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INCREASING IRRIGATION EFFICIENCY AND SOIL PROTECTION BY REUSING EXCESS WATER USING THE CLOSED DRAINAGE TECHNIQUE

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Abstract

Elaborating this paper, the authors took into account previous research that highlighted the following: Romania falls into the category of countries with modest exploitable water resources; over 85% of the arable land arranged with irrigation works is fragmented in small plots; soil water deficit is the most important risk factor in agriculture. Watering efficiency depends on the watering method; sprinkling is the main watering method; the concept of water monitoring provides for the complex recovery, and quantitative and qualitative control of water sources; sustainable use of irrigation water requires watering at the optimum time, depending on the optimal real evapotranspiration (ETRoptim = Kt × Ev). It is necessary to know the physical evaporation of water, Ev and the monthly value of the indicator Kt, as an average over a series of at least 30 years, for a certain plant. The proposed method captures the irrigation water, so that once the water has passed the root zone it gets absorbed and stored in a modular underground tank. The excess water collected in the modular basin will be reused when the soil and plant sensors will signal the presence of the humidity deficit.

***Key words**: soil, irrigation, draining.*

INTRODUCTION

As early as 1924, on the occasion of the drought of that year, Gheorghe Ionescu-Şişeşti, referring to the frequency of drought years in our country, he showed that out of 100 years, 3 were very dry, 58 were dry, 24 were rainy, 5 were very rainy, only 10 were normal (Botzan, 1984). The worst situation is when the soil drought is concomitant with atmospheric drought, as happened in 1946 (Staicu et al., 1977). The negative effects of the drought in July and August are amplified high temperatures, low relative humidity and hot and dry winds (Pleşa, 1979).
In other countries, such as the United States, there are concerns about water supply to agriculture and horticultural crops are of vital importance. Due to the rising costs of water irrigation, it is increasingly necessary to use technological means, management and plant genotypes that can reduce water use in irrigated agriculture (Howell, 2001). There are years when only irrigation saves crops, like it happened in 2007 in the southern part of the country. The purpose of this paper is to present the need for the efficient use of irrigation water by storing it in retention basins on a land arranged with closed modulated drainage.

MATERIALS AND METHODS

The influence of full-time and part-time irrigation on the lawn and roses in a dendrological park is sought.
Periodically, the soil moisture reserve is determined from the entrance to the vegetation until the end of October, collecting soil samples which are compared with the measurements given by the weather station, which in addition to gravimetric humidity measures the N, P, K content.
Watering is applied by spraying on the lawn and by dripping on the roses when the soil moisture reserve decreases, a decrease signaled by the sensors with which the weather station is equipped, near the minimum ceiling of 50% of the IUA, at a depth of 80 cm. The water administered in the plots is measured by the meteorological station, watering stopping is when the full norm is achieved on the optimally irrigated variant.

As pedological drought is often associated with atmospheric drought, unfavorable conditions are created for the growth and development of lawns and roses, requiring watering to be applied in April, May, June and July. In the summer months, on the 0-40 cm layer, the soil moisture deficit (% from the IUA) can reach the level of wilting coefficient, therefore a dual irrigation-drainage system with the possibility of storing excess water is an optimal solution. It is also mandatory to assess the quality of the water periodically because water quality is changes over time, under the influence of various environmental and anthropogenic factors. The soluble salt content of irrigation water is between 0.15-3 g/l. If the soluble salt content is 4 g/l, the water becomes harmful to plants. The most harmful salts are carbonate and sodium chloride not exceeding 1 g/l.

The temperature of the irrigation water must be as close as possible to the temperature of the environment in which the plants grow. The irrigation water for the experimental perimeter in Figure 1 comes from a borehole at a depth of about 40 meters, with PREMO type tubes. In the experimental site where the risk factors are represented by both excess and/or water deficit, the hydro-ameliorative arrangement being autonomous, it adapts to the given conditions, excess or deficit of humidity, being reversible. The research of the water recovery solution from the drainage system is first of all a resource research and then an arrangement scheme, more and more used in the countries with hydro-admirable tradition.

The water quality monitoring equipment for lawn and rose cultivation is made at the experimental model phase. It has the following composition:

- hydraulic measuring circuit laid on a type fixing system panel, on which the sensors are located for determination physical and chemical parameters of water: turbidity, electrical conductivity at 25 degrees C, Na^+ ions, Cl^- ions; a sensor must be included for nitrates;
- Devices for connecting the sensors to the circuit measurement: turbidity sensor mounting device; pH sensor glass; vat electrical conductivity sensor, thermostatic bath for ion sensors selective chlorine and sodium;
- Collection tank with drain pipe;
- Filtration system;
- Solenoid valve for purging the filtration system;
- Fittings and passage valves.

From the turbidity transducer, water passes through a filtration system which removes solid suspensions based on the attraction exerted by granules of filter media and the effect of surface stresses created at passing water over the granular filtration bed. In case of water recirculation for laboratory analysis the water is stored in a vessel that must provide a time of stationary both to ensure the amount of water needed for cleaning filter as well as to ensure a long system life filtering. The filtration system goes through a cleaning process once per day. The cleaning process can be started automatically or by manual control. The vessel in which the water is recirculated is fed by an electric pump (Q = 60 l/h; H = 10 m H_2O).

Automatic compensation of temperature influence on the measurement of pH and electrical conductivity is done by software means taking into account the measured value of the temperature. The concentration of sodium and chlorine ions is measured at constant temperature, their mounts being inserted in a tank with a thermostat with continuous stirring.

The drainage system that ensures reversibility is modular and has in its componence (Figure 1):

- draining prisms (height = 1.0 m, width = 0.25 m);
- reflated absorbent drains (diameter = 110 mm);
- PVC collector drains (diameter = 250 mm);
- Fittings, plugs, dampers.

RESULTS AND DISCUSSIONS

The parameters below allow us to easily appreciate water quality, which in order to be good for irrigation, must fall within the limits shown below:

• Mineralization, g/l <1;
• Mg = [Mg/(Ca + Mg)] x 100% <50%;
• Na = [Na/(Ca + Mg)] x 100% <70%;
• Na = [Na/(Ca + Mg + Na)] x 100% <50%;
• Na/Ca ratio <1;
• Potential sodium absorption coefficient (SAR) <10.

The quality of water for irrigation depends on the total content of salts, the nature of the salts present in the solution and the proportion of Na of Ca, Mg, bicarbonates and other cations.

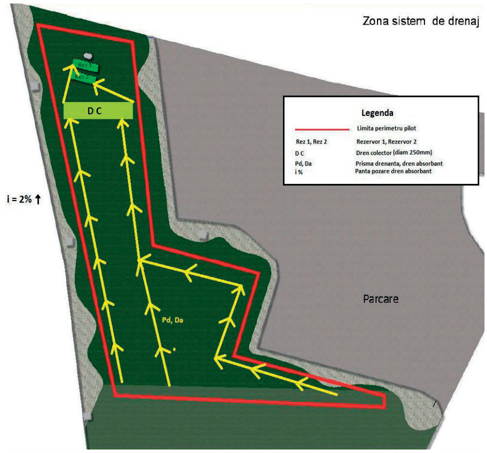

Figure 1. Drainage system

The water source used to irrigate the experimental perimeter comes from a borehole dug at a depth of about 40.0 m. The site under study is equipped with dual irrigation-drainage system in order to achieve a local arrangement, with groundwater supply (drilling), characterized as follows:

- **Geographical and geomorphological characterization**

The studied perimeter is located within the city of Arad located in the northwestern part of our country and is part of the Tisza Plain, named after the main collector, which flows into the rivers in northwestern and western Romania. The northern plain of the Tisza is bounded on the west by the Hungarian border, and on the east by the hills that make up western Piedmont, stretching in some parts to the mountains.

- **Climate characterization**

The northern plain of the Tisza, which also includes the city of Arad, is characterized by a moderate continental climate, due to the Carpathian chain that prevents the entry of cold air from the north and east in winter. Thermal regime: The average annual temperature is 10.8°C, in the Arad area, and the average winter temperature is around -1.1°C, one month of the year registering negative values. Precipitation regime: The amount of precipitation falling annually in the northern Tisza Plain decreases from north to south (630 mm in Satu Mare, 483 mm in Chişinău-Criş) and from east to west (640 mm in Ineu, 483 mm in Chişinău-Criş). The analysis of climatic factors shows the tendency of arid soils due to climatic excesses, on large areas in the southern part of the country and moderate in the rest of the territory (Figure 2).

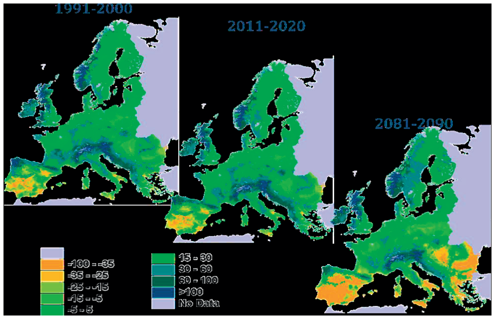

Figure 2. The trend of the average annual precipitation over three decades: historical data (1901-2000) and modeling over two periods: 2011-2020 and 2081-2090 through the Indicator "Cumulative average annual water deficit" (ICPA source)

The configuration of these changes is similar to that observed during the twentieth century. It is "very likely" that the trend of increasing the values of extreme maximum temperatures and increasing the frequency of heat waves will continue.

- **Hydrographic characterization**

The northern Tisza Plain is bordered by a network of waters running from east to west. This whole network is tributary to the river Tisza. The hydrographic network has a medium density. Most of the plain has a density of 0.1-0.3 km/km^2. The studied area is located in the Mureş river basin, the average slope is 1.5‰, and in the plain 0.2‰, the length of the river is 718.5 km, the surface of the hydrographic basin on the territory of Romania is 27,919 km^2 and the altitude of 90 m (Figure 3).

- **Hydrographic system**

In the studied area, the studied hydrographic system is represented by the Mureş River. It flows in the plain at a distance of about 90 km. It has abandoned riverbeds that spread like a fan both north and south of the current riverbed. It has no major tributaries in this sector. The average flow of Mureş is 169 m^3/s in the Arad area. During the summer, the volume of water decreases considerably, reaching a minimum flow of 13 m^3/s. The hydrological characterization of the Northern Tisza Plain consists of clayey alluvium in the low plain, where the Mureş Plain is located, which also has the greatest hydrogeological differentiation. Groundwater is found near the soil surface, at 5-10 m and is poorly mineralized (salts <1 g/l). In Arad Park, where the soil has a large amount of colloidal clay, the groundwater is at a depth of 3-5 m and is poorly mineralized, but with salts > 1 g/l, and drainage is good.

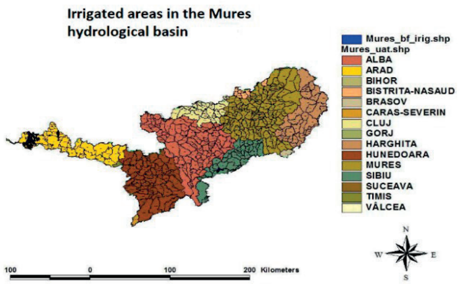

Figure 3. Irrigation potential of the Mureş river basin (ICPA source)

- **Hydrogeological characterization**

The most important groundwater aquifers in the Arad area are located in the Holocene deposits (represented by sandy clays, silts, sands, gravels) in the Mureş meadow and in the upper Pleistocene-Holocene deposits in the Mureş alluvial cone. The groundwater aquifer in these deposits are local sources of water supply. The direction of groundwater flow in the area is oriented, from west to east, to the Mureş River.

We also considered the improvement of the properties of the saline soil known for the fact that saline soils have physical, chemical and biological properties unfavorable to the growth and development of plants in general and horticultural plants in particular.

Due to the high content of exchangeable sodium, there is a dispersion of soil colloids, which leads to the destruction of the structure. This entails an extremely low permeability for air and water, the halomorphic soils being compact, difficult to work. The high content of soluble salts of these soils increases the osmotic pressure of the solution beyond the limits of water accessibility for plants, which leads to a deficit in their water supply.

The suction force of the plant roots can be a maximum of 14 atmospheres, and the suction force of a strongly salinized soil can reach 200 atmospheres, far beyond the possibility of supplying the plants.

The chemical properties are influenced by the high content of slightly soluble salts, sodium chlorides and sulfates, carbonates and bicarbonates of Na +, Ca^+, and Mg^+, which in the quantities in the soil can only be supported by a very small number of adapted plants.

Salinity and alkaline reaction also cause changes in the processes of absorption of nutrients from the soil by plants.

Under these conditions the nitric form of nitrogen is absorbed to a lesser extent compared to the ammoniac form. The explanation for this selectivity is the increase in the activity of OH ions in the soil solution, which prevents the exchange of anions from the surface of the root hairs. High concentrations of Na +, disrupt plant nutrition and prevent the absorption of other species of cations, $Ca^{2\ +}$ and K^+, partially replacing them.

Plants have a different capacity to withstand soluble salts in the soil: some are very sensitive, others more resistant, and some of them, salt plants, are well adapted morphologically and physiologically, to excess salts. Roses have a low tolerance to soluble salts in the soil. This plant trait is called "salinity tolerance."

The following indices are used to characterize the salinity tolerance of plants:

- lower tolerance limit for salinity 60-90 mg soluble salts/100 g soil;
- upper limit of tolerance to salinity 200-700 mg soluble salts/100 g soil;
- tolerance range;
- agronomic tolerance.

Roses have the highest sensitivity to the negative effect of salts immediately after planting. Seedlings that do not possess the ability to soak in water under conditions of high osmotic pressure cannot grow.

Criteria for correcting the alkaline reaction of the soil

In order to establish the need to amend the saline and alkaline soils, the following criteria are used:

- pH, in aqueous suspension - pH values greater than 8.5 indicate the presence of

$NaCO_3$ or a high exchangeable sodium content in the colloidal complex;

- the total content of soluble salts - determined conductometrically in aqueous extract with soil ratio: 1:% solution, is a criterion in establishing measures to improve saline soils, and the content of carbonates and bicarbonates (CO_3 + HCO_3), greater than 1 me/100 g soil, is used to calculate the dose of amendments, along with the sodium saturation of the adsorbent complex;
- sodium saturation of the adsorbent complex - or the percentage of adsorbent sodium (PSA) is the main criterion in assessing the opportunity to correct the alkaline reaction, while serving to calculate the dose of amendments:

$$PSA = \frac{meNA \cdot sch}{meT} \cdot 100$$

Soils with an adsorbent sodium content greater than 10% of the total exchange capacity (T), the sum of alkaline carbonates and bicarbonates greater than 1 me/100 g soil, need to be amended to correct the alkaline reaction.

- urgency to apply gypsum amendments (GU) - It can be evaluated with the help of the index, the percentage of adsorbing sodium (P.S.A.) for all cultures according to the relation: UG = 4.0 - 0.1 x PSA.

The first soils that will be subject to the fine are those with the lowest UG values: the value "0" (zero) indicates the highest urgency; value 1-2 = high urgency; 3 = medium urgency; 4 = amendment not required.

Materials used to correct the alkaline reaction

Depending on their origin, the materials used to improve the properties of saline and alkaline soils are grouped as follows:

a. actual amendments: gypsum, sulfur, lignite, limestone;

b. chemical preparations: H_2SO_4, aluminum sulphate, iron sulphate;

c. industrial waste: phospho-gypsum, defecation foam, industrial residues containing iron sulphate and aluminum sulphate, residues from the manufacture of furfural, residual waters from the manufacture of sulfuric acid.

Native gypsum, $CaSO_4 \bullet 2H_2O$, is found in nature in an amorphous or crystallized state, having a white-yellow or gray color. It is used to improve solonets and sodium solonceacs. The material is finely ground so that 70-80% of the particles pass through the sieve with 0.15 mm mesh and the rest through that with 1 mm mesh. Contains 15-18% S and about 31% CaO. It is sparingly soluble in water. It solubilizes slowly in the soil and participates in the replacement reactions of exchangeable Na in the calcium adsorbent complex and in the neutralization of the alkaline reaction.

The replacement of Na from the colloidal adsorbent complex with Ca favors the coagulation of the soil colloids, and the calcium humate that is formed and $CaCO_3$ produce the leaching of the particles into stable aggregates. This improves the circulation of air and water in the soil. Sodium sulfate is a neutral salt, not harmful to cultivated plants when it is in small amounts. When large amounts result, Na_2SO_4 must be removed by freshwater irrigation.

Gypsum can also be used to improve salts that contain a lot of Mg in exchangeable form or as salts in toxic concentrations. In Romania, the natural gypsum reserves are very high.

Phosphogypsum is a residue that results in wet phosphoric acid production and the manufacture of trisodium phosphate. Contains 75-80% $CaSO_4 \bullet 2H_2O$ and 3-8% P_2O_5. Due to the phosphorus in its constitution, it gives superior results to gypsum when applied as an amendment on saline soils. The disadvantage of phosphogypsum is that, after evacuation from the installations, it presents itself as a sludge that is difficult to wilt if it is not placed in small piles. For field application it must contain at most 10% humidity.

Compared to gypsum, whose acidification value is 100%, phosphogypsum has an acidification value of 75-80%.

Calcium chloride, $CaCl_2 \bullet 6H_2O$, obtained as waste at soda factories. After application to the soil, calcium replaces sodium in the adsorbent complex, giving rise to NaCl which can be removed from the soil profile by washing with fresh water.

Native sulfur is rarely used as an amendment because it is expensive but has good efficacy. By oxidizing it under the action of thiobacteria, sulfuric acid results, which, reacting with $NaHCO_3$ or Ca $(HCO_3)_2$, gives rise to salts.

Formulas for calculating the doses of gypsum amendments

The amount of amendments applied to alkaline and saline soils must ensure that the sodium ion moves out of the colloidal complex, so that it represents less than 10% of the cation exchange capacity. Dose amendments are established using calculation ratios applied to soils with a carbonate and bicarbonate content <1 m/100 g soil.

DAG = 0.086 (Na^+ - 0.1 * T) * h * DA * 100/ CGA DAG - dose of plaster amendments
0.086 grams per gypsum
Na^+ - changeable Na content in the soil complex
0.1 - Na content tolerated by plants
T - total cation exchange capacity
h - the thickness of the soil layer desired to be improved
DA - bulk density
CGA - the plaster content of the amendment

For soils with carbonate and bicarbonate content > 1 me/100 g soil the DAG = 0.086 (Na^+ - 0.1 * HCO_3 - CO_3 * T) * h * DA * 100 / CGA

Soil improvement in the experimental perimeter

The soils in the dendrological parks are subjected to intense salinization and alkalization processes as a result of the accumulation of salts coming from the irrigation water as well as from the organic fertilizers that are administered in high doses. Because of this, in the short time since the commissioning of the parks, even if the initial reaction of the soil was weakly acid-neutral, it tends to become neutral-alkaline and even alkaline which leads to poor crop development.

When the pH value, determined in aqueous suspension, in the ratio soil: water of 1:5, exceeds the value of 7.5, it is necessary to apply the amendments.

In order to research the alkaline reaction of park soils, strong acid oligotrophic peatlands with a pH between 3 and 4.5, and hydrolytic acidity around 90 m per 100 g soil, as well as mesotrophic peatlands with pH=5 are used as amendments. 0-5.5, from Miercurea Ciuc, Paraul Rosu, Mandra.

The doses of peat administered are conditioned by the sum of the exchange bases, the degree of saturation in the bases, the hydrolytic acidity of the peat and the thickness of the soil layer desired to be improved. Also in order to correct the alkaline reaction of the soils in the parks, the forest compost can be used, resulting from the bark of softwood or beech, it has a pH of 4.5-5.5. The doses required for the amendment can be calculated using the same reactions as in the case of peat.

Fertilization of degraded soils in parks

Organic fertilization is the main agrotechnical measure by which the soil humus regime is positively influenced. Organic fertilizers with a solid consequence, as well as plant residues left in the soil from flower crops, are sources of raw material for nutritious humus, but also for the synthesis of stable humus. Both contribute, along with other links in plant cultivation technologies, to maintaining or increasing the humus content of cultivated soils.

Organic fertilizers with fertilizing and/or ameliorating value

There are many organic fertilizers that can be used in our country. The group of vegetable fertilizers includes composts, green manures and peat fertilizers. Animal manure, produced in the household and in the industrial animal husbandry system, consists of manure, urine, manure and sludge, compost, turbidity and wastewater, respectively. The residual origin has sludge from urban and industrial wastewater treatment plants, composts resulting from them as well as household waste. Currently in our country, as well as in other countries, organic fertilizers of animal origin are the most widely used.

Peat and composts of animal and vegetable origin are used to stimulate the growth of rose cuttings. The introduction of plant residues into the soil, for improvement purposes, is not a common practice. The use of sludge and compost from various treatment plants on agricultural land has gone beyond the experimental stage.

The ameliorating effect of organic fertilizers is due to the appreciable contribution of organic matter, which consists of both easily and hardly degradable compounds. The more stable fraction of organic matter, consisting mainly of lignin, persists longer in the soil, causing the lasting effect of organic fertilizers and soil improvement, including the humus regime.

With the exception of semi-liquid (turbid) and liquid organic fertilizers (urine, manure, sewage), whose organic matter is completely readily biodegradable, all organic fertilizers with solid consistency constitute to a greater or lesser extent in soil improvement. Comparatively the efficiency of equal doses of organic substances introduced into the soil such as manure, roots, cereal straw, green manure, leaves, wood sawdust and Sphagnum peat in increasing the humus content is inserted in order 1; 0.55; 0.45; 0.35; 0.25; 2; 2.5. Numerous experiments have shown that 1/5 of the dry mass of traditional manure and only 1/8 - 1/9 of the mass of straw is converted into humic substances.

Of the organic fertilizers of animal origin, cattle manure contributes the most to the formation of stable humus, as it contains the highest amount of lignin relative to the organic substance. In relation to the animal species, the proportion of hardly biodegradable compounds in manure increases from animals fed with concentrates (birds, pigs) to animals fed with coarse manure (horses, sheep, cattle); In the same sense, the effect of organic fertilizers with solid consistency from these species in the long-term improvement of the soil also increases. The ameliorating effect of sludge from industrial livestock complexes also depends on the presence or absence of bedding and the total amount of unused feed. Composts from sludge of non-zero origin, plant residues and other additives, subjected to aerobic fermentation directed for several years, bring into the soil a significant amount of humic substances already formed during the composting process, contributing substantially to the complex improvement of soil properties. At present we have in the experimental phase the use of biocompost obtained from food residues that also contributes to the improvement of the soil structure and to the increase of permeability for water and air, an extremely important property to consider in the cultivation of roses and ornamental plants.

CONCLUSIONS

The advantages of using groundwater for irrigation are the following:

- low costs for pumping water (wells are drilled near the agricultural areas to be irrigated);
- low electricity costs for water pumping;
- the possibility of operating on a diesel generator;
- automation and control of flow and pumping pressure;
- low maintenance costs.

Recommendations for the use of groundwater for irrigation

In order to guarantee the real prospects for the use of groundwater for irrigation, it is necessary to carry out a feasibility study based on the results of hydrogeological research, groundwater monitoring and the physico-chemical and physical characteristics of the soils. In order to have an efficient and suitable irrigation system, the farmer must choose the right system for the given situation in the field, must take into account the costs of purchasing and installing the system, as well as pumping costs, operation and maintenance and periodic inspections.

When choosing the irrigation system, the following are taken into account: type of crop, water requirements, soil type, energy source, location of the water source and financial availability (both for purchase and for operation and maintenance). Small irrigation systems, powered by groundwater, are more efficient in terms of consumption because they are adapted to the needs of each farmer, the main advantages being the savings of electricity and water. Thus, these individual groundwater irrigation systems are more profitable for vegetable farms (vegetable crops in solariums, but also in the field), parks, vine farms and small vegetable farms.

In the conditions of a dry year, by irrigation with rationally dimensioned irrigation norm, good results are obtained for lawns and roses in conditions of maximum efficiency by storing water in retention basins and reusing it.

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