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THEORETICAL IMPLEMENTATION OF WATER MANAGEMENT, USING THE DRAINAGE RETENTION CAPACITY EQUATION IN FORESTRY AREA

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Declaration

I hereby declare that this thesis entitle “Drainage and integrated water management in forestry and agronomy” written and submitted by me, in partial fulfilment of University regulation for the award of Degree Master of Engineering (Ing.) in Environmental Sciences. I further declare that this thesis has not been submitted to any other University for any degree or equivalent course.

Prague, 1th of April 2021 Oleksandr Zhdaniuk

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Abstract

This study presents the design of a drainage system, located nearby the southern border of the Czech Republic in Bohemia region. Research methodology based on the Drainage Retention Capacity (DREC) in forestry. Drainage systems in saturated soils decreases the level of the subsurface water table and enables the creation of groundwater reservoirs without gravity water. DREC can be defined as a groundwater reservoir, which is limited by soil surface and which occupies an intermediate position in the water table. Records for this study was collected from previous study of Štibinger et al. (2015), which was conducted in the same Forests.

The area of the research is located in the Krisak agricultural area of mountain meadows, close to Lucany on Nisa locality, in Jizera Mountains, (Northern Bohemia), Czech Republic. These mountain forests are in danger due to annual temperature increase, which could lead to dry period together with limited amount of water and low precipitation. The use of DREC can help to determine the capacity of potential infiltration area and can contribute to the water regime and water resources protection very significantly.

Keywords: drainage system, drainage retention capacity (DREC), drain ditches, climate dynamics.

Abstrakt

Tato studie představuje návrh odvodňovacího systému, který se nachází poblíž jižní hranice České republiky. Metodika výzkumu založená na drenážní retenční kapacitě (DREC) v lesnictví. Odvodňovací systémy v nasycených půdách snižují hladinu podzemní podzemní vody a umožňují vytváření nádrží podzemní vody bez gravitační vody. DREC lze definovat jako rezervoár podzemní vody, který je omezen povrchem půdy a který zaujímá mezipolohu ve vodní hladině. Záznamy pro tuto studii byly shromážděny z předchozí studie Štibinger et al. (2015), který byl proveden ve stejných lesích.

Oblast výzkumu se nachází v zemědělské oblasti Krišak na horských loukách, v blízkosti Lučan na lokalitě Nisa, v Jizerských horách (severní Čechy), Česká republika. Tyto horské lesy jsou ohroženy ročním nárůstem teploty, který by mohl vést k suchému období spolu s omezeným množstvím vody a nízkými srážkami. Použití DREC může pomoci určit kapacitu potenciální infiltrační oblasti a velmi významně přispět k vodnímu režimu a ochraně vodních zdrojů.

Klíčová slova: drenážní systém, retenční kapacita drenáže (DREC), odvodňovací příkopy, dynamika klimatu.

1. Introduction

The first stone and tubular drainages, according to historical documents, were used before the Christian Era. Some of them were discovered during excavations. In the Middle Ages, drainage was forgotten, and only starting in 1650 did drainage systems of wood, fascines, stone (gravel) begin to appear in England. Later in Scotland, and then in Germany, they began to use shingles made of shingles, used for roof skates, which should be considered the forerunner of pottery drainage pipes. The invention of the press for the manufacture of pottery drainage pipes and in 1840 in England contributed to the rapid development of drainage throughout Europe.

Over the course of a subsequent period of more than a century, machine-made drainage pipes made of baked clay were manually laid in trenches. The drainage parameters were determined empirically, i.e., based on field agro-reclamation experiments and soil studies.

The German Committee dealt with the drainage problem for Land Reclamation. Then this function was performed by the Land Reclamation Building Curator, as evidenced by its annual reports (since 1952) and articles in the journals Der Kulturtechniker (1897 - 1944), Wasser und Woden (from 1949), and Zeitshrift Für Kulturshnik und Flürbeinigung "(since 1960)," Drenaivisung ".

Since 1940, in the Netherlands and the USA, based on German and Swiss studies, the physical and mathematical theory of soil drainage has been developed. Gradually, in the field of drainage, the hydraulic theory of the movement of moisture spread more and more.

Beginning in 1950, tubular drainage was more and more often arranged with the help of special trench drainage-laying machines, which was explained first by rising labor costs, and then by a shortage of workers. In 1960, the first plastic drainage pipes appeared on the market. Initially, these were smooth PVC pipes with slots. In 1962, smooth pipes began to be replaced by pipes made of polyvinyl chloride with corrugated walls and pushed openings for water intake. The continuous mechanization of drainage work, as well as the use of a variety of materials, led to a reduction in costs, but at the same time difficulties appeared when laying drainage in wet soils. Moreover, in some places, despite the impeccably performed drainage, the areas remained excessively moist.

Due to the lack of specialists and new information in the field of soil mechanics, the use of trenchless drainage mechanisms has further expanded. At the same time, it was important to ensure the correct deepening of the working body, otherwise the design bias of the drain is violated. The success of this rational method of drainage is achieved only with qualified personnel.

Soils containing bound moisture, compacted and characterized by poor water permeability, along with or simultaneously with drainage, need to improve the structure, which is achieved through various measures (mole drainage, deep loosening or deep plowing), carried out simultaneously with chemical (liming, fertilizing) and biological measures (growing plants with a deep root system).

Irrigated agriculture faces a number of difficult problems in future. One of the major concerns is the generally poor efficiency with which our water resources are being used for irrigation. A relatively safe estimate is that about 40 per cent or more of the water diverted for irrigation is wasted at the farm level through either deep percolation or surface run-off. The other evident problem in future is the growth of alternative demands of water for urban and industrial needs. These uses place a higher value on water resources and, therefore, tend to focus attention on wasteful practices.

Irrigation science in future will, thus, face the problem of maximizing the efficiency of our irrigation systems. Efficient utilization of irrigation water is, therefore, the most important factor in irrigated agriculture. It involves several practices like conveying water from the source to the field without seepage losses, following the right method of irrigation consistent with the topography, soil characteristics and other local conditions and applying water to the crop at the right time and in proper amounts. Efficient irrigation systems apply right amount of water to the crop at the right time and ensure its uniform distribution in the field. The method of irrigation determines greatly the duty of water and the profitableness of irrigation.

The considerable labour which always attends the application of water to land is one of the big charges to be made against irrigation and one that must be made as low as possible. Besides, the method of irrigation frequently affects directly the degree to which plants may use the water applied.

The technology of agricultural water management is situation specific and the choice of a right irrigation method will depend on its economics and the performance requirements. The factors influencing the selection of an irrigation method are the soil characteristics, cropping system, land topography, quantity and quality of irrigation water and the nature and availability of inputs like labour and energy. There are recurrent discussions on the pros and cons of different irrigation methods. Especially controversial are the arguments about the choice between open gravity as opposed to sprinkling methods. Unfortunately, opinions are often based on limited local experience where a method has been employed which may have been utterly unsuitable to existing conditions and should never have been chosen.

Success is often taken for granted and receives little publicity; on the other hand, one who fails in a certain endeavour is likely to broadcast the shortcomings of a method, rather than question his own merits. The broad terms in which articles and papers usually describe irrigation methods as gravity or surface irrigation make the analysis of the different claims still more difficult. These articles may include methods and applications of the most inefficient and outdated types, some probably dating back thousands of years.

This fact may give the explanation for the extreme variety of findings, depending on where and by whom the experience has been gained. Every modern irrigation method has both advantages and disadvantages and certainly has a definite place in an irrigation system. The irrigation engineer must, therefore, evaluate the project and choose the method best suited to local conditions. An irrigation method should fulfill one or more of the following requirements:

1. To afford a uniform water distribution with a small depth of application for light irrigations.
2. To allow a heavy and uniform application of water and under some conditions as much as 25 cm per application for salt leaching in problem soils.
3. To allow use of large concentrated water flows for reduction of conveyance losses, network and labour cost.
4. To be suitable for use with economic conveyance structures.
5. To facilitate mechanized farming.

There are only two general methods of applying irrigation water: irrigation above ground and irrigation below ground. Each of these two methods appears under several variations and possesses a special advantage. The water at the surface may be applied by flooding it on the field surface or in small channels, by spraying it under pressure overhead and by applying it in drops.

The terms subsurface, surface or gravity, overhead or sprinkler and drip irrigation are used to describe these four methods of irrigations, respectively. The use of sub-surface method is very limited. The drip method and sprinklers have certain advantages but their initial high cost of installation and some other limitations make them suitable only for specific conditions. Surface irrigation methods are, therefore, the most commonly used methods of irrigation across the world.

The previous study of Štibinger et al. (2015) conducted in Krisak Mountain Meadows Agricultural Area. Designing a drainage system in saturated soils decreases the level of the subsurface water table and enables the creation of groundwater reservoirs without gravity water. The professor's research shows that with proper study of the area: soil, climate, water resources, etc. can help create the most beneficial drainage system.

2. Objectives

The aim for this study was to solve the forest drying problem in mountain area by implementing using groundwater flow system combine with drainage. Based on that idea, are developed objectives in the following:

a) Review the literature on existing rational analysis of drainage system, and select one model using simple mathematical equation with a very close result with complicated developments.

b) Analyze the summary of the hydrological data, focusing on average precipitation corresponding and annual average temperature.

c) Designing using data of drainage system from previous study, located in Bohemia Region, Czech Republic, nearby the border with Poland.

d) Calculate and analyze the possibility of integrated irrigation system, along with suggestion corresponding with drainage system.

e) Suggest few recommendation for further research or project in future and also which drain design is good for the local foresters.

3. Literature Review

The environmental benefits provided by forests and woodlands are increasingly recognized and valued by society. Benefits for the water environment include the ability of woodlands and trees to protect aquatic habitats and species, preserve the quality of drinking water, alleviate flooding, and guard against erosion, landslides and the loss of soil. It is essential that managing of forests sustainably to protect the environmental goods and services they provide (Figure 1).

Many forest management practices can impact on the water environment as a result of soil and vegetation disturbance or through the alteration of the pathways of water movement. Poor forest management can diminish or reverse the benefits provided by forests and woodlands, contribute to local flooding and risk severe water pollution (e.g. by increasing sediment run-off and water turbidity). Although larger-scale forest operations generally pose the greatest risk, small-scale working can also cause significant water problems.

Figure 1. View over Liberec to the Jizera Mountains from Mt. Ještěd (2007)

3.1. Surface drainage system

Usually drainage is used to improve the productivity of planted forests on poorly drained sites where excessively wet soil conditions limit tree growth and access for harvesting and other management activities. However, inappropriate or poorly designed drainage systems can negatively impact on water flows and on the wider freshwater environment. The main issue relates to drains speeding up or diverting surface run-off, which can increase erosion (Figure 2) and the siltation of watercourses. It can also promote landslips and debris flows, and affect downstream flood risk.

Figure 2. Excessive run-off has caused major erosion and gullying within this drain.

For new planting

- Assess the site using soil maps, detailed topographic data and information on planned cultivation to identify drainage needs.
- Assess the layout and condition of any existing drainage system; and plan any restoration work to reduce the risk of erosion and sediment run-off.

- Plan the drain layout in relation to pathways of water movement, existing drains and local watercourses, starting with cut-off drains and then cross-drains.

- Avoid creating drains on steep (>18º) slopes and moderate (11–18º) slopes with medium or highly erodible soils.

- Plan adequate buffer areas to protect watercourses and vulnerable habitats/species.

- Design the length and spacing of cross-drains to control the volume of run-off so that it does not exceed the capacity of the drainage system.

- Design drains to discharge water to flatter areas to enable flows to fan out and slow down.

- Reduce the drain gradient on highly erodible soils to less than <2º and increase the recommended widths of buffer areas.

- Avoid drains discharging directly into watercourses.

- Never divert significant volumes of water from one catchment to another.

- Avoid drains discharging onto neighbouring land, unless by agreement.

- Keep forest drains and road drains separate: do not discharge water into road drains.

- Plan to install drains at the same time or as soon as possible after cultivation operations, especially where run-off could reach and overload road drains.

- Plan ahead for changes in the weather that could affect site conditions.

For restocking

- Assess the condition of the existing drainage system.

- Identify and assess watercourses (including any that are dry/redundant).

- Redesign the drainage system to correct any problems such as drains discharging directly into watercourses.

- Only infill drains to create a buffer area where drain flows are manageable and unlikely to washout the fill; otherwise redesign the drainage system.

- Where a drain has become a main watercourse and is not subject to erosion problems, treat it as a natural watercourse and create a buffer area along its length.

- Avoid redraining wet hollows and flushes in valley bottoms and instead convert them to open glades or wet woodland.

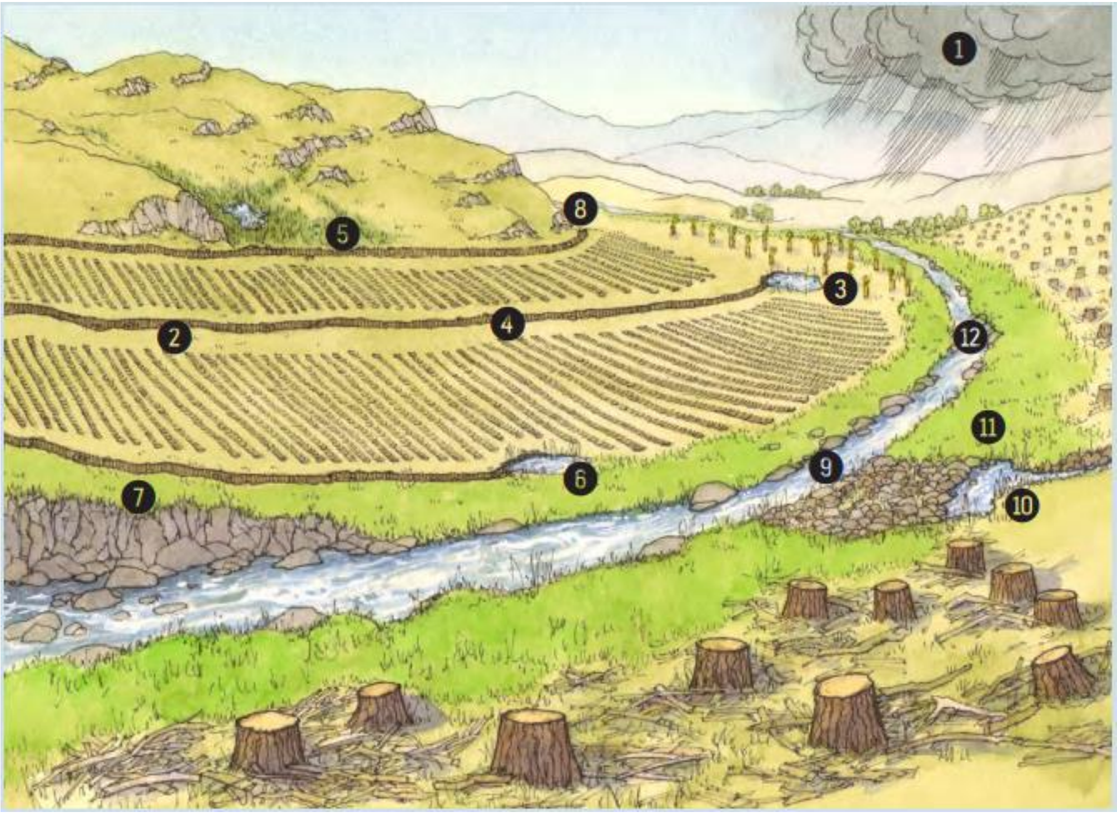


Figure 3. Protecting the water environment from drainage operations

1. Consider the weather and aim to carry out drainage works (including drain maintenance and silt trap cleaning) during dry periods.

2. Cut drains to run at a even gradient of 2º (3.5%) or less leading towards the head of the valley;

ensure water does not discharge into lower cultivation channels.

3. End drains in a shallow turnout.

4. Space drains so that the volume of run-off does not exceed the capacity of the drainage system.

5. Provide ‘cut-off’ drains so that plough furrows do not carry significant volumes of water from wet areas above.

6. Stop drains at the edge of buffer areas, preferably on flat ground where water can fan out.

7. Ensure drains do not discharge to the edges of steep gully sides or unstable slopes.

8. Avoid drains diverting water to adjacent catchments.

9. Do not end drains in natural channels, ephemeral streams or old agricultural drains.

10. Redesign existing drainage systems to meet current standards and correct any erosion problems; ensure restock drains discharge to a minimum 10 m wide buffer area.

11. Where an existing drain has become a sizable and stable watercourse, treat as a natural watercourse and establish buffer areas along its length; if in doubt, seek advice.

12. Avoid fording streams and rivers, unless there is an existing purpose-built ford.

3.2. Water table

Groundwater (GW) is one of the types of underground liquid. On the territory of Europe, groundwater is infiltration by origin. The water of atmospheric precipitation seeping into the thickness of the soil under the influence of gravity penetrates into the depths until it reaches the impermeable rocks. The impervious rock on which groundwater is retained is called an impervious layer. At the confining layer, water accumulates and fills the voids of the overlying rock.

A rock saturated with gravitational water is called an aquifer. A characteristic feature of ground gravitational water is the ability to flow out of the ground into a well (pit) arranged in it. The distance from the day surface to the steady-state water level in the well is called the depth of occurrence or GWL - groundwater level, and the steady-state level of free water is called the water mirror (Fig. 4).

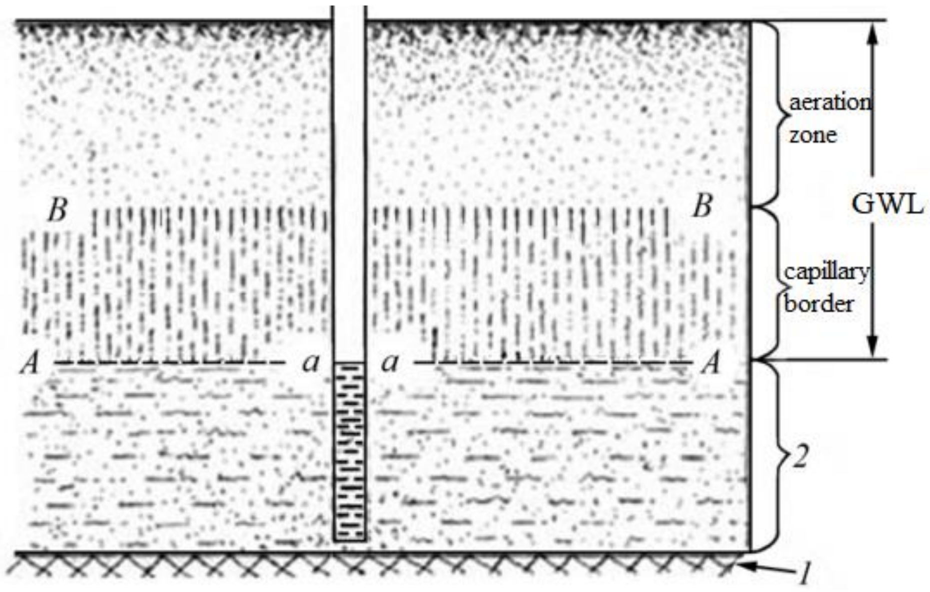


Figure 4. Groundwater level and capillary rim (according to AA Rode): aa - water level in the well; AA - groundwater mirror; BB is the upper border of the capillary border; GWL - groundwater level; 1 - water-resistant horizon; 2 - aquifer

With a relatively shallow occurrence of GW from the day surface, three zones are distinguished in the soil profile: excess moisture, optimal moisture, and lack of moisture, which qualitatively differ from one another in the water-air regime (Fig. 5).

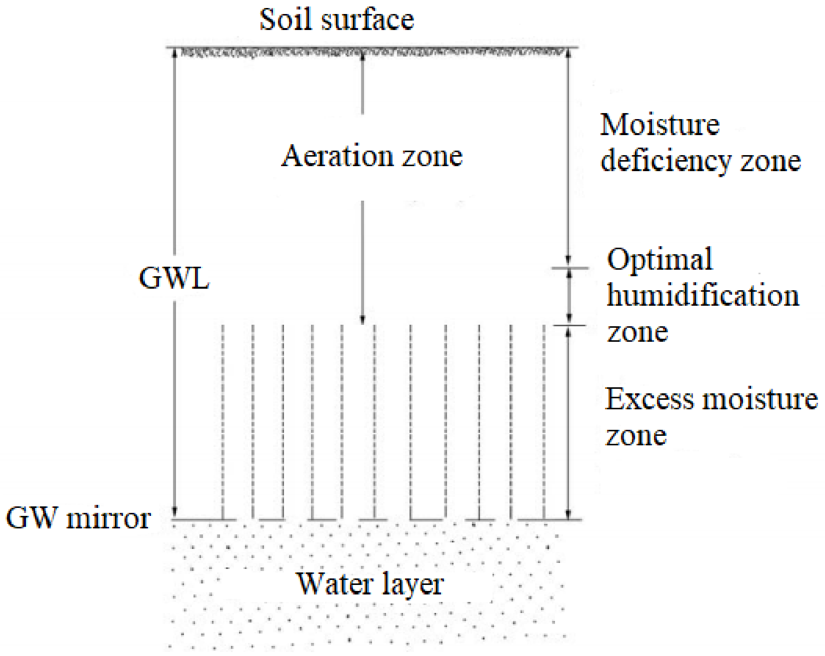


Figure 5. Changes in the water-air regime of soils in the soil profile: GW mirror - the upper surface of the aquifer (horizon); GWL - GW level (depth of their occurrence); CB - capillary border

The zone of excess moisture is located above the water table. The moisture content of the soil in it is determined by the capillary rise of moisture from the groundwater and in magnitude exceeds the lowest moisture capacity (HB). The main factor in this zone limiting the growth and development of plants is the lack of oxygen. This zone is characterized by its especially low content if it lies in the surface humus layers of the soil, which, as a rule, have a high biological saturation (roots and rhizomes of plants, soil organisms, humus), which causes an intensive consumption of oxygen from the soil solution. The thickness of this zone is determined by the particle size distribution.

Above the zone of excess moisture is the zone of optimal moisture. The moisture content of the soil in it fluctuates between HB and critical moisture, that is, it is within the optimal limits for the growth and development of plants. Here, the oxygen regime is also better, since, in addition to the intake of atmospheric precipitation with moisture, the oxygen content in the soil solution increases due to soil aeration. However, the thickness of this zone is insignificant (for example, on sandy soils it is only about 10 cm). The upper layers of the soil profile are occupied by a zone of lack of moisture. Soil aeration in this zone should be considered satisfactory even in peat bog soils with a significant decrease in the level of groundwater (for example, on drained peat bogs).

The moisture content of the soil in the zone of lack of moisture fluctuates within wide limits, but during the growing season it is mainly between the critical moisture and wilting moisture (WM), that is, there is a lack of moisture in the soil. The minimum moisture content to which especially the surface layers of this zone are dried is determined by its thickness.

The larger the zone of lack of moisture, the more, other things being equal, the surface layers of the soil can dry out more strongly, deeper and more often, even below the WM due to physical evaporation. Thus, the water-air regime that develops in a particular soil profile is determined by the presence and thickness of each of the indicated zones, i.e., ultimately, the depth of the groundwater determines it.

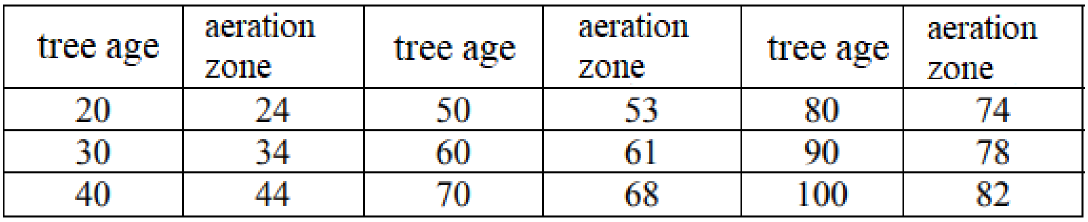
The thickness of the zones of excess moisture and optimal moisture is constant for a particular soil profile, since it is determined by the soil texture composition. Therefore, natural or anthropogenic disturbance of the groundwater depth leads, first of all, to a change in the thickness of the moisture deficiency zone. It should be noted that we borrowed the name of the categories of soil moisture (lowest moisture capacity, critical moisture, wilting moisture) from.

The aeration zone (ZA) includes the zone of lack of moisture and the zone of optimal moisture, i.e. the zone of aeration is the soil layer located from the soil surface to the zone of the capillary border. When the capillary rim emerges on the day surface, gas exchange between the soil solution and the atmosphere occurs due to the diffusion of gases in the aquatic environment, which, as is known, occurs thousands of times slower than in air. In this case, the enrichment of the soil solution with oxygen occurs at an insignificant depth.

Phytomass - the total amount of living organic matter of plants (both higher and lower), accumulated to this point in the aboveground and underground areas of the plant community of land (forest area, meadows, etc.) or water space.

Higher plants with low phytomass and tree species in the initial period of life are able to grow and develop under such conditions. With age and, consequently, an increase in phytomass for normal growth and development of trees, a certain amount of aeration zone is required. The size of the optimal aeration zone depends mainly on the age of the stands, since with the increase in the aboveground phytomass, the phytomass of the roots increases and, accordingly, the thickness of the root-inhabited soil layer. In addition, the optimal level of groundwater is determined by the soil difference, since with a change in the soil texture composition, the height of the capillary rise of moisture from the groundwater changes accordingly. The optimal aeration zone for pine stands ranges from 24 cm in 20-year-old stands to 82 cm at the age of 100 years (Table 1).

Table 1. Optimal aeration zone for pine stands, depending on age (cm)



tree age	aeration zone	tree age	aeration zone	tree age	aeration zone
20	24	50	53	80	74
30	34	60	61	90	78
40	44	70	68	100	82

For other tree species, the value of the optimal aeration zone can be taken the same

The height of the capillary rise of moisture from groundwater (*CB* capacity) is determined by the formula

$$y = 52.7 + 8.7x, \qquad (1)$$

Where y is the height of the capillary rise of moisture from the GW (*CB* power), cm; x is the content of physical clay particles in the capillary border zone, %. When assessing soil and ground conditions in pine plantations, the value of the optimal aeration zone must be taken for an 80-year-old stand, i.e. at the age of the main felling. Therefore, the optimal depth of occurrence of GW, or the groundwater level (GWL) can be determined by the following formula

$$y = 3A + CB = 74 + 52.7 + 8.7x = 127 + 8.7x, \qquad (2)$$

Where y is the optimal GWL, cm; x is the content of physical clay particles in the capillary border zone, %. Using this formula, it is possible to determine the optimal GWL on soils of various soil texture composition (Table 2)

Table 2. Optimal level (optimal depth of occurrence) of groundwater for 80-year-old pine stands, depending on the content of physical clay in the capillary border zone

Physical clay content,%	Optimal GWL, cm
3	153
5	171
10	214
15	258
20	301
30	388
40	475

From the data table 2 it follows that when establishing the dependence of the productivity of stands on the depth of groundwater, it is necessary to select objects of approximately the same age of the stand and the soil texture composition of soils. Ignoring this circumstance leads to an erroneous conclusion about the absence of a relationship between the productivity of forest plant community and the depth of HS.

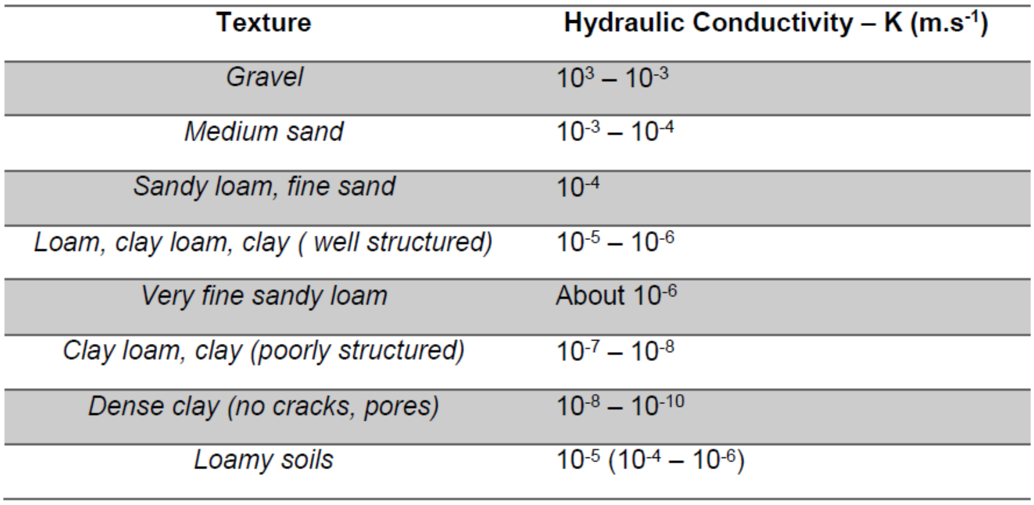
3.3. Hydraulic conductivity

In theoretical terms, hydraulic conductivity is a measure of how easily water can pass through soil or rock: high values indicate permeable material through which water can pass easily; low values indicate that the material is less permeable. Hydraulic conductivity is typically given the symbol k and has units of velocity, for example meters/sec or meters/day. A key aspect of hydraulic conductivity is that a very wide range of values exists in natural soils and rocks, perhaps a range from 10^{-2} m/s (for very open gravels and cobbles) to 10^{-11} m/s.

Since hydraulic conductivity is a characteristic physical property of a porous media, it would seem reasonable to assume that it relates to specific measurable properties of the soil pore geometry, e.g., porosity, pore-size distribution, internal surface area, etc. However, the many attempts to develop a functional relation of universal applicability for the range of soils and soil materials, has been generally unsuccessful. The simplest approach is to seek a correlation between hydraulic conductivity and total porosity. However, it can be concluded that such an approach is generally futile (except for comparison of otherwise identical media) owing to the strong dependence of flow rate upon width, continuity, shape, and tortuosity of the conducting pores. This is the reason why coarse-textured soils (with less total porosity and fewer individual pores, but larger and more uniformly sized pores) will have greater saturated hydraulic conductivity than fine-textured soils (which have greater total porosity, but smaller, more irregularly sized, tortuous pores).

Numerous theoretical models have been introduced to represent porous media by a set of relationships that are amenable to mathematical treatment. Scheidegger (1974) gave a comprehensive review of such models, including the straight capillaric, parallel, serial, and branching models and concluded that the preferred model of a porous medium should be based upon statistical models. One of the most widely accepted theories on the relation of saturated hydraulic conductivity to the geometric properties of porous media is the Kozeny-Carman theory, which is based on the concept of hydraulic radius. The measure of hydraulic radius is the ratio of the volume to the surface of the pore space, or the average ratio of the cross-sectional area of the pores to their circumferences. Now usually using table of hydraulic conductivity (K) value range by soil texture (Table 3).

Table 3. Hydraulic conductivity (K) value range by soil texture



Texture	**Hydraulic Conductivity – K ($m.s^{-1}$)**
Gravel	$10^{3} – 10^{-3}$
Medium sand	$10^{-3} – 10^{-4}$
Sandy loam, fine sand	10^{-4}
Loam, clay loam, clay (well structured)	$10^{-5} – 10^{-6}$
Very fine sandy loam	About 10^{-6}
Clay loam, clay (poorly structured)	$10^{-7} – 10^{-8}$
Dense clay (no cracks, pores)	$10^{-8} – 10^{-10}$
Loamy soils	10^{-5} ($10^{-4} – 10^{-6}$)

The determination of K could be as in situ or ex situ. Laboratory measurement or so called ex situ is not the most used way which researcher take to compare to the in situ which is on the spot. For laboratory measurement, the collection of the sample must ensure few points below (Ilek & Kucza, 2014):

(1) Preservation of continuity of the sample with surrounding soil

(2) Preservation of natural residual system of soil, such as root system and soil channels within the boundary of the sample

(3) Preservation of natural porosity

(4) Preservation of main, vertical direction of infiltration of water flowing through the sample during testing

(5) Measurement errors of K will be eliminated due to leakage the boundary

Clay soil with low hydraulic conductivity often have a top layer with surprisingly high hydraulic conductivity because of the activity of plant roots or the presence of a tiled layer. Clay is a heavy soil type that benefits from high nutrients. Clay soils remain wet and cold in winter and dry out in summer. These soils are made of over 25 percent clay, and because of the spaces found between clay particles, clay soils hold a high amount of water. Because these soils drain slowly and take longer to warm up in summer, combined with drying out and cracking in summer, they can often test gardeners. In such cases, rainfall will build up a perched water table on the layer just below the top layer. Under these conditions, a subsurface drainage system can be effective because of the interflow in the permeable top layer, but it will only work as long as the backfilled trench remains more permeable than the original soil (H. P. Ritzema, 2006).

3.4. Soil Type

The regularities of the origin, formation and development (genesis) of soils as a result of long-term interaction with the environment determined their qualitative differences, which necessitated the development of principles for the classification of the soil cover of the Earth.

Soil classification in soil science is one of the most difficult theoretical problems. Its task is to combine soils into taxonomic groups according to structure, composition, properties, origin and fertility.

The scientific basis of the classification is soil systematics, the task of which is to establish qualitative differences and relationships between soils existing on the earth, to give their full description in a possible logical sequence, to present the available knowledge about the soil in the system, to show the specific features of each species and each group of soils.

The classification of soils is the association of soils into groups according to their most important

properties, origin and characteristics of fertility.

Soil classification work includes:

- the establishment and precise formulation of the principles of classification;
- development of a system of subordinate taxonomic units (type, subtype, etc.);
- drawing up a classification scheme or a systematic list of soils;
- development of a system of names or nomenclature of soils;
- the establishment of signs by which the soils of each classification subdivision can be found in nature (soil diagnostics) and highlighted on soil maps.

Figure 6 represented the soil layer contrasts structure that is not typical but simple prediction of the soil profile, where horizon A represents aggregated crumb like structure, horizon B with columnar structure, C horizon incompletely weathered rock fragments.

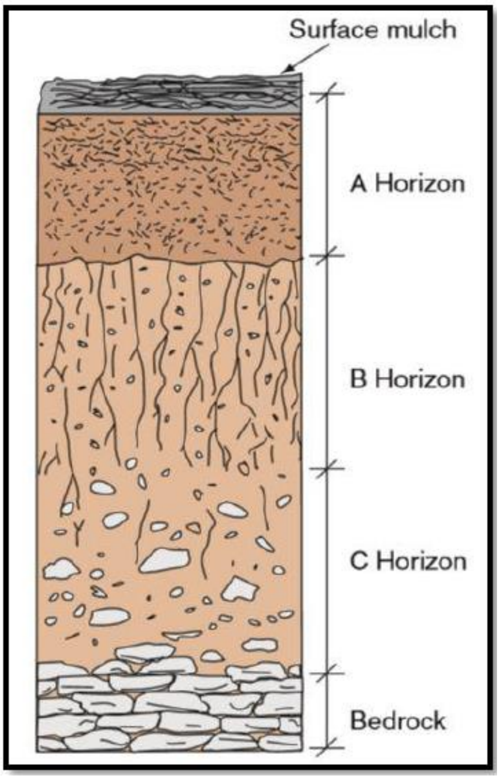


Figure 6. Prediction of soil profile (Sheler, 2013)

Soil texture is a classification instrument used both in the field and laboratory to determine soil classes based on their physical texture. Soil texture can be determined using qualitative methods such as texture by feel, and quantitative methods such as the hydrometer method. Soil texture has agricultural applications such as determining crop suitability and to predict the response of the soil to environmental and management conditions such as drought or calcium (lime) requirements. Soil texture focuses on the particles that are less than two millimeters in diameter, which include sand, silt, and clay. The USDA soil taxonomy and WRB soil classification systems use 12 textural classes whereas the UK-ADAS system uses 11 These classifications are based on the percentages of sand, silt, and clay in the soil.

The sides of the soil texture triangle are scaled for the percentages of sand, silt, and clay. Clay percentages are read from left to right across the triangle. Silt is read from the upper right to lower left. Sand is read from lower right towards the upper left portion of the triangle.

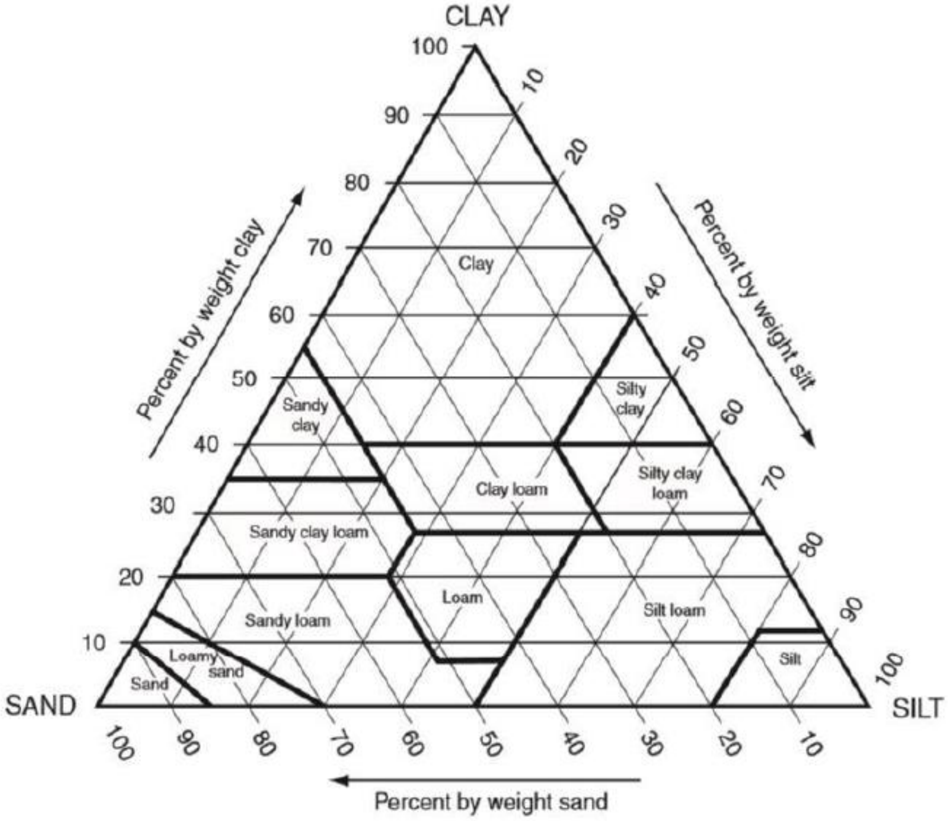


Figure 7. Textural Triangle (Hillel, 2004)

3.4.1. Sand

It is most extensively used construction material. It consists of particles of rock and hard minerals, such as silicon dioxide. They are the largest type of soil particles, where each particle is visible to naked eye. The large, relatively stable sand-particle size increases soil aeration, improves drainage in tight soils and creates plant-growth supporting qualities, or tilt.

The particle size of course sand ranges from 2 – 4.75mm, Medium sand ranges from 0.425 – 2 mm and fine sand ranges from 0.075 – 0.425 mm (Figure 8). The bigger particle size of the sand gives wet or dry sandy soil a grainy texture when you rub it between your fingers, and it makes the soil light and crumbly even when you try to stick it together in your hand. The particle shape is angular, sub angular, rounded, flat or elongated. The texture is rough, smooth, or polished.

3.4.2. Silt

Silt is a sediment material with an intermediate size between sand and clay. Carried by water during flood it forms a fertile deposit on valleys floor. The particle size of silt ranges from 0.002 and 0.06 mm (Figure 8).

Silt is a non-plastic or low plasticity material due to its fineness. Due to its fineness, when wet it becomes a smooth mud that you can form easily into balls or other shapes in your hand and when silt soil is very wet, it blends seamlessly with water to form fine, runny puddles of mud.

3.4.3. Clay

Clay particles are the finest of all the soil particles, measuring fewer than 0.002 mm in size (Figure 8). It consists of microscopic and sub-microscopic particles derived from the chemical decomposition of rocks. Clay is a fine grained cohesive soil. They stick together readily and form a sticky or gluey texture when they are wet or dry.

Clay is made of over 25 percent clay, and because of the spaces found between clay particles, clay soils hold a high amount of water. Clay expand when in contact with water and shrink when getting dry. Compared to sand particles, which are generally round, clay particles are thin, flat and covered with tiny plates. Organic clay is highly compressible and its strength is very high when dry, which is why it is used in construction as mud mortar.

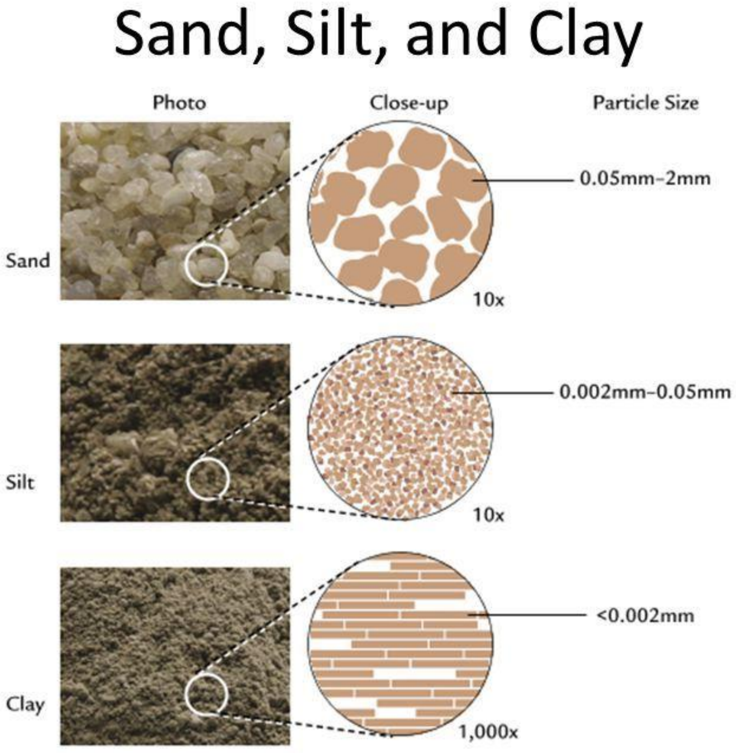


Figure 8. Soil classification scheme

3.5. Hydrological Parameter

3.5.1. Precipitation

One of the factors causing excess water on the soil surface is high rainfall combined with low soil permeability. In conclusion, precipitation and evaporation are two interrelated processes in the water cycle. Also mentioned by Pickels (1941), the source of precipitation is water, which evaporates from oceans, lakes, rivers and other water surfaces, as well as from soil, which is released through the leaves of plants during evaporation. It was mentioned earlier that precipitation and evaporation are linked together in the same cycle and are influenced by temperature, causing water to evaporate into the atmosphere.

It constantly diffuses into the air, causing the air temperature to decrease, as the air gets colder until the relative humidity is 100%, after which it is saturated with water vapor. In addition, due to the low atmospheric pressure, the temperature continues to decrease, which will lead to condensation of water vapor that forms in the clouds. When the condensation is large enough, cloud particles coalesce and form rain (Pickels, 1941). Another case: if the temperature in the clouds is below freezing, it will cause snow instead of rain (Luthin, 1966).

Indeed, there are many theories related to how precipitation occurs, but most theories emphasize that it is largely caused by cooling water vapor that condenses into clouds and falls as rain / snow. Three deposition methods based on the movement of air masses in the atmosphere, such as cyclonic, convective and orographic, are described below.

3.5.1.1. Cyclonic

Cyclonic sediments or some of their names. Frontal precipitation is caused by the superposition of a cold air mass on a warm, moist air mass. Another case caused by the movement of air mass due to the pressure difference in the low-pressure area occurred internally, the air would flow horizontally from the environment, causing air rise and precipitation as a result of this condition called non-frontal deposition (Luthin, 1966).

3.5.1.2. Convective

Convective precipitation caused by the heat on the surface at low pressure pushes the air movement towards an upright position. Due to the high surface temperature, it heats the air and forces the air molecule to move further and rise into the atmosphere, continuing to condense into clouds and precipitation.

3.5.1.3. Orographic

Orographic precipitation falls mainly in mountainous areas, it is caused by the rise of air mass over the mountain barrier, as well as other changes in the terrain. Orographic barriers tend to increase cyclonic precipitation as well as orographic precipitation due to increased lift (Luthin, 1966). To pass through the mountains, the air moves horizontally and is forced to rise, causing moisture deposition from the air on the windward slope (Pikels, 1941).

Precipitation measurement is essential for data collection and future flood risk assessment. Each country in most cases provides hydrological data, including precipitation, for each region. However, it is still possible to estimate precipitation from flow fluctuations, which allows the reconstruction of past precipitation, in the absence of precipitation records, only flow records are available (Kirchner). Kirchner (2009) also explained how he explores this possibility using a river flow record from 1974 – 2000.

To reconstruct precipitation in two catchments using equation (4), the analysis of which starts with the basic mass conservation equation (3) after all the mathematical processes to simplify the system.

$$\frac{dS}{dt} = P - E - Q \tag{3}$$

$$P_t \approx \max\left(0, \frac{\frac{Q_{t+l+1} - Q_{t+l-1}}{2}}{\frac{[g(Q_{t+l+1}) + g(Q_{t+l-1})]}{2}} + \frac{Q_{t+l+1} + Q_{t+l-1}}{2}\right) \tag{4}$$

Where S is the volume of water stored in the catchment, P is precipitation, E is evapotranspiration, Q is discharge, where P, E, Q and S are a function of time, also l is explained as the transit time lag for changes. in unloading to reach the dam.

As mentioned earlier, how important it is to collect a precipitation database, permanent data storage will help us determine the intensity of precipitation. It will be low or high depending on the duration of the rain. The result of the simulation will be one of the important aspects for the design of a proper drainage system related to the drainage capacity with an estimate of the flow. Liutin (1996) also mentioned that the intensity of rain is the rate at which it falls at one time.

It is possible to calculate the rain rate using the Rational Method. According to Boucher (2010), Duration-Frequency-Depth (DFD) curves can be one way to determine rainfall for a rational method. Several steps need to be taken to get a reliable reading of the rainfall rate (Boucher, 2010), for example:

- ✓ Determine the average seasonal rainfall in your area.
- ✓ Select an estimated storm frequency and use the appropriate DFD drawing.
- ✓ Choose a suitable time for concentration (T in minutes).
- ✓ Select the curve that corresponds to the average seasonal rainfall for the selected area.
- ✓ Find the corresponding precipitation depth on the vertical axis.
- ✓ Calculate the rain rate using the following formula in inches / hour.

Rain rate (inch / hour) = P / T (min) * 60 (min) (5)

In this study, we will simply use the formula to calculate the rain rate without drawing a curve.

3.5.2. Evapotranspiration

Evapotranspiration is a combination of evaporation of water from the soil surface and evaporation from plants (Tancreto, 2015). Evapotranspiration (Et) occurs due to increased temperatures, which also affect aeration and the types and rates of chemical reactions in the soil (Hillel, 2004). As mentioned earlier, evapotranspiration is involved in the rainfall cycle. Actual evapotranspiration can be measured using a soil water balance approach or micrometeorological methods (H. P. Ritzema, 2006). Recently, several hydrological models have been developed to provide tools for measuring such parameters.

DRAINMOD is one hydrological model that is designed to model the soil regime of a drainage landscape, as well as to predict surface runoff, infiltration, evapotranspiration, subsurface drainage and soil seepage, mainly using water balance for the vertical soil column (Scheler, 2013). DRAINMOD will calculate the evapotranspiration using temperature based on Thornthwaite's method (Wang, Mosley, Frankenberger, & Kladivko, 2006).

Wang et al. (2006) also mentioned how the Thornthwaite method calculates ET using the maximum and minimum daytime temperatures from an experimental drainage field or any nearby weather station, based on latitude and an average heat index calculated from the long-term average monthly temperature in the study area. Evapotranspiration rates will be higher in the warm climate zone, and therefore hazardous salinity is likely to be higher than in the cool climate zone (Hillel, 2004).

Excess surface water that does not evaporate enters the soil layer by infiltration, as we discuss below. The rest of the surface water can be runoff.

3.5.3. Penetration

Infiltration is a process where surface water, as a result of irrigation or precipitation, penetrates into the soil, mainly by vertical or downward movement through the soil layer. Hillel (2004) explained that later surface waters will be divided into several conditions, some of them will be returned to the atmosphere directly by evaporation or transpiration from plants after absorption, the rest of the excess water will be stored as groundwater. The amount of water that is retained as groundwater or captured by plants and then absorbed is called the infiltration rate, which is defined by Hillel (2004), which is the infiltration rate as the volumetric flow of water per unit through the profile. soil surface area.

Infiltration separates precipitation into runoff and soil water, and soil water seeps into deep soil or groundwater and becomes inaccessible to plants (Huang, Li Barbour, Elshorbadi, Zettle and Cheng Xi, 2011). Huang et al. (2011) also mentioned some studies describing infiltration and drainage used to study the mechanisms of water flow and transport of solutes in layered soils, while other studies focus more on developing numerical algorithms to estimate the interlayer hydraulic conductivity between two adjacent nodes. in different layers.

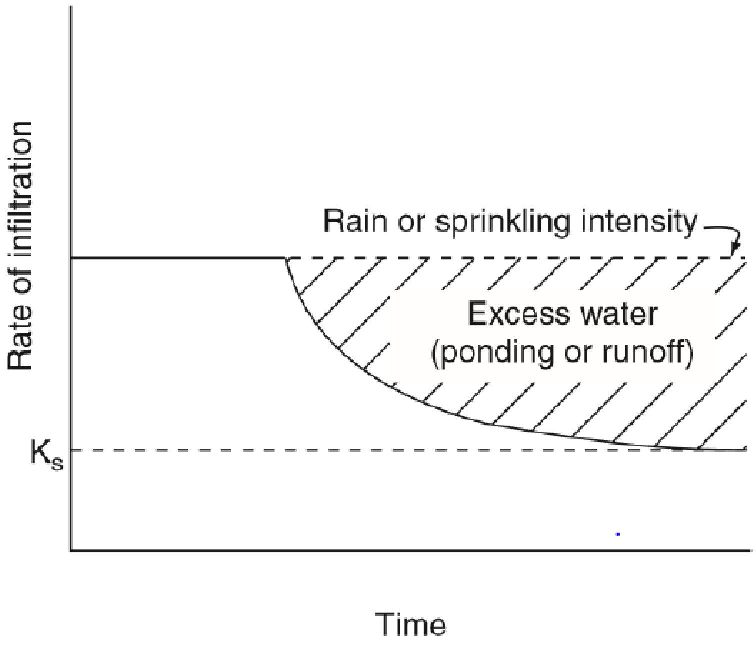


Figure 9. Time dependency of infiltration rate (Hillel, 2004)

Figure 9 shows us the infiltration rate depending on time under rainfall. In some cases, Hillel (2004) explained that in downward flow into vertical column under continuous ponding, the infiltration rate intend to be steady, gravity – induced rate that approximates the soil saturated hydraulic conductivity if the soil profile is homogenous and structurally stable.

4. Methodology

4.1. Study Area

The hydrological data collected in northern part of Czech Republic, in Jizera Mountains (Czech: Jizerské hory), part of the Western Sudetes on the border between the Czech Republic and Poland (The Western Sudetes are the western part of the Sudetes range system on the borders of the Czech Republic, Poland and Germany). The chosen area is located near Liberec city which surrounded by the Jizera Mountains and Ještěd-Kozákov Ridge. Figure below showed the location of selected study area.

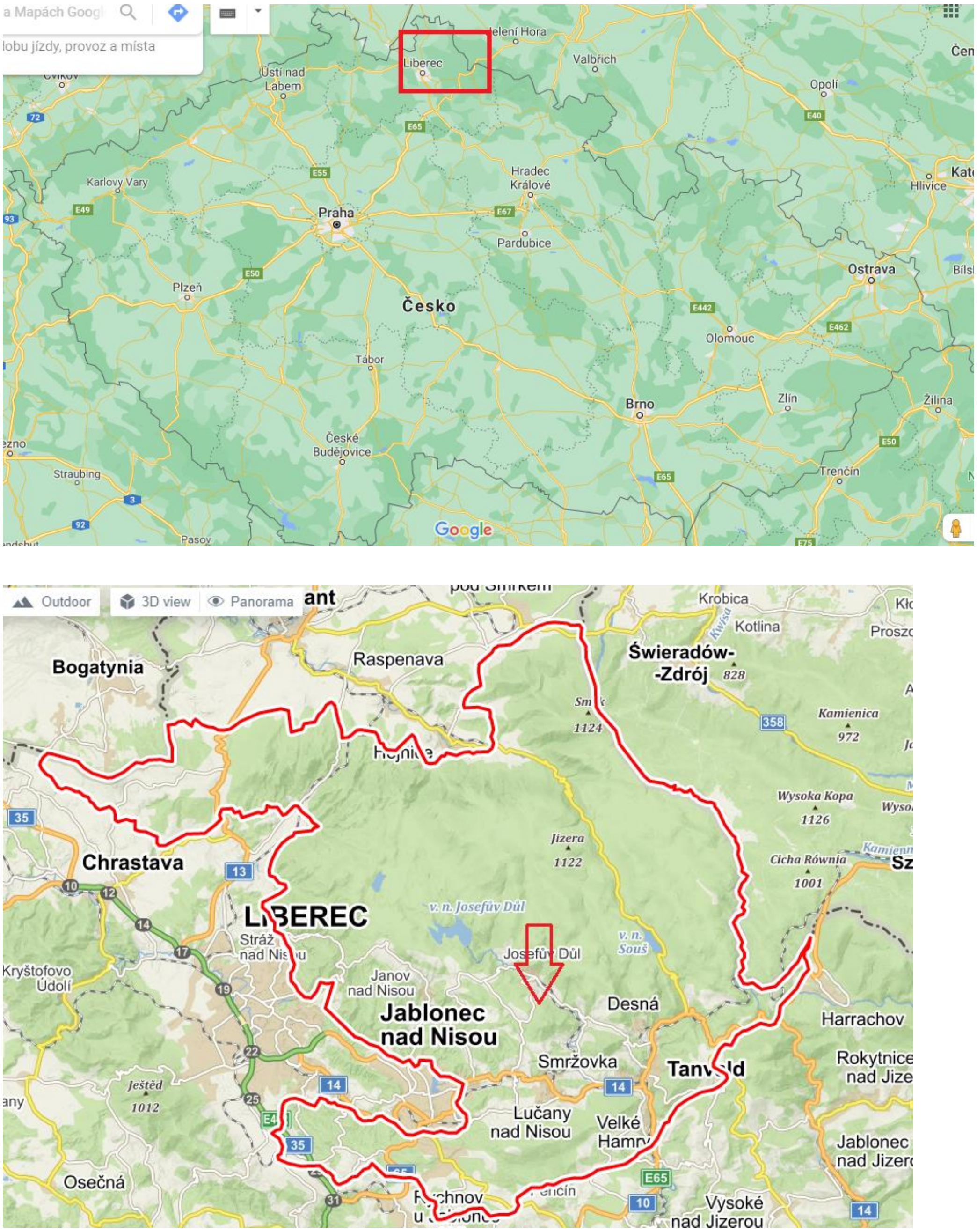


Figure 10. Selected study area in Northern Bohemia , Czech Republic, Krisak Mountain Meadows Agricultural Area

Primary data such as soil hydraulic conductivity and other parameters for drainage design were collected from previous study of "Drainage Retention Capacity (DREC) of Krisak Mountain Meadows Agricultural Area (Jizera Mountains, Czech Republic) for Mitigation of Negative impacts of Climate Change" under group of Stibinger et al. (2015).

Secondary data from this area will be hydrology parameter, precipitation and temperature were collected from Czech Hydrometeorological Institute (CHMI). The calculation will continue using Hooghoudt's Equation and we will discuss more detail in further chapter.

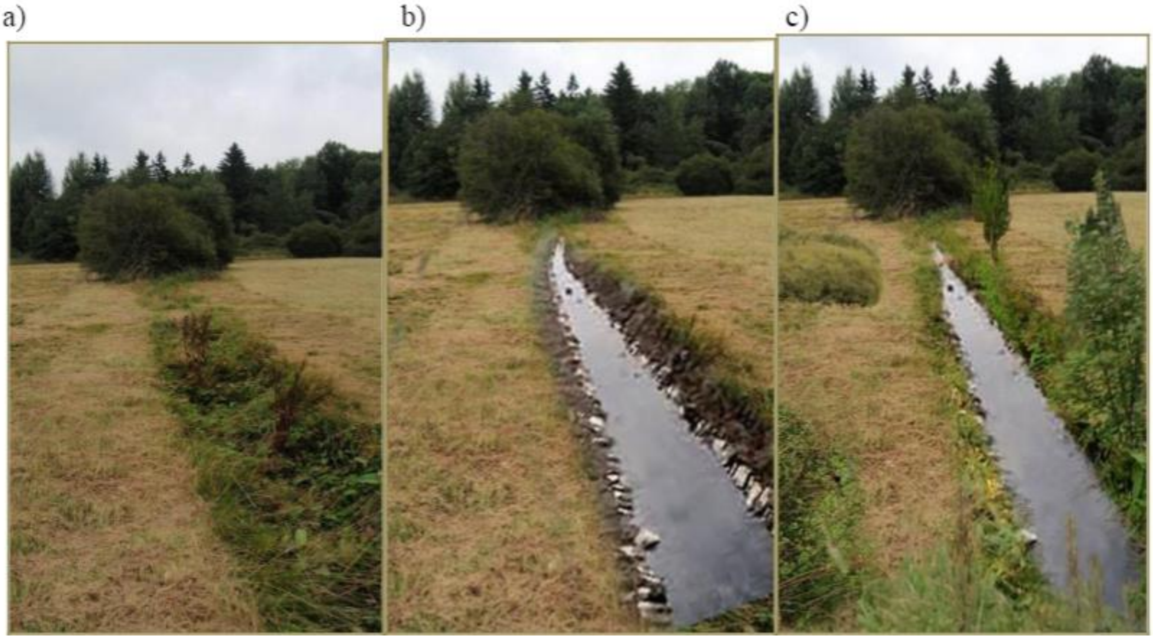


Figure 11. Drain ditches in agricultural area of mountain meadows, Krisak location (Jizera Mountains, Czech Republic) (a) present non-functioned ditch (b) renovated ditch with free water level (c) maintained, fully functional ditch with bushes and trees floor (Štibinger et al, 2015)

4.2. Hydrological Data

The interconnected systems of the atmosphere, oceans, water streams, land, ice cover and biosphere, which form the natural environment, are threatened by human activities. However, as fragile environments become more vulnerable to natural disasters, natural disasters also destroy the environment in a cycle of adverse cause and effect.

Observational data for weather, climate and atmosphere, collected through observing, data transmission and forecasting networks, provide policymakers with information about the state of the environment so that they can take action to prevent further deterioration.

The natural environment suffers, for example, from lack of rainfall for extended periods of time and uncontrolled land use, which leads to desertification. It is estimated that one third of the Earth's surface and one fifth of the world's population are facing the threat of desertification. For this reason, it is necessary to focus on the aspects of climate variability and change that affect the environment.

Data collected from Czech Hydro meteorological Institute from past 10 years 2010 – 2019 both precipitation and air temperature in table 4 and table 5. The possibility is using data history of Liberec region. The meteorological institute provides us with monthly precipitation since 1961 – 2019. The same thing for air temperature was served monthly with long-term history from 1961 – 2019.

Table 4. Territorial precipitation (mm) from 2010 – 2019 in Liberec region, Czech Republic (database on Czech Hydro meteorological Institute)

YEAR / MONTH	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
JANUARY	49	63	135	99	30	83	67	48	85	92
FEBRUARY	32	15	79	53	7	13	69	41	3	35
MARCH	67	35	34	35	56	61	47	57	55	65
APRIL	27	33	39	39	49	34	44	61	36	23
MAY	143	66	37	133	131	30	33	43	60	119
JUNE	79	82	64	201	44	92	145	97	68	28
JULY	156	299	151	125	101	45	132	175	26	40
AUGUST	414	86	139	64	88	77	46	102	27	44
SEPTEMBER	170	65	35	94	76	34	80	90	35	49
OCTOBER	12	50	33	57	56	54	72	119	41	44
NOVEMBER	109	1	75	65	11	111	38	67	12	62
DECEMBER	93	108	48	40	56	26	44	79	127	45
SUM	**1354**	**905**	**871**	**1009**	**709**	**665**	**823**	**982**	**580**	**649**

Table 5. Territorial air temperature (°C) from 2010 – 2019 in Liberec region (database on Czech Hydro meteorological Institute)

YEAR MONTH	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
JANUARY	-5.5	-0.6	-0.6	-2.3	0.7	1.3	-1.3	-4.6	1.9	-1.7
FEBRUARY	-1.6	-2	-5.4	-1.8	3	0.2	2.4	1.4	-3.5	2
MARCH	2.7	3.8	4.8	-1.5	6.4	4.6	2.9	5.5	0.6	5.5
APRIL	7.3	10.3	8.2	7.8	9.8	7.5	7.2	6.4	12.4	9.5
MAY	10.6	13.1	14.3	12	11.9	12	13.2	13.2	15.5	10.3
JUNE	15.8	16.3	15.9	15.5	15.5	14.9	16.6	17.2	16.6	20.5
JULY	19.5	15.8	17.7	18.6	19.1	19.2	17.8	17.6	19	18.1
AUGUST	16.5	17.4	17.2	17.2	16	21.2	16	17.5	20.1	18.9
SEPTEMBER	11.1	14.2	13.1	11.6	14.2	12.7	15.5	11.5	14.2	13.1
OCTOBER	6.3	8.4	7.5	10.1	10.8	8	7.6	9.8	10.5	10.3
NOVEMBER	4.5	3.6	53.	43.	6.8	6.6	2.7	3.9	4.5	6.1
DECEMBER	-5.1	2.2	-0.9	2.4	1.8	4.6	-0.1	1.1	1.6	2.6
AVERAGE	**6.8**	**8.5**	**8.1**	**7.8**	**9.7**	**9.4**	**8.4**	**8.4**	**9.4**	**9.6**

4.3. Drainage Retention Capacity (DREC)

Methodological procedure for determining the drainage retention capacity (DREC) of surface layers under conditions of unsteady-state groundwater flow was demonstrated below. DREC of the drainage system can be defined as a groundwater reservoir situated between the soil surface and the intermediate position of a parabola shaped water table above the drain level. Computation of DREC is based on analytical approximation of the subsurface total drainage discharge in unsteady-state groundwater conditions. DREC formula can serve as a simple tool for immediate estimation that requires only minimum amount of basic information (drainage design parameters, soil hydrology data). DREC is an important phenomenon of drainage policy, an inseparable part of drainage processes, which can mitigate negative impact of climate dynamics. A properly applied drainage policy, with the possibility of manipulating the retention capacities in the soil layers, can significantly improve soil and environmental protection. In agriculture, DREC extended by a drainage system can mitigate the negative effects of hydrological extremes such as floods and droughts.

Assuming a fully saturated soil profile with a high position of the water table level that is identical with the surface. For this soil profile, there is a subsurface pipe drainage system with drain spacing L (m), drain diameter r0 (m), and drain depth h_d (m). The depth of the impervious floor below the level of the drain = 1 m. Symbol h0 (m) means the initial water table level (m) at time t = 0, and because the water table level is identical with the soil surface, the expression h0 = h_d is valid. The water table level, drained by the subsurface pipe drainage system, begins to decrease from h0 (m). In this case no recharge to the water table has been recorded and it means that the unsteady-state drainage flow principles can be applied. DRC developed by operation of the subsurface pipe drainage system in unsteady-state groundwater conditions can be defined as a free gravity water drainable pore space under the surface. This drainable pore space, which does not contain any gravity water, is limited from above by the soil surface level and by parabola shaped water table situated above the drains from below (Figure 12).

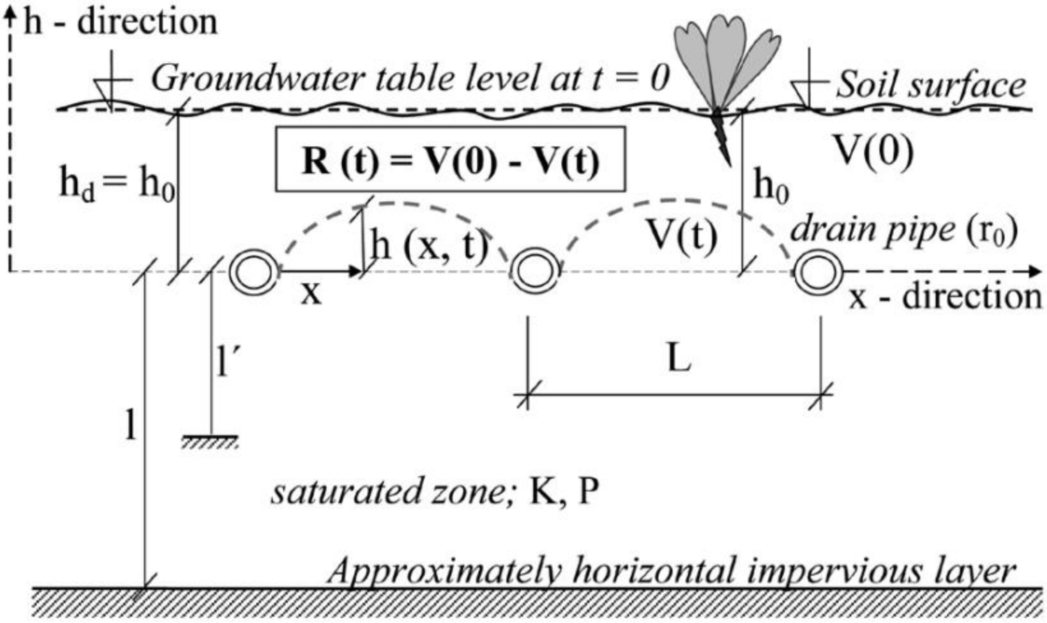


Figure 12. Height of the groundwater table h (x, t) at the distance x > 0 at the time t > 0, at saturated unsteady-state groundwater conditions and retention capacity of surface layers R(t) at the time t > 0

Determination of DRC is based on analytical approximation of subsurface total drainage quantity in unsteady-state groundwater conditions (Stibinger 2003). The solution coming from Boussinesq equation (1904) describes the unsteady-state saturated groundwater flow without any recharges to the water table:

$$HK\frac{\partial^2 h}{\partial x^2} = P\frac{\partial h}{\partial t} \qquad (6)$$

where:

h – height of the water table level (m)

H – constant representing the average depth of the aquifer (m)

K – hydraulic conductivity (m/day)

P – drainable pore space, effective drainage porosity (–)

x – horizontal x-direction (x-coordinate) (m)

t – time (days)

The volume of the soil gravity water above the next two parallel drains at the time t = 0 can be expressed as

$$V(0) = h_d \times P \qquad (7)$$

where:

$V(0)$ – volume of the soil gravity water above the level of the parallel horizontal subsurface drainage pipe system (at the time $t = 0$), expressed in m per unit surface area

Next step of the process will be clarified in the same way at the time t > 0. The area above the next two parallel drains with drain spacing L (m) at the time t > 0 is approximately

$$\int_0^L h(x,t)dx \quad (\mathrm{m}^2)$$

and in the same way as Eq. (7), Eq. (8) can be modified into:

$$V(t) = (P/L)\int_0^L h(x,t)dx \qquad (8)$$

where:

$V(t)$ – volume of soil gravity water (water quantity) above the level of the parallel horizontal subsurface drainage pipe system (at the time $t > 0$), expressed in m per unit surface area

The expression

$$\int_0^L h(x,t)dx$$

can be modified into:

$$\int_0^L h(x,t)dx = \frac{8h_0 L}{\pi^2}e^{-at} = \frac{8h_d L}{\pi^2}e^{-at} \qquad (9)$$

Parameter a represents drainage intensity factor

$$a = \frac{\pi^2 KH}{L^2 P} \quad (1/\text{day}) \qquad (10)$$

By substituting the end of Eq. (9) into Eq. (8), we can define the formula for expressing V(t) (m) and Eq. (8) can be written as:

$$V(t) = \frac{8h_d P}{\pi^2}e^{-at} \qquad (11)$$

The retention capacity of soil layers R(t) (m) created by the hydraulic function of the subsurface pipe drainage system at the time t > 0 and expressed in m per unit surface area is shown in Figure 1. Retention capacity of soil layers R(t) (m) is actually the released space under the surface. It is the difference between the volume of the soil gravity water V(0) (m) at the time t = 0 and the volume of soil gravity water V(t) (m) at the time t > 0, which can be expressed as:

$$R(t) = V(0) - V(t) \qquad (12)$$

After substitution of Eq. (7) and Eq. (11) into Eq. (12) and rearrangements, the equation for estimation of retention capacity of soil layers R(t) (m) can be defined as:

$$R(t) = h_d P(1 - \frac{8}{\pi^2} e^{-at}) \tag{13}$$

At this moment it is important to note, that the expression h0 = h_d is valid just for the case when position of the water table level is high and identical with the surface. But it means that the final formula (13) for approximation of the retention capacity of soil layers R(t) (m) can also be written as:

$$R(t) = h_d P(1 - \frac{8}{\pi^2} e^{-at}) = h_0 P(1 - \frac{8}{\pi^2} e^{-at}) \tag{14}$$

From the way of derivation of retention capacity of soil layers R(t) (m), which leads to Eqs (13) and (14), and from the analysis and equations presented above, the expression for approximation of retention capacity of soil layers R(t)1 (m) was extrapolated in

a case where hd > h0 is valid. This equation can be expressed as:

$$R(t)_1 = P(h_d - h_0) + h_0 P(1 - \frac{8}{\pi^2} e^{-at}) \tag{15}$$

After rearrangements, Eq. (10) is as follows:

$$R(t)_1 = P(h_d - h_0 \frac{8}{\pi^2} e^{-at}) \tag{16}$$

By approximation made in Eqs (13) and (16) with the knowledge of the basic subsurface drainage system parameters (L, r0, h_d) and soil hydrology characteristics (K, P, h0), it is possible to evaluate retention capacity of soil layers R(t) (m) for a case where h0 = hd is valid as well as R(t)1 (m) for a case where h_d > h0 is valid, at the time t > 0. Dieleman and Trafford (1976) showed that all formulas and expressions derived from Boussinesq equation, which includes Eqs (13)–(16), are valid at a certain time, which was defined as:

$$\tau(\text{days}) = 0.4\,(-)/a\left(\frac{1}{\text{days}}\right) \tag{17}$$

It should be kept in mind, that R(t) (m) and R(t)1 of the approximations (14) and (16) represent, from the physical point of view, a scalar. This means that volume, quantity, amount of drained space or mass is in this case expressed in length units (m). RISWC experimental drainage field in Středočeská pahorkatina Upland (Czech Republic).

Measured real values of the subsurface drainage discharges were obtained from the experimental field area, owned by the Research Institute for Soil and Water Conservation (RISWC) Prague-Zbraslav, Czech Republic (Soukup et al. 2000). From the geological point of view, the parent rock of the Cerhovice brook watershed area is formed of shale. All soil layers have low permeability, and the approximate depth of the impervious barrier is more than 1.0 m below the soil surface. The approximately 41.0 ha experimental field areais drained by a subsurface pipe drainage system. The thickness of the low permeable soil profile = 0.90 m, and the initial water table level h0 = 0.50 m. The horizontal parallel systematic drainage system with drain spacing L = 11 m, average drain depth hd = 0.75 m, and diameter of the lateral drain r0 = 0.06 m is a typical shallow subsurface drainage system for heavy soils, with a low drainable pore space and hydraulic conductivity value K = 0.075 m/day, effective drainage porosity P = 0.015. The scheme of the drainage system parameters and soil conditions is shown in Figure 13.

The soil hydrology characteristics of the drained soil layers were measured in the terrain and verified in a laboratory (undisturbed core samples were used). The approximation of the hydraulic conductivity was carried out by the application of the single augerhole method, partially with the inversed single augerhole method and double ring infiltration method. The effective porosity was approximated from the soil water retention curves (Soukup et al. 2000).

The data used for the verification study were measured from June 2000 through July 2001. The measured subsurface drainage rate values were selected from the period May 4–17, 2001 after intensive precipitation (30 mm of recharge during May 4–6, 2001). During the drainage process, which was characterized by recession of the water table, no recharge to the water table level was recorded (e.g. through irrigation following rainfall, heavy rains or floods). The drainage process came to an end on May 29–30, 2001, when the drainage rate dropped below a value of 0.1 mm per day. The same data (Soukup et al. 2000) were used for approximation of subsurface drainage discharge by De Zeeuw-Hellinga theory (De Zeeuw & Hellinga 1958) and its verification (Štibinger 2009).

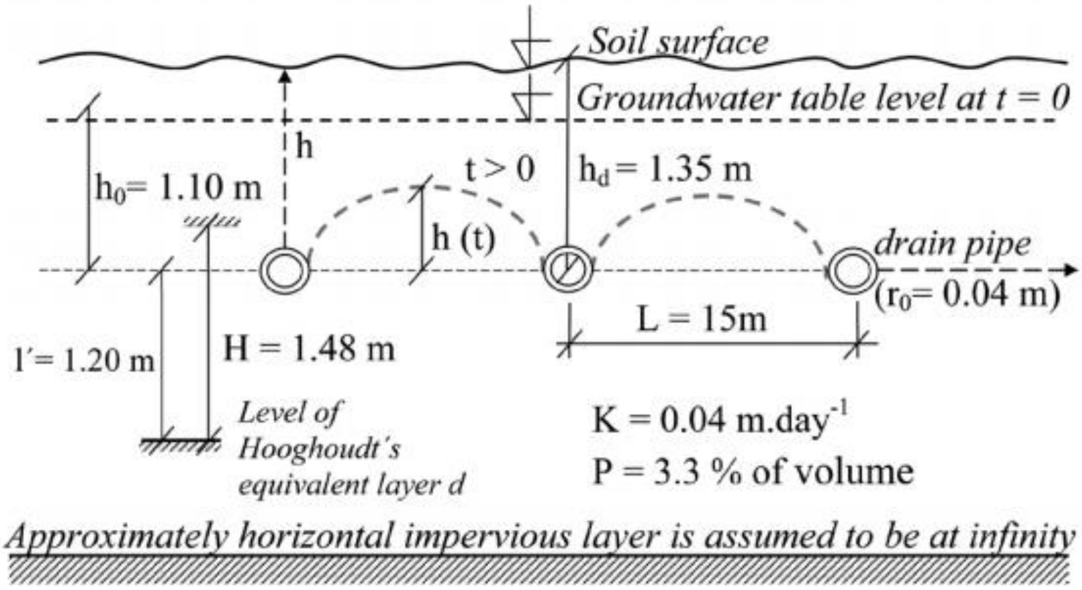


Figure 13. Drainage system parameters under unsteady-state groundwater conditions of the RISWC experimental drainage field in Prague-Zbraslav (Czech Republic)

5. Result

Calculate impact of implementation of drainage system (DREC) in forestry area of Jizera Mountains (Northern Bohemia).

After searching and determining the place with a fully saturated soil profile with a high position of the water table level that is identical with the surface. For this soil profile, based on previous researches, the most effective distance between drains can be determined as drainage system with drain spacing L (m) = 15 m, drain diameter on bottom r0 (m) = 0.5 m, and drain depth h_d (m) = 1 m.

On this area was indicated homogenous isotropic a porous environment, with representative value of hydraulic conductivity K = 1 m.day^{-1} and effective porosity P = 0.075. Impermeable barrier is placed approximately 2.0 meters below the surface. Constructed drain ditch will have width of 1.3 – 1.5 m at the terrain level and with width 0.5 m at the bottom.

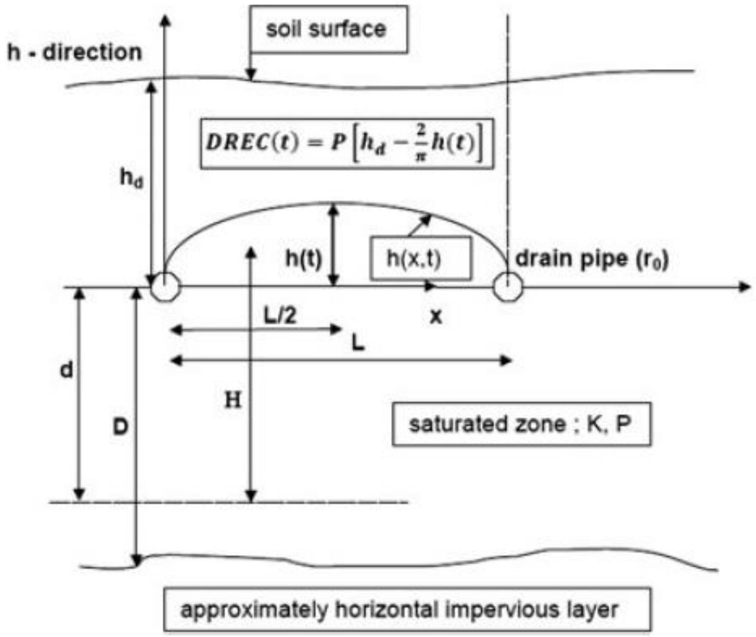


Figure 14 Water level h (x, t) at the distance x > 0 at the time t > 0, in unsteady drainage flow, supposing the horizontal initial water level (at time t = 0), with DREC(t)

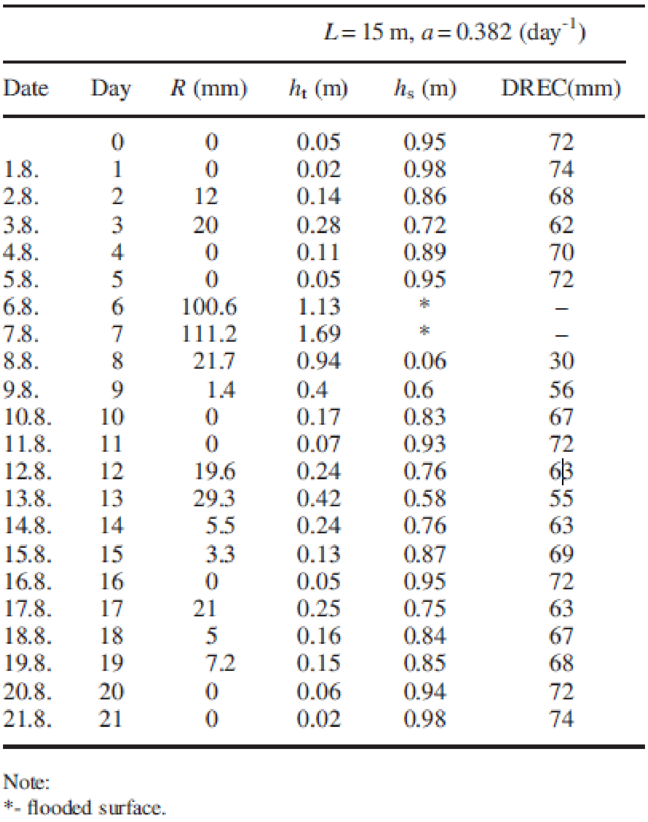
$$DREC(t) = P\left[h_d - \frac{2}{\pi}h(t)\right] \tag{18}$$

For drainage systems drain level ≤ h(t) ≤ terrain surface, respectively $0 \leq h(t) \leq h_d$ is applicable. Equations 10 for approximation of DREC(t) (M) are applicable if $h_d \geq h(t)$. In the case of transient drainage flow, inequality $h_d \angle h(t)$ implies that the surface will be flooded or waterlogged and the value of DREC(t) (M) cannot be determined by Equations 15.

The drainage system will help to avoid the negative impact of heavy rainfall and floods. The table 6 shows the successful results from the previous research.

Based on the table 4 (Territorial precipitation), months of prolonged drought can be distinguished, for example, February and November of such years as 2011, 2014 and 2018, as well as heavy precipitation in 2010, 2011 and 2013.

Table 6. Values of DREC (mm) and flooded surface in forest area, Jizera Mountains



			$L = 15$ m, $a = 0.382$ (day^{-1})		
Date	Day	R (mm)	h_t (m)	h_s (m)	DREC(mm)
	0	0	0.05	0.95	72
1.8.	1	0	0.02	0.98	74
2.8.	2	12	0.14	0.86	68
3.8.	3	20	0.28	0.72	62
4.8.	4	0	0.11	0.89	70
5.8.	5	0	0.05	0.95	72
6.8.	6	100.6	1.13	*	–
7.8.	7	111.2	1.69	*	–
8.8.	8	21.7	0.94	0.06	30
9.8.	9	1.4	0.4	0.6	56
10.8.	10	0	0.17	0.83	67
11.8.	11	0	0.07	0.93	72
12.8.	12	19.6	0.24	0.76	63
13.8.	13	29.3	0.42	0.58	55
14.8.	14	5.5	0.24	0.76	63
15.8.	15	3.3	0.13	0.87	69
16.8.	16	0	0.05	0.95	72
17.8.	17	21	0.25	0.75	63
18.8.	18	5	0.16	0.84	67
19.8.	19	7.2	0.15	0.85	68
20.8.	20	0	0.06	0.94	72
21.8.	21	0	0.02	0.98	74

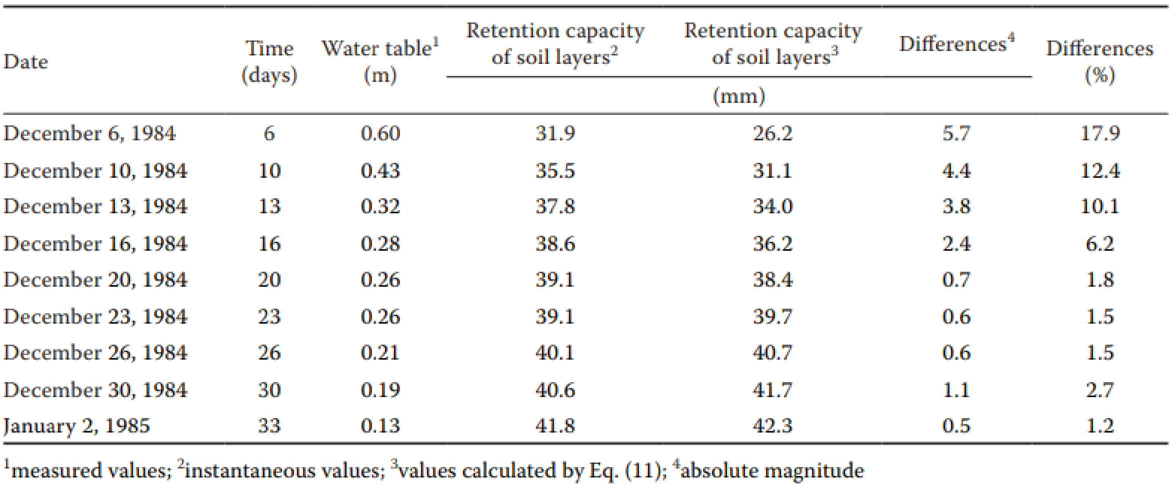
Note:
*- flooded surface.

As we can see on Table 6, with similar indicators in flooded surface, DREC shows values about 60mm, protecting the surface of the forest area well against excess runoff and floods.

Moreover, the historical record of the water table fluctuation data from winter 1984 and from the beginning of 1985 were used. Shortly after irrigation, the highest water table of 0.25 m below ground level was recorded. As the drain depth h_d = 1.35 m, this means that h0 = 1.10 m. During the drainage process, the water table h(t) falls relatively slowly with time t, following the typical exponential shape, and almost reaches the drain depth level. During the test period, no precipitation was recorded in the experimental drainage unit area. The process of subsurface unsteady-state flow into the drains was therefore not influenced by any recharge to the drainage water table (Table 7).

Table 5 shows results with the same characteristics of dry period for both the Mashtul and the RISWC experimental fields. It even seems that the calculated approximations used in Eq. (11) fit the instantaneous values closely, especially at the end of the test period. As can be seen, DREC also has a positive effect during prolonged dry periods.

Table 7. Instantaneous and calculated values of the retention capacity of soil layers from the Masthul Pilot Area (Nile Delta, Egypt) and comparison of the differences between instantaneous and calculated values



Date	Time (days)	Water table[1] (m)	Retention capacity of soil layers[2]	Retention capacity of soil layers[3]	Differences[4]	Differences (%)
			(mm)			
December 6, 1984	6	0.60	31.9	26.2	5.7	17.9
December 10, 1984	10	0.43	35.5	31.1	4.4	12.4
December 13, 1984	13	0.32	37.8	34.0	3.8	10.1
December 16, 1984	16	0.28	38.6	36.2	2.4	6.2
December 20, 1984	20	0.26	39.1	38.4	0.7	1.8
December 23, 1984	23	0.26	39.1	39.7	0.6	1.5
December 26, 1984	26	0.21	40.1	40.7	0.6	1.5
December 30, 1984	30	0.19	40.6	41.7	1.1	2.7
January 2, 1985	33	0.13	41.8	42.3	0.5	1.2

[1]measured values; [2]instantaneous values; [3]values calculated by Eq. (11); [4]absolute magnitude

After analyzing the average annual statistics in Table 3, we can conclude that the air temperature is constantly rising and possibly dry periods in this region will become more frequent. To mitigate negative consequences of these natural phenomena, you can use this drainage system. Before installing the system itself, you can calculate the utility thanks to the DREC formula and firstly to find out if the territory under consideration is efficient enough to carry out such work.

The potential of DREC can be hampered by the infiltration capacity of the upper soil layers. If the recharge intensity is higher than the intensity of infiltration of surface layers, the DREC potential will not be fully used. Low hydraulic conductivity of the surface soil layers can be problematic for the potential use of DREC. The parabolic shape of the lower permeable surface between two neighboring open drains allows non-infiltrated water to run off through the drain into the ditches. A good example of such a traditional type of surface drainage practice is the still functional bedding system in large agricultural areas

6. Discussion

This new implemented DREC is ready by infiltration to decrease the amount of precipitation and by this way to mitigate the risks of the negative impacts of floods very significantly. The renovated surface drainage system situated in agricultural mountain meadows will be equipped by mobile barriers with the possibility to control the free water level in the ditches. By suitable management of the mobile stops in the reconstructed ditches and channels it will be possible to developed drainage processes, which can function during the period of floods, heavy rains or snow melting. Furthermore, it will be possible to implement irrigation measures in case of enduring droughts. The use of DREC can help to determine the capacity of potential infiltration area and can contribute to the water regime and water resources protection very significantly. This in turn can be a good basis for designing drainage system parameters in natural sites as well as in land used for agricultural purposes.

In the period from 1997 to 2013 (16 years) there had been a total of 106 flood related casualties reported in the Czech Republic. From May 2010 to June 2013 (3 years), there had been 16 casualties reported in the Czech Republic, by Stibinger (2013). Optimising drainage capacity and infiltration conditions in landscape surface layers, in agricultural as well as in urban areas, cannot completely resolve the problem of flooding. However, these measures can mitigate negative impact of flooding, by Humannet et al. (2011).

The main purpose of agricultural or engineering drainage systems is to control the water table level in specific hydrological conditions, meeting the requirements of agriculturalists and other stakeholders. This implies the identification of the basic design parameters of drainage systems – drain spacing, drain diameter, drain depth – which affect (besides other things), the water table position and drain discharge, by evacuation of groundwater excess.

The use of DREC can help to determine the capacity of potential infiltration area and can contribute to the water regime and water resources protection very significantly. This in turn can be a good basis for designing drainage system parameters in natural sites as well as in land used for agricultural purposes.

7. Conclusion

Floods with bad outcomes have recently occurred in the Czech Republic. In addition, foresters are worried about long dry periods that negatively affect the planted forests. With climate change on our planet, the risk of flooding is only increasing. Moreover, this means that in the future, the economies of countries, individual cities and villages will be damaged, people will suffer. A small but helpful contribution to safety, both economic and social side, can be providing by Drainage Retention Capacity.

Long-term annual precipitation of this location is about 1020 mm/year, and in the past times just as at present the really extremely rainfall events was recorded there. In August 2010 the entire area of the Jizera Mountains was impacted by intense rains (100.6 mm on 6 August and 112.0 mm on 7 August) with massive flash floods. Compare to the values of precipitations demonstrated above, the DREC values presented in Table 4 are evidently smaller. But the soil surface with the certain values of DREC can infiltrate part of these precipitations, what represents not negligible amount of water of this region. By this way can DREC mitigate negative impact of hydrological extremes e.g. stormy rains, waterlogging and floods.

Drainage retention capacity (DREC) developed by reconstruction of ditches in forestry area as 60 mm and agricultural area of mountain meadow in Krisak location situated in Jizera Mountains (Czech Republic) can get the value of 92 mm. The groundwater reservoir, space between the terrain surface and the water table above the drains, without any gravity water – drainage retention capacity (DREC), can serve as an infiltration area. It is clear that this DREC values presented in Table 4 are evidently smaller than the values of the extreme rainfalls recorded in 1897 and 2010 at this region. Of course, the DREC infiltration capacity obtained by reconstruction of ditches placed at the agricultural area of mountain meadows in Krisak locality cannot eliminate the whole volume of the extreme heavy rains recorded in this region. It is very important fact that this new restored DREC is ready by infiltration to decrease the amount of precipitation and by this way to mitigate the risks of the negative impacts of floods very significantly. The renovated surface drainage system situated in agricultural mountain meadows will be equipped by mobile barriers with the possibility to control the free water level in the ditches.

By suitable management of the mobile stops in the reconstructed ditches and channels it will be possible to developed drainage processes, which can function during the period of floods, heavy rains or snow melting. Furthermore, it will be possible to implement irrigation measures in case of enduring droughts. The use of DREC can help to determine the capacity of potential infiltration area and can contribute to the water regime and water resources protection very significantly.

This in turn can be a good basis for designing drainage system parameters in natural sites as well as in land used for agricultural purposes. The approximation of DREC, at time $t > 0$ by the height of the water table midway between the drains, i.e. by equation (18), represents a great benefit for specialists in drainage hydrology engineering. By this method, DREC can be estimated in combination with the Hooghoudt Equation for steady-state drainage flow or with the Glover-Dumm solution for the case of non-steady state drainage flow or with use of transient drainage flow, the De Zeeuw-Hellinga theory may be applied. This means that the value of DREC can be assessed for any type of drainage flow conditions.

The final formula for DREC which determines the parabola shape of the initial water table and for the equation for DREC estimation in a case of the horizontal initial water table (11), are nearly identical and both very well approximate the actual values of DREC. The equations, expressions and formulas demonstrated in this paper, coming from analytical approximation and leading to the direct calculation of DREC, should be used as a simple tool for immediate assessment. They will serve as a very useful and suitable tool for DREC approximation, which requires only a minimum amount of fundamental information ,i.e. the basic soil hydrology data and parameters of the drainage system.

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