessary depth of 70 - 80 cm.
- *the draining porosity* was correlated with the values that resulted in the case of the filtration coefficient, being characterized by medium to high values of 44 - 54 % of the arable layer (0 - 25 cm) and by small values of 2 - 6 % in the underlying layer of 25 - 65 cm.

Pores larger than 10-30 μ form the drainage porosity, usually occupied by air, but through which is drained by way of infiltration the water excess. The 30 μ diameter is found in sandy soils and the 10 μ in the medium and coarse textured soils. Utile porosity includes medium-sized pores with a diameter between 0.2 and 10 to 30 μ, which are able to retain either air or mobile water accessible to plants. Inactive porosity includes smaller pores, with diameters under 0.2 μ, which retain the water inaccessible to plants (Canarache, 1990). Drained porosity, utile porosity and inactive porosity are the basic components of total porosity. The

variation of these three components characterizes the soil compaction condition according to the determining factors. For organic and organo-mineral soils, favourable conditions exist when the drained porosity is greater than 20%; however, this requires installation of a drainage system (Canarache, 1991).

3.5.5 The behaviour during the use of draining pipes

In the case of the soils with excessive rain water, the functioning system of the drain pipes is determined by the size and the aleatory distribution of the rain water quantity. In a series of successive periods of time water excess appears in the soil and/or on the surface of the soil, excess that must be evacuated through a drainage system.

The evaluation of the water survey in the conditions of the existent *18 draining lines* (1, 2, 3, …., 18) and respectively, of the *six experimental drainage variants* (A, B, C, D, E and F) was analyzed taking into consideration the long time observations that were realized on the following factors:

- the daily precipitations;
- the average daily temperature of the air;
- the real maximum daily evapotranspiration;
- the daily water flow evacuated by drain pipes;
- the water volumes evacuated by drainage network.

The annual dynamic of the climatic factors from the period 1978 - 2010 that was also presented in the previous paragraphs respected the characteristics of the areas from the wet climate area of Romania, area that includes the Baia Depression as well.

The synthesis of the results obtained during the entire period of time when pipes drain experiments were made, can be characterized according to the annual and the seasonal dynamic of the climatic factors and the functional efficiency of the drainage system, as follows:

- *The multiannual precipitation regime* - it was characterized by a medium quantity of 806 mm, with an annual distribution between the maximum quantity of 968 mm (1981), with a 5 % assurance, and the minimum quantity of 455 mm (1986), with a 95% assurance.
- *The real maximum evapotranspiration,* having a medium multiannual value of 599 mm situated between the limits of the normal distribution from the wet areas.
- *Effective water surplus* that resulted from the equation of the water survey from the drained soil, from the periods of time the drainage system with pipes worked registered a medium multiannual value of 325 mm or 3250 $m^3 \cdot ha^{-1}$ (Table 10).
- *The medium volumes of drained water* differentiated, in general, according to the dimensional elements and the nature of the construction materials used at the draining system. In the conditions of the equipping the 18 draining lines, the maximum norm of drained water 2070 $m^3 \cdot ha^{-1}$ (64 % of the medium water excess) was reached at the drain 17/variant F. The minimum norm of 1110 $m^3 \cdot ha^{-1}$ was found at drain 12/variant D with the distance between the drains of 20 m and the medium depth of the pipes of 0.80 m (Table 10).

- *The medium daily water flow* was individualized between the maximum values of up to 3.5 mm·day^{-1} (drain 17/variant F) and the minimum values of 1.8 mm day^{-1} (drain 12/variant D), according to the materials that were used and the dimensional elements of the drainage system (Table 10).

Variant and spacing between drain lines /depth drain (m)	Drain line number	Pipe type and diameter (mm)	Surface of the pipes joints / perforations (cm^2·m^{-1})	Drained soil water balance			
				Mean water excess (m^3·ha^{-1})	Mean drained water		Mean daily water flow (mm·day^{-1})
					m^3·ha^{-1}	%	
A 20/1,0	1	Tile Ø 70	10-15	3250	1830	56	3.0
	2	Tile Ø 125	13-20		1610	50	2.7
	3	Tile Ø 70	10-15		1390	43	2.3
	Average		-	-	1610	50	2.7
B 15/1,0	4	Tile Ø 70	10-15	3250	1370	42	2.3
	5	Tile Ø 70	10-15		1460	45	2.4
	6	Tile Ø 70	10-15		1440	44	2.4
	Average		-	-	1423	44	2.4
C 12/1,0	7	Corrugated plastic Ø 65	15-30	3250	1870	58	3.1
	8	Smooth plastic Ø 63	15-30		1850	57	3.1
	9	Tile Ø 70	10-15		1770	55	2.9
	Average		-	-	1830	57	3.0
D 20/0,8	10	Corrugated plastic Ø 65	15-30	3250	1260	39	2.1
	11	Smooth plastic Ø 110	30-40		1360	42	2.3
	12	Tile Ø 70	10-15		1110	34	1.8
	Average		-	-	1243	38	2.1
E 15/0,8	13	Tile Ø 70	10-15	3250	1800	55	3.0
	14	Tile Ø 70	10-15		1840	57	3.1
	15	Tile Ø 70	10-15		1790	55	3.0
	Average		-	-	1810	56	3.0
F 12/0,8	16	Corrugated plastic Ø 65	15-30	3250	1900	58	3.2
	17	Smooth plastic Ø 63	15-30		2070	64	3.5
	18	Tile Ø 70	10-15		1750	54	2.9
	Average		-	-	1907	59	3.2

Table 10. The regime of the volumes of drained water in the period 1978 - 2010.

From the analysis of the functional efficiency of the experimented draining variants that were analyzed during the entire period of exploitation, results the following:

- The growth of the drains depth from 0.8 to 1.0 m and keeping the spacing between the drain lines to a constant level of 12 m contributed at the decrease of the functional efficiency of the drainage system, with an average of 11 %.
- The growth of the spacing between the drain lines from 12 to 20 m and keeping of the drains depth at 0.80 m determined a decrease of the functional efficiency, with an average of 16%.
- The surface of the drain pipes joints / perforations determined the growth of the functional efficiency, with an average of 11 - 12 % (drain 17), in relation to drain 18 when the spacing between the drains was of 12 m and the medium depth was of 0.80 m (variant F).
- The association of the pipe drainage system with the land shaping in the bedding system with ridges and furrows, with an average of 23 % (variant A).

3.6 Classification and qualitative evaluation of soil

Soil-field mapping units, considered ecologically homogeneous, were established between the limits of the *six experimental* (Figure 1) plots arranged for subsurface drainage, having the following useful areas: 0.60 ha (A and D); 0.45 ha (B and E); 0.36 ha (C and F).

The calculation of classification notes for crops was done according to the 17 eco-soil indicators of natural conditions for unimproved soil and, respectively, of the conditions for drained, improved and cultivated soil. According to the classification marks, established for each plot of the two plots, we gave the average mark per uses and crops of the control plot and of the drainage plot.

In the case of quality classes, the classification marks were grouped from 20 to 20 marks: I (81-100 points); II (61-80 points); III (41-60 points); IV (21-40 points); V (0-20 points).

- *Classification and qualitative evaluation of unimproved soil*

Under soil genetic conditions of the microclimate from the Baia Depression, with a *lower mean annual temperature* (7.9°C), early frost and late thawing, at which higher *mean annual rainfall* are added (806 mm), frequently stagnant water excess takes place on the field surface, at different periods of the year.

Among the important limitative factors of the production that were found in the natural conditions of albic stagnic-glossic Luvosol, used as "*hygrophilous natural meadow*", we noticed the following: stagnant moisture excess, soil acidity, soil compaction, low humus content.

Soil texture is dusty-loam at the depth 0-20 cm, and then it becomes average loam-clayey, in the subjacent layer 20-40 cm and clayey-loam deep in the soil.

Total porosity was generally correlated to the clay content (< 0.002 mm), being characterized by equal values of 52-65 % at the depth 0-20 cm and respectively, 44-47 % at the depth 20-40 cm.

Soil response is moderately acid at depth 0-40 cm.

Base saturation degree (V_{Ah}) is found within the oligomesobasic limits of 40-70 %.

The humus content has recorded relatively high values until 194-199 t·ha^{-1} in the layers 0-5 and 5-18 cm. In the next two horizons EaW (18-30 cm) and EBW (36-40 cm), the humus reserve decreases once with depth until very low values.

The classification of farm field for the above-mentioned soil genetic conditions and actual use of "*hygrophilous natural meadow*" led to average classification marks of 39 points (Table 11).

Soil unit	Soil unit area (ha)	Agricultural use and crops	Classification note	Quality class
Unimproved albic stagnic-glosic Luvosol	3.0	Pastures	42	III
		Hayfield	35	IV
		Average field meadows	39	IV
		Wheat	10	V
		Barley	9	V
		Maize	9	V
		Potato	10	V
		Flax	14	V
		Alfalfa	26	IV
		Average arable land	13	V

Table 11. Field classification for the natural conditions of the control plot- Baia Depression.

In the case of using albic stagnic-glossic Luvosol as arable land, we have evaluated the suitability of the first six crops in the wet climatic area. The average classification marks comprised between 9 points (barley and maize) and 26 points (alfalfa) led to an average of the control plot of 13 points.

The natural soil classification has shown the following defaults: water stagnation at field surface, soil stagnogleyzation, soil-ground water depth and soil acidity and compaction.

- *Classification and qualitative evaluation of improved soil*

By planning the subsurface drainage and applying agro-soil ameliorative works, we noticed a significant improvement of the general physical and chemical condition of the drained soil.

Soil texture was dusty-loam at the depth of 0-20 cm, while at the depth of 20-40 cm it was dusty clayey-loam, because of the mixture between genetic horizons, after soil loosening and cultivation works.

Total porosity with values between 50 and 55 %, at depths 0-40 cm, has shown a weak soil loosening after the three exploitation cycles.

Soil acidity was maintained within the limits corresponding to moderately acid to weakly acid soils, because of the long-term effect of limestone applied in 1978 and 1988.

Base saturation degree (V_{Ah}) was maintained in the first two cycles (1978 - 1986 and 1986 - 1997) between the limits of 71-90 %, moderately mesobasic. In 2010, the base saturation degree of 48-53 %, corresponding to the extremely oligomesobasic field, required limestone amendment.

Humus content that was determined after the 32-year exploitation periods, pointed out the effect of intense mineralization of humic substances.

By the application of controlling moisture excess works, the "*increase*" of classification marks of natural conditions was done.

Thus, we mention the diminution of defaults determined by classification coefficients for average annual rainfall, stagnant moisture excess and soil stagnogleyzation.

Agro-soil ameliorative works have also contributed to the "*increase*" of classification marks for the favourable correction of soil response, total porosity and organic matter content from soil. For the increased conditions of using soil for "*pastures and hayfields*" there were good average classification marks of 79-88 points, with an average of the drainage plot of 84 points that framed the improved farm field in the first quality class, with a very good fertility (table 12).

Soil unit (SU)	SU area (ha)	Agricultural use and crops	Classification note	Quality class
Improved albic stagnic-glossic Luvosol	2.82	Pastures	88	I
		Hayfield	79	II
		Average field meadows	84	I
		Wheat	57	III
		Barley	50	III
		Maize	56	III
		Potato	61	II
		Flax	79	II
		Alfalfa	81	I
		Average arable land	64	II

Table 12. Field classification for the increased conditions of the drainage field-Baia Depression.

The use of the improved soil as "arable field" framed the drained field between the average classification marks of 50 points for barley and until 81 points for alfalfa. The average of the classification marks of the drainage group for the first six crops of 64 points framed the use as "arable field" in the second quality class with a good fertility.

4. Conclusion

Sustainable development of the agricultural area of Romania requires a balance between economic growth and environmental protection, depending on soil quality and the strategy of exploitation for land fund.

Comprehensive soil studies in Suceava County, on an area of 398,771 ha has allowed for classification of soil in ten classes and nineteen types of soil. Among the limiting factors of agricultural growth in the natural sol-units, one can mention: excess moisture, erosion by water, acidity, flood hazard, soil compaction and low permeability soils.

Excess moisture of pluvial nature and/or from groundwater, plus the overflowing of hydrographic networks, showed up in various forms and intensities on a surface of 185,316 ha, which represents 21.7% of the total area of Suceava County.

The diversity of natural conditions and the intrinsic characteristics of soil resources have determined a condition of middle to poor quality and suitability of the soil-units for agricultural use. In accordance with the specific requirements for soil crust improvements, in time were laid out a succession of hydro-ameliorative works.

Among these types of works, there can be emphasized the systems with ditches on a surface of about 55,000 ha and the pipes drainage on approximately 27,000 hectares, comprised in 20 large and local systems.

In order to increase the quality of the countryside and to promote sustainable farming systems, one has to protect the soil through both, the rehabilitation and / or extension of the existing barren hydro-ameliorative works, as well as by resizing the plots of the agricultural exploitations.

The pipe drainage system with spacing between drain lines of 12 - 15 m and of maximum 20 m resulted to be an efficient solution for the proper evacuation of excess water.

The process of removal of the excess water from the surface of the soil and/or within the soil, water that resulted from the rainfalls of 40 - 160 mm, which fell in periods of 1 - 5 consecutive days, was made in the conditions that were studied with the specific water flow of 1.5 - 2.5 $l \cdot s^{-1} \cdot ha^{-1}$.

The growth of the spacing between the drain lines with up to 20 - 30 m must be associated to the agro- and soil improvement: periodically deep loosening works, mole drainage and land shaping in the bedding system with ridges and furrows.

Classification and evaluation of soil quality for usages and crops is the database of qualitative farm cadastre at the level of soil-field mapping units of soil.

For the natural conditions of albic stagnic-glossic Luvosol from the Baia Depression, we have estimated an average classification mark of 39 points for grasslands and hayfields and of 13 points for the arable land, with extremely severe limitations caused by water excess.

By the arrangement of the farm field for water excess removal and the corresponding application of agro-soil ameliorative works, we have achieved the "increase" of some classification indicators, obtaining an average mark of 84 points for "improved pastures" and 64 points for "arable land".

5. Acknowledgment

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Edited by Prof. Muhammad Salik Javaid

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