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JUSTIFICATION OF KINEMATIC PARAMETERS OF COUPLING FOR WIDE-SPAN ROW-CROP UNIT

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Abstract: *Effective use of the KhTZ-160 tractor is possible, with the specified width, combining the implementation of the main technological process with an additional, i.e. sowing with cultivation. Shows the results of calculations of the transverse displacements of the working bodies as a function of their placement along the width of unit and along its length relative to the transverse geometric axis that passes through the kinematic the center of the tractor without taking into account the curvature of the trajectory of tractor and possible changes in the position of kinematic center along the unit. The largest values of the transverse displacements of the working bodies, which are placed at a distance of 2.6 m, i.e. at the machine which is attached to the rear hinged system of the tractor, reach 14.5 cm at maximum angles of rotation of the unit (3 degrees). The smallest transverse movements of the working bodies are observed when placed on a geometric axis that passes through the axis of the rear wheels (less than 1 cm). The lateral movements of working bodies of 18-row wide-coverage row-crop unit depending on the tractor turning angle and their placement in the unit are considered. Kinematic parameters and coupling scheme are recommended.*

KEY WORDS: UNIT, TRACTOR, COUPLING, WORKING BODIES, PLACEMENT, ANGLE, DEVIATION, SCHEME.

1. Introduction

The tractor KhTZ-160 in its performance indicators refers to the tractors of traction class 3. The undercarriage system of this wheeled tractor allows it to be used for growing row crops with a row spacing of 70 cm.

The possibility of using this tractor for growing row crops (maize, sunflower) proved by research [1], but the working width of such units is equal to 8.4 m (with a 12-row scheme). Effective use of the KhTZ-160 tractor is possible, with the specified width, combining the implementation of the main technological process with an additional, i.e. sowing with cultivation (the presence of front hinged system allows you to complete such unit) [3].

According to the traction properties, this tractor is able to provide a work with three SUPN-6 seeders (or three KRN-4.2A cultivators). Creating three-machine units is possible only if there is a special coupling, which would ensure the location of extreme machines in optimal position according to criterion of movement straightness of working bodies. The placement of three working machines in the trailed machine-tractor unit (MTU) according to the traditional scheme, i.e. with rank placement, it is possible only under the condition that only sowing is performed, and inter-row cultivation of tilled crops is not performed. The use of row-crop cultivators in the three-machine version of MTU according to the rank scheme does not allow to accurately copy of the unit movement, respectively, with direction of crop rows that is being processed [4, 5].

2. Preconditions and means for resolving the problem

Based on research [2] and extensive verification of farm producers, the use of wide-span three-machine MTU is possible only when using class 3 caterpillar tractors, provided that working bodiess of side machines are located in the zone of transverse geometrical axis that passes through the kinematic center of the tractor. Therefore, for creating of such units, we have proposed to use only the semi-mounted SN-75M coupling with some modernization.

3. Results and discussion

In a wheeled tractor KhTZ-160, in contrast to a caterpillar tractor, the kinematic center is located in the area around the geometric axis of the rear wheels and this coupling does not allow for optimal placement of the side machines. Therefore, there was a need to develop a semi-mounted coupling for an KhTZ-160 tractor that would ensure optimal placement of side machines in row crop units that could be used in sowing and inter-row processing of row crops (mainly maize and sunflower). The performance of three-machine units is much more than two-machine, which is especially important when sowing a given culture (because the field is sown in one or two days).

At these technological operations there are special requirements for the straightness of the movement of the MTU and the damage to plants in the rows of the crop that is being processed [6-8]. This is explained by the fact that reliability of damage to plants of a crop that is processed depends on the rows straightness and movement of the working bodies of cultivators during inter-row processing. The main statistical indicators, as is known, are the standard deviation of the working bodies from a given direction of movement and the placement of plants in a row. The values of these indicators depend on the angular deviations of tractor from the given direction of movement and on the characteristics of tractor's trajectory curvature. According to our previous studies, the transverse displacements of the working bodies, with some assumptions, are expressed [2]:

$$\sigma_{po} = K_2 \sqrt{\left[\frac{K_1(1-\cos\alpha)}{\grave{a}\cdot\sigma_\rho}\right]^2 + \left[L\cdot\sin\alpha \pm B(1-\cos\alpha)\right]^2}, \quad (1)$$

where σ_α , σ_ρ – root mean square values of the angular deviations of tractor and the radius of curvature of its trajectory; B, L – parameters that characterize placement of working body on the width and length of the unit; K_1, K_2 – correction factor and the coefficient of "conditional stiffness" of the entire system of the unit; a – coefficient of proportionality, which takes into account the proportion of standard deviation and for the normal distribution is taken 0.63.

Considering that in this case, we consider only the coupling parameters that affect the deviation from the direction of movement, Table 1 shows the results of calculations of the transverse displacements of the working bodies as a function of their placement along the width of unit and along its length relative to the transverse geometric axis that passes through the kinematic the center of the tractor without taking into account the curvature of the trajectory of tractor and possible changes in the position of kinematic center along the unit.

The results of calculations of the values of the transverse displacements of the working bodies are presented in the graphs (Fig. 1-3). Previous studies have revealed that lateral deviations of the working bodies from the direction of movement to the outside and towards the center of the unit are different, therefore on the graphs in fig. 1-3 shows only external transverse movement of working bodies, as more significant).

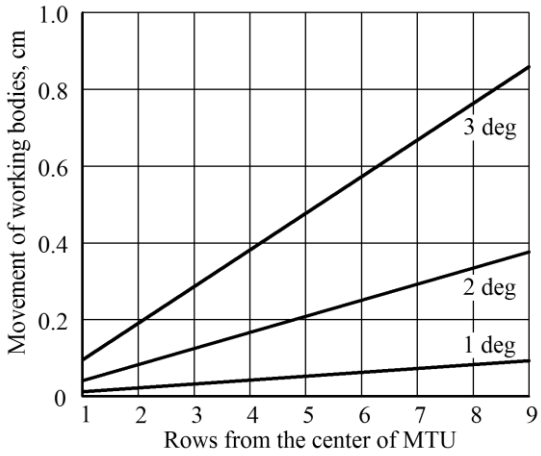

Fig.1. *Transverse movement of the working bodies at L = 0 and turning angle of MTU 1, 2 and 3 degrees*

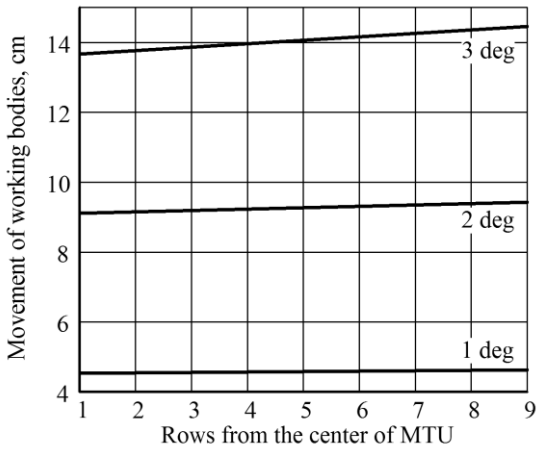

Fig.2. *Transverse movement of the working bodies at L = 260 cm and turning angle of MTU 1, 2 and 3 degrees*

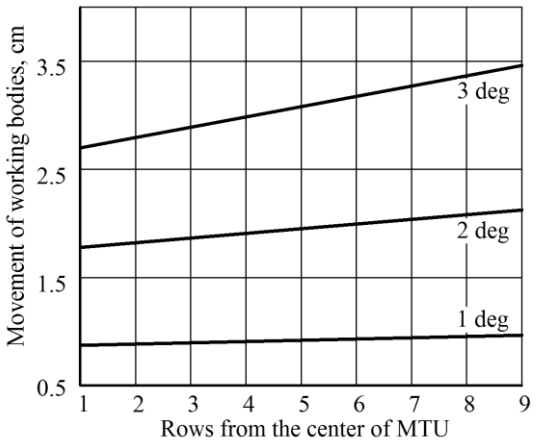

Fig.3. *Transverse movement of the working bodies at L = 50 cm and turning angle of MTU 1, 2 and 3 degrees*

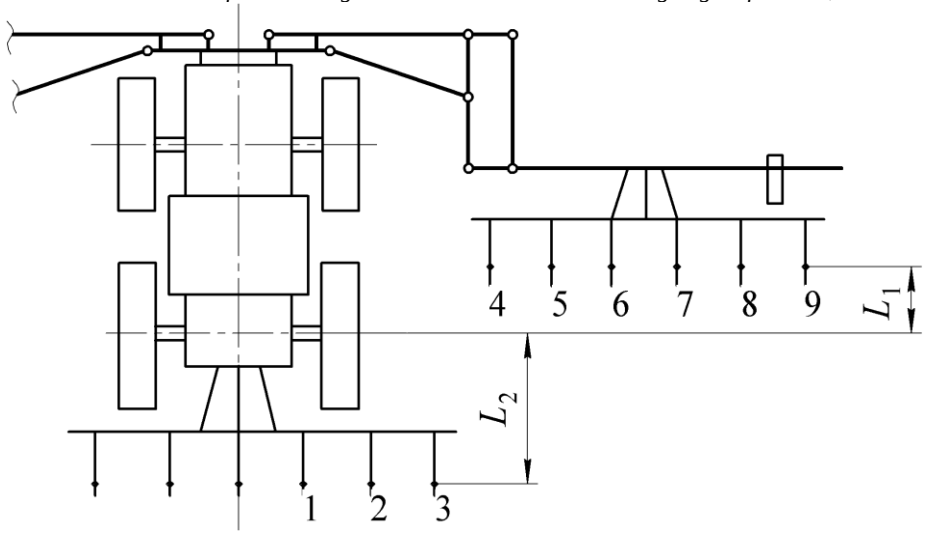

Fig.4. *The simplified scheme of the unit with an experimental coupling ZPN-18*

4. Conclusions

1) The largest values of the transverse displacements of the working bodies, which are placed at a distance of 2.6 m, i.e. at the machine which is attached to the rear hinged system of the tractor, reach 14.5 cm at maximum angles of rotation of the unit (3 degrees), fig. 2

2) The smallest transverse movements of the working bodies are observed when placed on a geometric axis that passes through the axis of the rear wheels (less than 1 cm).

3) The lateral movement of the working bodies when placed at a distance of 50 cm from the transverse geometric axis of the rear wheels of the tractor is insignificant and fully meets the agro demands.

4) The transverse movements of the working bodies increase with their distance from the longitudinal geometric axis of the unit, especially with significant angular deviations of the MTU.

When developing the actual design of the proposed coupling, minor deviations can be allowed with respect to the placement of the side machines along the unit in order to reduce the forces on the longitudinal links and some articulated joints. But the deviation of the placement of side machines from optimal position, in our opinion, is not allowed more than 50 cm. In this case, if the kinematic center of the unit will move slightly in longitudinal direction and transverse movements of working bodies will be minimal.

Based on the above requirements, the following coupling scheme is proposed. Fig.4.

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BIOGEOCHEMISTRY OF LIGNIN IN SOILS OF MOUNTAINOUS LANDSCAPES

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Abstract: *The relative proportions of lignin phenols are determined by the phylogenetic origin of plants and allow the formation of various low- and high-molecular-weight products of lignin decomposition in the soil, which are involved in humus formation. A whole spectrum of transition vegetation zones are concentrated in the mountain landscapes. The immediate aim of this work was to study the transformation of lignin structures in the soils of different mountainous ecosystems of Tian-Shan and Caucasus. The determination of the lignin in the plants, and soils involved the alkaline oxidation with copper oxide at 170° C under pressure in a nitrogen environment. The phenolic components of the lignin were separated using a gas-liquid chromatography. The composition of lignin phenols in soils serves as a molecular trace of land vegetation and palaroenviromnents.*

Keywords: LIGNIN PHENOLS, MOUNTAIN SOILS, CAUCASUS, TIAN-SHAN, ORGANIC MATTER, BURIED SOILS

1. Introduction

The periglacial edges of the biosphere, represented by biogeosystems of high mountain landscapes, are the first to react to any fluctuations in the regional or planetary climate. It is in the mountain landscapes a whole spectrum of transition zones between the steppe and meadow, the forest and the meadow, the steppe and the meadow are concentrated, and the boundaries of which are mobile in time and depend on the climate. In some mountain regions, for example, Tien-Shan mountains, the forest belt properly is absent. The whole interval from 1800 m to 2800 m a.s.l. is regarded as transition between the steppe and the alpine meadow. It was just geographic feature of the region and serve an impotant argument in favor of this area as an object for key study.

On the other hand, technological advances and the rapid development of new high-resolution instrumentation in the study of soil organic matter, including high-performance liquid chromatography, and gas chromatography combined with mass spectrometry, make it possible to detect molecular traces of both recent and relict biochemical processes in soils. Soil organic matter is the informative archive of Holocene climatic and paleoenvironmental events, since it has different types of biomarkers - molecular traces of life..

Biomarkers are organic molecules of the known structure and origin. Many biomarkers are resistant to degradation and mineralization in soils under specific conditions because of their specific structure and biochemical functions; therefore, they serve as molecular traces of paleobiota (lipids) and land vegetation (lignin) and as indicators of the rates of recent and past biochemical processes occurring in the biosphere. Individual organic compounds are well preserved not only in the normal profiles of postlithogenic soils, but also in their redeposition products, soil-colluvial and soil-alluvial complexes, pedosediments, pedoliths, derivatives of separate horizons, bottom sediments of water bodies, etc. The information role of biomarkers is important when the pool of molecular products of organic matter decomposition in soils is not identical to the sum of individual waste components because of the masking effect of the mineral matrix. The organomineral soil particles or soil concretions favor the preservation of individual organic molecules in time (Angst et. al., 2017) by marking the paleoconditions of their formation.

But the current database on the contents of similar individual compounds in soils is still poor. For example, lignin is the most prevalent natural phenolic compound of plant origin. Lignocelluloses make up 70 to 90% of the dry weight of plant tissues. The highest contents of lignin are in woody plants: lignin makes up 18–25% of wood biomass in deciduous species and 25–33% in coniferous species, while grasses contain about 4–9% lignin. Chemically, lignin is an irregular three-dimensional biopolymer of high molecular weight composed of branched phenylpropane units with colloidal properties (Ertel and Hedges, 1984). The relative proportions of the component phenols are determined by the phylogenetic origin of plants and thus cause the appearance of many various low- and high-molecular-weight products of lignin decomposition in soils of different ecosystems. Different types of plants and plant communities produce a phylogenetically specific and strictly individual set of phenolic compounds.

Microorganisms capable of completely decomposing lignin do not exist (or are unknown). Their oxidizing enzymes of peroxidase type only catalyze the breakage of bonds in the lignin molecule under good aeration conditions and at low phenol concentrations: 0.025–0.050 for bacteria and up to 1% for brown and white rot fungi (Amelung,, 1997). The high stability of lignin phenols in buried soils is due to the fact that the phenylpropane moieties after burial enter in carboxylation and fragmentary condensation reactions, and their structural unites become less capable of entering into biochemical reactions, especially at the decreased biological activity.

Therefore, the aim of this work was to assess the information role of individual organic compounds of lignin origin and their applicability as molecular traces of paleoenvironments, focusing on the mountain soils of complex genesis.

1. Materials and Methods

Lignin preparations were isolated from different tissues of woody and herbaceous plants of the temperate and subtropical regions, surface humus and mineral soil horizons and buried humus horizons of mountain soils. Studies were performed in the ecosystems of vertical natural zones under subboreal humid (Northern Caucasus) and subtropical continental climatic conditions (Tian-Shan).

The soil–vegetation zones included, first, the mountainous biocenoses of the Northern Tian-Shan (at the longitude of the city Bishkek, 74º 42´ E at elevations between 1800 and 3400 m above sea level on and interfluve of the Alamedin and Ala-Archa Rivers of Kirgizskiy Range). The studied valley contains typical glacial features including U-shaped cross-sections, cirques, moraines, and glaciofluvial sediments. Bedrock is comprised of limestone, diorite, porphirite and metamorphic rocks. This study examined 40 soil profiles, representing the change of soil types from the foothills to the top slope of the Tatyr, Chon-Kurchak, Kurchak-Tor valleys.

The older members of the chronosequence developed on the lowest frontal moraines of the Last Glacial Maximum (Kovaleva et. al, 2018) at altitudes of 1900-2100 m. These soils are Chernozems Haplic. Vegetation cover is herbage-estragon meadow-steppe. Soil texture is strongly affected by aeolian silt additions, that have resulted in burial of soil horizons (e.g., Bb_1, Bb_2, Bb_3 horizons above). Upvalley polygenetic soils, having buried A and B horizons

are formed on the moraines of Late Glacial Ice advances at 1200, 2350, 2450 and 2600 m above sea level. These soils are can be classified as Leptosols Mollic. Vegetation is a prairie-grass-herbage meadow steppe and dry subalpine meadows. Cambisols Humic are formed under Spruce and Juniper forest or under walnut-apple trees forest on the slopes at 2400 - 3000 m. Monogenetic Holocene soils developed on the frontal moraines with large porphyrite and granite-diorite boulders occur at altitudes of 3100 m. These soils are in the initial stages of their formation and are classified as Leptosols Umbric. Vegetation is cobresia meadow.

Studies were also conducted in the Northern Caucasus region: in the steppe zone of mountain Chernozems Haplic in the Kislovodsk region (11 soil profiles at altitude from 500-1300 m; N $43^0$91'; E $42^0$72') on the lowest frontal moraines of the Last Glacial Maximum; in the prairie-grass-herbage meadow steppe with Leptosols Mollic on moraines of Late Glacial ice advances (Arkhys settlement at 1300 m; N$43^0$68'44"; E$41^0$47'53"; 19 soil pits); in the hornbeam chestnut and fir forests on Cambisols Humic on the slopes at 1000-2000 m (Teberda reserve, 7 soil pits); in the subalpine and alpine meadows on Leptosols Umbric on the frontal moraines (15 soil profiles, Teberda reserve, Karachai-Cherkessia region) at 1500-3000 m in glacial valleys of Alibek and Myschy.

All samples taken from soil pits were air dried, sieved (<2mm), and ground prior to chemical analysis.

Lignin phenols were isolated in triplicate from living plant tissues (wood, roots, needles) and soils, using Amelung's version (1997) (described below) of the Ertel–Hedges procedure (1984). The determination of the lignin involved the alkaline oxidation with copper oxide at 170°C under pressure in a nitrogen environment; the precipitation of humic acids; and the concentration of the phenolic products under pressure on compact disposable C18 columns. After the samples were passed through the columns, the columns were dried and the lignin was dissolved in ethyl acetate. The lignin preparations were isolated by the evaporation of ethyl acetate using a rotor evaporator. The phenolic components of the lignin were separated using a gas-liquid chromatograph after preliminary derivatization and conversion into trimethylsilyl esters. A gas chromatograph with a mass spectrometer (Hewlett-Packard, Palo Alto, CA, United States) equipped with a flame-ionization detector and a capillary column was used. Nitrogen was the main and marking gas. The injector temperature was 250°C; the detector temperature was 300°C. The individual reaction products (vanillin; syringic aldehyde; and vanillic, syringic, *p*-coumaric, and ferulic acids) were identified by comparing the retention times (in minutes) and peaks with those of known components in known concentrations used as external standards. Although the method is highly sensitive and can determine trace amounts of phenols, the analysis was accompanied by significant losses of lignin decomposition products (up to 50%). To improve the reproducibility of the analytical results, glucose was added to the soil samples as an oxidation catalyst and ethylvanillin was added as an internal standard before the alkaline oxidation. Phenylacetic acid was added to the samples as the second internal standard before the derivatization. The reproducibility was thus increased to 95%. The alkaline oxidation of vascular plant materials and residues with copper oxide in the soil yields 11 phenols (Hedges, & Mann, 1979), which can be grouped in accordance with their chemical nature into three structural families: vanillic (V), syringic (S), and cinnamilic (C) ones. The first two phenol types are found in mixed oxidation products of plant tissues as aldehydes (al), ketones, and acids(ac); the latter include only acid forms: ferulic (F) and *p*-coumaric (K) acids. The phenol mixture obtained after the oxidation of lignin is best described by the parameters characterizing the weight combinations of its components. The sum of the oxidation products is thus indicative of the total lignin content in the sample. In the plant tissue and soil samples from the above objects of study, the carbon and nitrogen were determined using a Carlo Erba ANA 1500 C/N/S Analyzer. The sampling procedure of the plant tissues and the values of the plant productivity were reported earlier. For the analysis of the above and underground plant biomasses, samples were taken in three and five replicates. The isotope composition of carbon in soil organic matter was determined on a Thermo V Plus isotope-ratio mass spectrometer and a Thermo Flash 1112 elemental analyzer. The soil was purified from carbonates by the HCl fumigation.

3. Results and Discussion

3.1. Lignin in plant tissues

The rate of lignin decomposition in soils is largely determined by the source of this biopolymer: the type of plant tissues and their anatomic structure. Although insufficient data are available on the biochemical composition of the different organisms involved in humification, it is considered established that different types of plant tissues (gymnosperms and angiosperms, woody and nonwoody, and aboveground and underground) have contrasting lignin parameters (Ertel and Hedges, 1984)). The data in Table 1 show that we confirmed the existing tendencies and found three known lignin types in our samples. First, the lignin of coniferous plants (soft wood lignin) contains vanillin phenols as major structural units: up to 60 mg/g Corg in juniper roots and up to 80 mg/g Corg in the fir falloff. The content of cinnamic alcohols in the needles, wood, and especially roots of pine and juniper is low; syringic acids and aldehydes are almost absent in the needles, and S/V = 0.

Table 1: *Lignin parameters of plant tissues* (mg/g Corg)

	Lignin (VSC)	V	S	C	S/V	C/V	V:S:C
Pine							
Needles	27,70	20,40	0	7,30	0	0,36	3:0:1
Roots	40,80	36,95	2,17	1,68	0,06	0,05	22:1:1
Falloff	12,33	7,07	0	5,26	0	0,74	1:0:1
Juniper							
Needles	6,98	2,24	1,46	3,28	0,65	1,46	1:1:2
Wood	23,01	62,40	5,38	4,64	0,42	0,26	2:1:1
Roots	66,88	12,96	1,43	3,05	0	0,11	41:1:2
Falloff	23,20	17,03	2,87	3,30	0,19	0,30	5:1:1
Fir							
Falloff	81,33	52,77	10,46	18,10	0,13	0,34	5:1:2
Walnut, apple tree							
Falloff	10,18	6,50	2,99	0,46	0,46	0,11	9:4:1
Steppe, grasses							
Phytomass	42,09	5,26	5,61	31,22	1,02	5,20	1:1:2
Detritus	10,12	4,17	4,31	1,63	1,03	0,72	3:3:1
Steppe, herbs							
Phytomass	25,00	9,91	11,08	4,01	1,12	0,40	2:3:1
Detritus	13,06	5,71	5,72	1,64	1,00	0,29	4:4:1
Subalphine meadow							
Phytomass	39,43	8,59	8,63	22,21	1,00	2,58	1:1:6
Roots							
0-30 cm	45,84	10,52	14,12	21,20	1,34	2,02	1:1:2
30-60 cm	48,72	11,73	15,80	21,19	1,35	1,82	1:1:2
Alpine meadow							
Phytomass	35,90	5,79	10,46	19,65	1,81	3,39	1:2:3
Roots							
0-30 cm	72,02	10,05	25,21	36,76	2,51	3,66	1:2:4
30-60 cm	48,48	8,48	17,29	22,71	2,04	2,68	1:2:3

Second, the lignin of deciduous trees (hardwood lignin) predominantly consists of similar amounts of vanillic and syringic structures. The lignin in deciduous species of Caucasian mountain forests (birch, beech, and chestnut) hardly differs from that in the tree leaves of the temperate zone and the walnut mountain forest of the Tien-Shan and contains similar amounts of vanillic and syringic phenols. The S/V and C/V ratios are higher than 0 but lower than 1. The content of cinnamic phenols is close to 0.

The third lignin type is the lignin of herbaceous plants, which

contain the largest amounts of cinnamic structural units: their content in steppe and meadow grasses and herbs increases to 20–30 mg/g C, which is higher than in woody plants by 4–6 times. The content of syringic phenols in herbs is similar to that in angiosperm wood but exceeds that in leaves by 5–6 times. Ferulic acids are mainly associated with hemicelluloses in the cell walls of grass fibers. Their content reaches 15–20 mg/g Corg in the aboveground phytomass and roots of grasses. It is also noteworthy that the largest amount of lignin phenols is in the underground tissues of plants.

Both in the tree and herbaceous plant covers, the root lignin is predominant: up to 66 mg/g C in juniper roots, as well as up to 51 mg/g C in grass roots at a depth of 0–30 cm and 49 mg/g C at a depth of 30–60 cm. The coefficient of correlation between the lignin content in the soil and root biomass is 0.92 (κ= 0.95) for subalpine meadow ecosystems, 0.93 (κ= 0.95) for alpine ecosystems, and 0.99 (κ= 0.95) for thin juniper forests.

This fact can be indicative of a more important contribution of the root biomass to the formation of soil humus than is generally considered. Thus, the oxidation and chromatographic separation of lignin biopolymers into simpler phenols provide information about the types of plant tissues. In addition, the S/V ratio can be used to discriminate between the tissues of gymnosperms and angiosperms, and the C/V ratio can be used to separate the organic matter of wood and nonwood origin. The type of plant tissues primordially creates unequal conditions for the transformation of aromatic components of plant origin into aromatic compounds of soils.

The comparative study of lignin accumulation in the living phytomass and falloff of plants allows the conclusion to be drawn that the amount of lignin arriving onto the soil surface in the ecosystems of coniferous forests is double that in hardwood forests. The highest content of lignin was found in the mats of subalpine (26.47 mg/g Corg) and Alpine (81.68 mg/g Corg) forests, whose role in the formation of carbon pools is usually not considered.

3.2. Lignin in mountain soils

A parabolic distribution of lignin from the foot to the tops of ridges with a maximum content of lignin in Chernozem Hapluc and chernozem-like soils (Leptosols Mollic) is observed for the soils of the vertical zonal series as in Tian-Shan mountains, as in Caucasus.

Different authors (Ertel and Hedges (1984), Amelung, W. (1997)) noted the good preservation of the composition ratios between the lignin phenols in soils. This fact can form the basis for diagnosing the origin of the lignin from the lignin parameters of the plant tissues that remain in the soil. For example, the lowest syringic-to-vanillic phenol ratios (S/V < 0.5–0.6) are typical for all the soils of coniferous ecosystems because of the absence of syringic phenols. The C/V ratio can be used for the separation of wood and nonwood materials in the soil organic matter, because cinnamic phenols are present only in the nonwood tissues of plants: it has the minimum value (0.22) in the brown soil of the fir forest and reaches 3.90 in the mountain-meadow Alpine soils. The *p*-coumaric-toferulic acid ratios are the maximum in the soils of the herbaceous ecosystems and tend to zero only in ecosystems with the predominance of grasses.

Ertel and Hedges (1984) convincingly showed that the content of aromatic acids relative to aromatic aldehydes increases with the degree of decomposition of organic matter. The results of using the above values are given in Tables 2 and 3. It follows that the higher the lignin contents (VSC), the lower the degree of oxidation of the biopolymer (Ac/Al)v typical for the mountain-meadow soils of Alpine and subalpine meadows, which well agrees with the retarded mineralization of the plant residues. The humid ecosystems of the Northern Caucasus region, which have low vanillic acid/vanillin ratios (0.08–0.13) show significantly lower degree of biotransformation of lignin structures compared to the droughty ecosystems of the Tien-Shan. In the latter case, the vanillic acid/vanillin ratio varies from 0.2 to 0.9. These results do not contradict our data on the humate character of the humus in the Tian-Shan soils (Kovaleval, 2018) compared to the predominantly fulvate humus character in the soils of the Caucasus region

Table 2: *Lignin parameters in soils of Northern Tian-Shan (mg/g Corg)*

Soil depth, cm	Lignin (VSC)	Vanillic acids/ vanillin	Syringic acids / syringic aldehydes	S/V	C/V	V:S:C
Chernozems Huplic (Steppe)						
12-38	1,37	0,59	0,75	0,16	0,52	2:1:1
38-53	1,13	0,20	0,89	0,21	0,14	5:1:1
53-83	2,34	0,22	0,42	0,63	0,20	3:3:1
110-120	0,94	0,91	2,01	0,50	0/10	8:4:1
Leptosoils Mollic (Meadow steppe)						
4-35	0.19	0.30	0.68	0.70	0.58	2:1:1
35-50	0.18	1.18	4.72	0.27	0.79	3:1:3
50-67	0.28	0.28	0.25	0.57	0.69	2:1:1
Leptosoils Mollic (Pine forest)						
10-33	3.91	0.46	0.55	0.55	0.47	2:1:1
33-52	8.23	0.34	0.47	0.47	0.34	3:1:1
Cambisoils Humic (Juniper forest)						
15-30	3.91	0.46	0.44	0.51	0.26	4:2:1
30-60	8.23	0.39	0.52	0.69	0.53	20:12:1
Cambisoils Humic (Walnut forest)						
10-20	7.79	0.27	0.01	0.96	0.00	18:17:1
Leptosoils Umbric (Subalpine meadow)						
5-20	3.19	0.29	0.50	0.35	0.59	2:2:1
20-50	1.12	0.46	0.46	0.85	0.56	2:2:1
Leptosoils Umbric (Alpine meadow)						
3-20	4.85	0.14	1.69	0.55	3.88	2:1:7
20-35	1.57	0.06	0.35	0.65	0.66	2:1:1
35-50	1.97	0.10	0.24	0.72	0.34	3:3:1

The results suggest different characters of the organic matter transformation in the soils of different ecosystems. The steppe biotransformation of lignin is characterized by the highest values of the oxidation parameter ((Ac/Al)v= 0.10–0.60) in the chernozems, chernozemlike soils, and Cambisoils. In the forest decomposition of lignin the (Ac/Al)v ratio has medium values. The meadow transformation type of lignin structures is characterized by minimum acid/aldehyde ratios. The highest degrees of oxidation of lignin molecules ((Ac/Al)v= 5–6) are typical for the buried humus horizons (Tables 2, 3). This fact can be related not only to the diagenetic transformations of humus but also to the different hydrothermal potential of the soil-forming environment.

3.3. Lignin in buried soil horizons

The composition of lignin phenols with the predominance of cereal cinnamyls in the buried horizons of chernozem-like Tien Shan subalpine soils (2 : 1 : 1) confirmed the supposition about the chernozem stage of pedogenesis in the middle Holocene (about 5500 years ago) and revealed the forest genesis of illuvial horizons about 7000 years old (Kovaleva, 2018). Their proportions of the vanillyl, syringyl, and cinnamyl phenols is typical for the woody plants with the predominance of vanillyls: 5 : 2 : 1.

Table 3: *Lignin parameters in soils of Northern Caucasus* (mg/g Corg*)*

Soil depth, cm	Lignin (VSC)	Vanillic acids/ vanillin	Syringic acids / syringic aldehydes	S/V	C/V	V:S:C
Chernozems Huplic (Steppe)						
0-10	10.12	0.10	0.18	1.03	0.39	3:3:1
10-30-	12.12	0.11	1.34	0.99	0.70	1:1:1
30-32	15.45	0.08	0.17	0.98	0.41	2:2:1
Cambisoils Humic (Fir forest)						
10-25	1.86	0.13	0.17	0.46	0.22	5:2:1
25-35	1.09	0.13	0.43	0.30	0.22	5:2:1
Leptosoils Mollic (Subalpinev meadow)						
10-25	16.68	0.13	0.34	0.60	0.35	3:1:1
30-40	38.08	0.12	0.26	0.88	0.29	3:3:1
Leptosoils Umbric (Alpine meadow)						
0-10	4.37	0.11	0.23	0.55	0.46	2:1:1
10-20	4.84	0.13	0.30	0.42	0.30	3:1:1
50-60	2.32	0.14	0.68	0.38	0.24	4:2:1

The lightening of isotope ratios δ13C to −28.8‰ in the studied horizon confirms the hypothesis about the distribution of coniferous forest in mountain valleys during the early Holocene. On the contrary, the accumulation of cinnamyl phenols in the second humus horizons of the late Holocene (3 : 1 : 3) (Table 3) well agree with the existence of the steppe period of landscape formation in mountain valleys that we proved earlier (Kovaleva, 2018). The molecular traces of the upward shift of vegetation zones are also preserved in the isotope composition of humus from subalpine chernozem-like soils (δ13C –25 to –24‰) typical for mountain chernozem.

Of special interest is the composition of lignin in the horizons of Pleistocene soils buried in loess deposits. The ratio V : S : C = 8 : 4 : 1 is similar to that in plants of tropical forest (Tables 2, 3) and close to the proportions of lignin phenols in red-colored soils under current juniper forest. In combination with the anomalously heavy δ13C (–8 to −12‰), the presence of molecular traces of the Pleistocene tropical flora in the studied soils can be supposed. It is known that all woody plants and most of the shrubs and herbs of the cold and moderate climate are classified among the C3 plants, and their δ13C values are about −28‰. The C4 plants with isotope ratios of about −14‰, including the herbs of tropical savannas, are adapted to a drier climate, high temperatures, and low CO2 concentrations in the atmosphere.

The molecular traces of an upward shift of the forest boundary were recorded in the Northern Caucasus from the proportions of lignin phenols typical for the forest soils (4 : 2 : 1) in the lower part of the humus horizons of mountain-meadow soils. The composition of lignin phenols in the humus horizon of mountain-meadow soil formed about 3600 years ago coincides with the heaving of δ13C (to –25.69‰), which indicates the shift of all zonal boundaries to the cosystems in the upper zones. This was the time of distribution of burozemic soils (with the predominance of vanillyl structures in the lignin composition) on slopes and the advance of meadow-steppe herb-grass associations (with the equal proportions of vanillyls and syringyls) on chernozems (2 : 2 : 1) upward in the mountain valleys. In the recent humus horizons of burozem and mountain chernozem, the proportions of lignin phenols are typical for the forest and meadow-steppe soils (5 : 2 : 1 and 3 : 3: 1, respectively). The isotope ratios typical for the woody and herbaceous plants of the temperate zone (–26.91 and –26.07‰, respectively) also agree with them. The proportions of lignin phenols inherent of herbaceous meadow associations (3 : 1 : 1) are established after the end of the medieval climatic optimum (Arkhyz interval) 500–300 years ago, which is also confirmed by the lightening of isotope ratios in the recent humus horizons of the studied soils (–25.70 to –26.91‰).

4. Conclusion

Analysis of the presented data on the composition of lignin phenols in plant tissues, as well as in the recent and buried horizons of different polygenetic mountain soils, reveals that the composition of lignin phenols in soils serves as a molecular trace of land vegetation and palaeoenviromnents. The proportions of lignin phenols remain unchanged in soils for a long time.

Within the ranges of the regional climatic conditions, the biochemical composition of the plants in different ecosystems has a decisive effect on the character of the humification and determines the humus formation mechanism and the structure of the soil humic acids. The steppe biotransformation of lignin is characterized by the highest values of the oxidation parameter in the chernozems, chernozem-like soils and Cambisoils. In the forest decomposition of lignin the (Ac/Al)v ratio has medium values. The meadow transformation type of lignin structures is characterized by minimum acid/aldehyde ratios. The highest degrees of oxidation of lignin molecules are typical for the buried humus horizons. This fact can be related not only to the diagenetic transformations of humus but also to the different hydrothermal potential of the soil-forming environment.

The qualitative composition of lignin phenols in plants is reflected in the δ13C values of soil humus. The cinnamyl phenols make heavier the isotope ratios, which are very sensitive to C3–C4 changes. At the same time, the vanillyls and syringyls of woods and shrubs (C3 type of photosynthesis) lighten them.

5. Acknowledgments

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6. Literature

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THE INCREASE IN THE YIELD OF VEGETABLES IN GREENHOUSES USING SUPERCAVITATION TREATMENT OF IRRIGATION WATER

УВЕЛИЧЕНИЕ УРОЖАЙНОСТИ ОВОЩЕЙ В ТЕПЛИЦАХ С ИСПОЛЬЗОВАНИЕМ СУПЕРКАВИТАЦИОННОЙ ОБРАБОТКИ ПОЛИВНОЙ ВОДЫ

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Abstract: *The use of hydrodynamic and thermophysical effects of cavitation (cavitational technology) facilitates mechanical thermolysis of the water structure with free hydrogen bonds production, dispersion and solution annealing treatment to produce resistant emulsions, suspensions, and mixtures finally promising to improve and intensify the processes in various industries. There are given the results of the cavitation treatment effect on the properties of water which at times is a dispersed phase and at other times is a dispersion medium. In agriculture the use of the cavitation-treated water allows to get a crop capacity gain for greenhouse vegetable cultures up to 30 % with simultaneous reduction of plants morbidity. It is obvious that the major factors influencing the produced effect are the increased oxygen content of the treated (activated) water as well as the complex physical and chemical processes occurring under the cavitation effect: redox reactions that proceed in the water between the dissolved substances and the water splitting products emerging in cavitation bubbles and passing into the solution after their collapse; reactions between the dissolved gases inside cavitation bubbles; chain reactions in the solution initiated by the products of splitting in impurities cavitation bubbles; macromolecules break-down and its initiated polymerization; water structure change with the production of free hydrogen bonds, etc.*

KEYWORDS*: CAVITATION, HIGH-VELOCITY HYDRODYNAMICS, POLYPHASE FLOWS, SUPERCAVITATION, THE INCREASE IN THE YIELD.*

1 Introduction

As bodies move in a dropping liquid at high speeds (about 30 m/s and higher) and pressure in the liquid reaches the pressure of its saturated vapors at the designed temperature, the phenomenon of cavitation appears. By the classification adopted in 1955 at a symposium in London [1], the mechanism of development of cavitation is treated as the inertial development of bubbles (vaporous cavitation) or as the diffusion of a dissolved gas in the cavitation core (gaseous cavitation) from a flowing fluid or from cracks on a body's surface (the Kornfeld–Suvorov hypothesis [2, 3]).

At present, basic and applied problems of research in cavitation within the modern objects of the technosphere are priorities for ensuring their safety. The hydrodynamics of cavitating flows, distinguished by the presence of gas–vapor inclusions (separate bubbles, bubble clusters and clouds, and supercavitation pockets), has a number of peculiarities that significantly hinder its study, simulation, and, ultimately, control. This is especially important for high-velocity flows. The motion paths of particles can mismatch the flow lines of the carrying medium; here the development of instabilities on the boundaries of the phase interface has a significant influence in gas–vapor inclusions. Shock-wave propagation has distinctive features in a polyphase medium. Studies on the dynamics of processes that occur near the surface of a body in the conditions of cavitation are extremely important.

The current state of the methods of numerical simulation of cavitation processes does not make it possible to ensure fully the acceptable level of their description even when using the most advanced models and supercomputers. This is due to the extreme complexity, immensity, and diversity of physical processes that take place during cavitation. Therefore, one of the main vectors to improve the efficacy of research into cavitation flows is the design and development of experimental equipment and technologies for model and field studies, taking into account the scale effect. Information about thermodynamic properties and phase equilibria in multicomponent systems is, as a rule, limited [4, 5].

Currently a trend has developed to unite state-of heart mathematical tools and computational technologies to solve practical problems in various industries. It is important that most continuous production flows are accompanied by heat–mass exchange processes in conditions of complex hydrodynamic phenomena, for example, supercavitation [5]. However, it is rather difficult to consider and study the above processes simultaneously. Basically, theoretical and applied problems are considered from different points of view separately, taking little account of how some processes affect others. Uniting the effects of the heat exchange, mass transfer, and hydrodynamics of interacting media into a single computational process based on large-scale physical simulation is one of the most important problems of high-velocity hydrodynamics.

Computational technologies based on state-of theart mathematical methods are becoming the main tool for the development of fundamentally new technologies and engineering systems. Mathematical modeling is an integral part of unique physical experiments and forecasts. On the other hand, the development of methods of mathematical description should, of course, be accompanied by a broad set of verifying experiments, performed on process units of various scales. This evolutionary process may result in scientifically substantiated methods of calculation of the main technological and design parameters (geometrical, hydrothermodynamic, and cavitational) when designing reliable and highly efficient technological apparatuses in industries in which the processes of heat and mass exchange and hydrodynamics of interacting currents play an important role [4–6].

2 Scientific problems of high-velocity hydrodynamics

In 1971, at the opening of the IUTAM International Symposium (Leningrad), Academician L.I. Sedov noted, "…a cardinal solution to high-speed motion of bodies in water is associated with solving hydrodynamic problems implementing fundamentally new schemes of flow around bodies and using new propulsion systems" [7, p. 9]. This thesis has retained its relevance to this day. The problem of water resistance and the problem of new and more powerful thrust-engine systems are closely interrelated and, regardless of the heat medium (chemical or atomic), are, basically, problems of high-velocity hydromechanics. The realm of problems associated with the flow of biphasic media (in this case, supercavitating flows) is extremely broad and includes studies on the flow of systems such as "fluid–fluid", "fluid–solid," and "fluid–gas" [7–11]. Many aspects of these problems are covered by numerous publications, the topicality of theoretical and experimental studies on biphasic systems increasing with the creation of samples of new equipment and armaments. Fundamental knowledge of specific propagation of disturbances in biphasic media (for example, in vapor–gas–fluid flows) of different flow

structures (regimes) is necessary to analyze the safety and efficacy of the corresponding systems.

Of interest are processes of exciting cavitation by pulses of negative pressure and of the propagation of these pulses in gas–fluid heterogeneous media. The technological importance of study of biphasic gas–fluid flow is great. However, despite the large number of works dedicated to this topic, designers still have no reliable calculation method or recommendations for designing special-purpose equipment. In the near future, it will be almost impossible to obtain a satisfactory theoretical model that would take into account all aspects of the flow of biphasic systems in which the surface of the interface between phases might have a very complex form. Significant success can be reached in the modeling of such flows if a certain degree of limitation is introduced into the description of the flow structure and the geometrical shape of the interface surface; in other words, the notion of flow behavior or flow regime should be introduced. The theory of advanced cavitating flows is especially necessary for the study of the motion of finite bodies when 3-D cavities appear. The methods of conformal mapping, which are traditionally used to analyze flat flows, prove to be inapplicable to spatial flows.

Interestingly, despite proofs that the uniqueness of solutions to specifically set Helmholtz–Brillouin problems exists, there is not a single precise analytical solution for spatial flows. The hybrid method of E. Trefftz and the asymptotic formulas of P. Garabedian are of a particular nature and are applicable only to the simplest bodies and their motions. Consequently, fundamental studies on spatial cavities and methods of their calculation for bodies of sufficiently arbitrary shapes are necessary. The development of a linearized theory of supercavitating flows for thin elongated bodies will be of great practical importance.

Trends in scientific and technological development anticipate new promising apparatuses and devices that move in water and other fluids at high velocities. This requirement should be accompanied by in-depth study of the most complex thermophysical and hydrodynamic phenomena, as a rule, in biphasic flows. The creation of an experimental technology for model and field studies, which develop the ideas contained in [3–5, 12–18], remains topical.

The use of hydrodynamic and thermo physical effects of cavitation (cavitation technology) [3] facilitates mechanical thermolysis of the water structure with free hydrogen bonds production, dispersion and solution annealing treatment to produce resistant emulsions, suspensions, and mixtures finally promising to improve and intensify the processes in various industries. In that work there are given the results of the cavitation treatment effect on the properties of water which at times is a dispersed phase and at other times is a dispersion medium.

3 Conclusion

In changing the characteristics of water it has been established that as a result of hydrodynamic treatment its physical characteristics change considerably and are kept long enough (up to 7-10 days) whereby the modified water can be used in various processes.

Fast oxygenation is observed in the air environment, which is explained by the presence besides diffusion mechanism (due to a high degree of compressing the steam-to-gas contents of a cavitation micro bubble), also the kinetic mechanism of saturation of water with the oxygen resulting in a noticeable non-equilibrium of its dissolution process.

Fig. 1 shows the increase of the oxygen equilibrium concentration in the medium of inert gases and nitrogen having effect on the intensity and nature of the oxygenation process kinetics. The nature of oxygenation change in the nitrogen medium is caused by the formation of NO, NO_2, HNO_2, HNO_3 binding oxygen and hydroxyl radicals. This is verified by the results and conclusions of the investigations of ultrasonic cavitation. An activated molecule of water alongside with radiation and dissipation of excess energy into heat, can dissociate. The O_2 concentration is increased due to both the hydrodynamic cavitation thermolysis of water onto $H\cdot$ and $\dot{O}H$ and the respective reactions behavior [5].

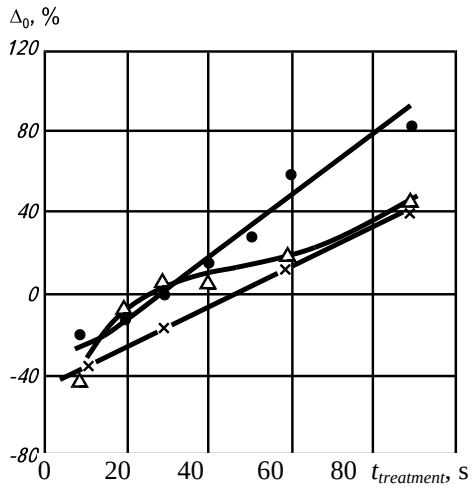

Fig. 1: The dependence $d_0 = f(t_{treatment})$ for the unsettled tap water: o – Ar; d – N_2; x – He; Under the initial O_2 concentration 40 %

In Fig. 2 is shown the dependence of chemiluminescence's intensity for a redistillate. The change of water pH following the cavitation treatment takes place due to the production of various chemical compounds which output depends on the operating mode, on the presence of impurities and gas content in the water. The water thermolysis results in the synthesis of H_2O_2, which makes for pH decrease. The treatment in the nitrogen medium increases the system acidity due to the production of HNO_2 and HNO_3. The concentration of CO_2 has a considerable effect on acid-base qualities, which quantity can change as a result of the treatment. The respective pH change under a hydrodynamic cavitation effect depending on the treatment time is shown in Fig. 3.

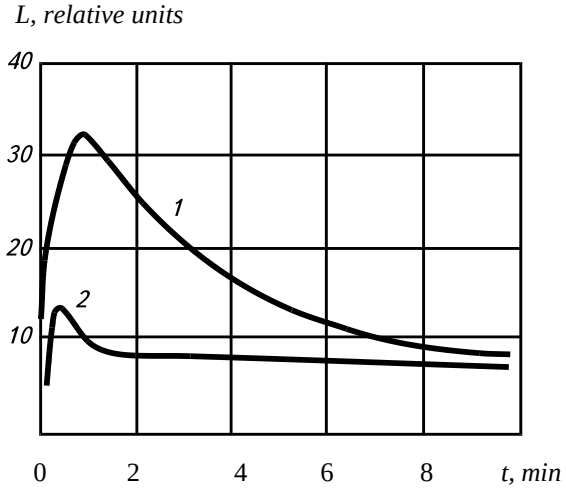

Fig. 2: *The kinetic curves of chemiluminescence's intensity in the redistill ate (C_0 = 100 %): 1 – redistill ate treatment in free air, $t_{treatment}$ = 60 s; 2 – raw redistill ate*

Thus, under the cavitation effect in the aqueous solution containing inert and active gases, it is possible to realize various chemical reactions. Their cavitation initiation is just the ionization and activation of water molecules, rare and active gases, and also the water molecules dissociation. Each of these processes is realized in a definite time $t \sim 10^{-14}$ s. In connection with the fact that the time of the bubble collapse final stage is $t \sim 10^{-9}$–10^{-8} s, there can be realized power transfer and overcharge processes involving inert

gases molecules, which develop in a gas phase according to the equations

$$Ar^{*}(He^{*}) + H_2O \rightarrow H_2O^{*} + Ar(He)$$
$$Ar^{+}(He^{+}) + H_2O \rightarrow H_2O^{+} + Ar(He)^{\cdot}$$

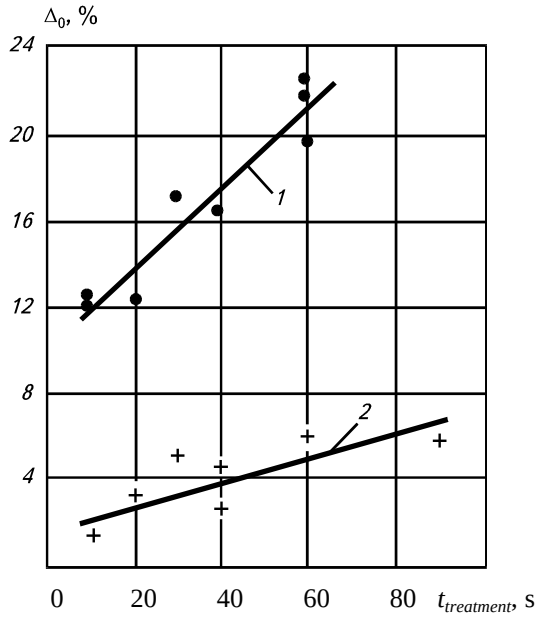

Fig. 3: *The dependence $d_0 = f(t_{treatment})$ in free air (C_0 = 100 %): 1 – redistillate, pH_0 = 5,4; 2 – the unsettled tap water, pH_0 = 7,0*

Along with the above mentioned reactions in the cavitation cavity there are also reactions of radicals transformation that involve chemically active gases and radicals recombination's in the time $t \sim 10^{-7}$–10^{-6} s. As a result of these processes after the cavitation bubble collapse, the products of radical decomposition of H_2O molecules and radicals recombination's detected with the help of a spin traps procedure pass on to a solution. As a result the water accumulates molecular O_2, H_2O_2, and other compounds.

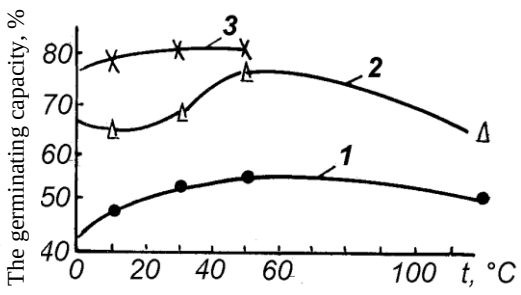

Fig. 4: *The seeds germinating capacity: 1 – "Nantes-4" carrots (d_{max} = 8.2 %, $HCP_{0.5}$ = 7.7 %); 2 – "kid" tomato (d_{max} = 4.7 %, $HCP_{0.5}$ = 5.9 %); 3 – "elite" tomato (d_{max} = 11.3 %, $HCP_{0.5}$ = 11 %)*

In agriculture the use of the cavitation-treated water allows to get a crop capacity gain for greenhouse vegetable cultures up to 30 % with simultaneous reduction of plants morbidity (Figs. 4, 5). It is obvious that the major factors influencing the produced effect are the increased oxygen content of the treated (activated) water as well as the complex physical and chemical processes occurring under the cavitation effect [19, 20]:

redox reactions that proceed in the water between the dissolved substances and the water splitting products emerging in cavitation bubbles and passing into the solution after their collapse;

reactions between the dissolved gases inside cavitation bubbles;

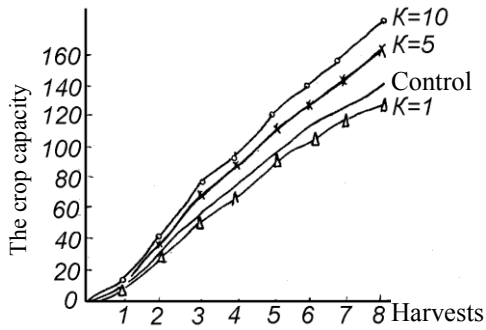

Fig. 5*: The results of the experiments with the "September" cucumber: K – frequency rate of treatment*

chain reactions in the solution initiated by the products of splitting in impurities cavitation bubbles;

macromolecules break-down and its initiated polymerization;

water structure change with the production of free hydrogen bonds, etc.

The obtained result is in good agreement with other researchers' experiments, who have applied the given technology with the efficiency of 15-20 % when using the cavitation-treated water as potable water in animal raising and in fish whitebait raising from berries.

In food industry the cavitation treatment makes for increased juice extraction (approximately by 15 %) (wine industry), for cutting the time of preliminary and base liming of beetroot diffusion juices approximately 10 times less (sugar industry), qualitative extraction of nutrients from fruits and plants when producing various food supplements and vitamins, etc. [5].

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DESIGN OF IRRIGATION SYSTEMS FOR GARDENS BY ALTERNATING GREYWATER AND WELL WATER

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Abstract: *Water is the basic source of life for plants, animals, and humans. However, the impact of climate change drastically reduces its sources. Rational consumption of clean water leads to the need for finding alternative water sources for irrigation of gardens. As an alternative source, greywater can play an important role. Greywater is waste water from households, which does not contain faecal compounds. The aim of this paper to present design concepts of systems for collecting, purifying and application of greywater and well water for irrigation of gardens. The concept is developed using previous own research results, as well as available literature, on the benefits and risks of using greywater, and the effects of purifying greywater and well water through various treatment systems. The paper presents two systems: (1) a system which allows the storage and irrigation using raw greywater and (2) a system where greywater supply is not continuous. The second system is suitable not only for households but also for other facilities, e.g. touristic, recreational and weekend resorts. This system proposes alternate irrigation with grey and well water for resolving two problems: inappropriate greywater quality and inappropriate water quantity. In general, the system reduces the risk of soil degradation and is water saving by automatically adjusting irrigation with regard to the soil moisture content.*

Keywords: GREYWATER, WELL WATER, IRRIGATION, SYSTEMS, DESIGN CONCEPT

1. Introduction

Water is the basic vital substance necessary for the survival of life on the Earth. However, the increasing impact of climate changes, the increased consumption of clean water and its pollution are causing a drastic decrease of this resource (UN Water, 2017). Regarding to this, it is necessary to find adequate solutions for the conservation of clean water supplies.

One of possible solutions is to find an alternative source for irrigating gardens. One of the potential alternative sources of irrigation water is grey water. Grey water is domestic wastewater originating from dishwasher, sinks, showers, bathtubs and washing machines (EPA, 2018). Grey water could have different characteristics (Dabić et al., 2019). Grey water potentials are its availability in large quantities and its nutrient content (WHO, 2006a; Siggins et al., 2016). Because grey water does not include toilet wastewater, it does not contain elevated levels of pathogens as municipal wastewater (WHO, 2006). Nevertheless, the presence of effluent from a kitchen in grey water can cause an elevated bacterial content (Maimon et al., 2014). Proper management of grey water, including collection, treatment and reuse or disposal, prevents direct contact with grey water and limits transmission, as well as the further spread of pathogens. Purified grey water is used for various purposes around the world, but it's most common application is for irrigation purposes (Imhof B. & Mühlemann J., 2005). In addition to grey water, well water can also be a significant irrigation source for various types of green spaces. The quality of or both, grey water and well water, is of great importance in irrigation. Since grey water consists of effluents from the kitchen, it may contain residues of food that could create the condition for the development of bacteria, and thus the increased biochemical oxygen demand (BOD_5). In addition, unpleasant odors can develop by keeping grey water for a long period (if it is not consumed for a short period of time).

Grey water is most commonly used in arid regions and/or areas affected by insufficient amount of clean water. Back in 2006, there was a trend of increasing use of grey water in the US, where most households used grey water from a washing machine for garden irrigation (Roesner et al., 2006). There are numerous projects in developing countries, as well as derived solutions for the collection, treatment and reuse of grey water for various uses, as well as different degrees of grey water purification (Abdo, 2001; Bark & Drabo, 2001; Dallas et al., 2004; May-Le Ng, 2004; Imhof & Mühlemann , 2005; Al-Hamaiedeh & Bino, 2010; OMICK, 2014).

One of the undesirable substances in well water is iron. Long-term application of well water containing an elevated iron concentration may lead to coloring of the surface treated with this water. Usually these surfaces become copper-orange over time. In addition, elevated iron concentrations adversely affect the quality and service life of the irrigation system. The long-term application of water of such quality leads to the deposition of iron in the pipes of the overfill system, which causes difficult flow of water, blockage of the system, as well as additional maintenance costs. In regard to both mentioned irrigation alternatives, in order not to cause negative effects on the environment and irrigation systems, adequate collection and purification of both grey and well water is necessary.

Although the problematic in not new, authors felt that it should be refreshed and upgraded, since during previous two years of research and investigation of this topic conducted by Dabić and associates (Dabić et al., 2017; Dabić et al., 2018; Dabić et al. 2019), safe application and proper installations are shown to be important aspects concerning grey water utilisation. Therefore, the aim of this paper is to present the design concepts of systems for collecting, purifying and applying grey and well water for irrigating gardens.

2. Method

The concept was developed using previous research findings, as well as the available literature, on the benefits and risks of using grey water, as well as the effects of purifying grey water and well water through different treatment systems. Two systems are presented in the paper: (1) a system that allows storage and irrigation using raw grey water and (2) a combined system in cases where the supply of grey water is not continuous.

Two systems are presented in the paper: (1) a system that allows storage and irrigation using raw grey water and (2) a combined system in cases where the supply of grey water is not continuous. Both systems are designed for private single-family residential buildings and are smaller in size than systems for multi-family residential buildings, tourist complexes, etc. The dimensions of the storage and irrigation system, that is, the reservoir in which the mechanical treatment and storage of raw grey water is carried out are 2 x 1 x 1 m (2 m^3), while the dimensions of the reservoir for the treatment - storage of grey/well water are 1 x 1 x 1.6 m (1.6 m^3). The raw grey water storage and irrigation system is a simple filter, according to the study on grey water purification technology through coarse filtration (Hall et al., 1974), while the combined system is somewhat more complex. This system consists of two tanks for the purification and storage of grey/well water separately. In addition, the purification filter itself is more complex and consists of a combination of many different materials used for these purposes (Zuma et al, 2009; Al-Hamaiedeh & Bino, 2010; Parjane & Sane, 2011). The combination of materials includes: small gravel

(5 cm - 0.05 m^3), large gravel (5 cm - 0.05 m^3), sand (30 cm - 0.3 m^3), geotextile (0.5 cm) and wire construction (3 cm).

3. Results and discussion

Raw grey water storage and irrigation system

The raw grey water storage and irrigation system is a simple system. Household waste water, including waste water from sinks, showers and tubs through the PVC pipes goes to the sewer or grey water collection tank. The direction of wastewater flow is determined by the automatic controller (Figure 1).

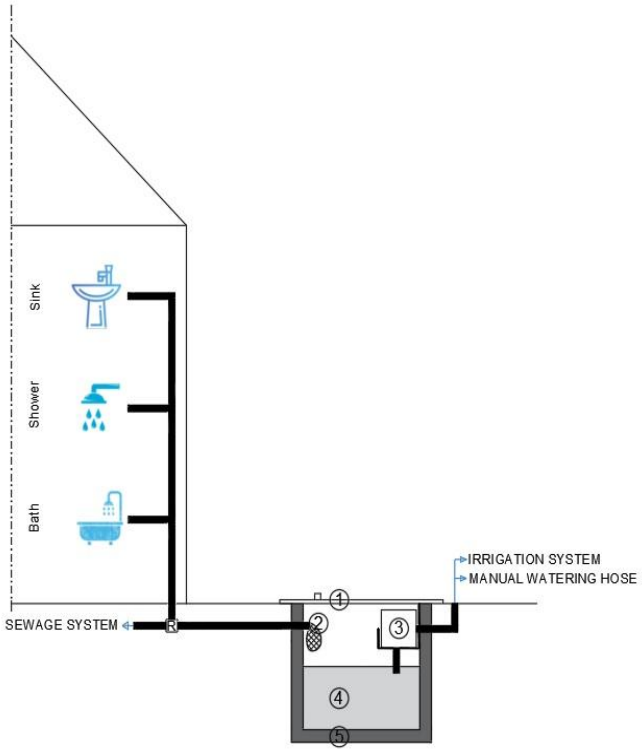

Fig. 1 *Design of raw grey water storage and irrigation systems. 1-cover; 2-sieve; 3-pump; 4-raw greywater; 5-concrete; R-regulator.*

The principle of operation of the regulator is by means of a sensor that allows the flow of wastewater into the tank to a maximum level of collection. When the maximum level of grey water is reached in the reservoir, or during the year when irrigation is not required, the regulator will automatically direct the wastewater towards the sewer. When the PVC pipe enters the tank, the waste water passes through a mechanical filter in the form of a wire sieve to collect the large particles of waste (e.g. food waste). By manually removing the tank cover, it is possible to obtain a mechanical filter, which needs to be cleaned occasionally and returned to its original position. Inside the tank there is a pump that pumps raw grey water in two directions: (1) to an underground irrigation system, in the form of a vessel buried into the soil near the plant root system (see Figure 2), and (2) to a valve for a hose intended for manual irrigation. The pumping of raw grey water from the reservoir takes place in two cases: (1) for system number 1, the sensor at the bottom of the vessel which regulates the water flow depending on the soil moisture (Figure 2), while (2) manually opening the manual irrigation valve where there is an automatic pumping of water from the tank. This system design is suitable for lawn irrigation, as well as for ornamental plants that are not used in as food.

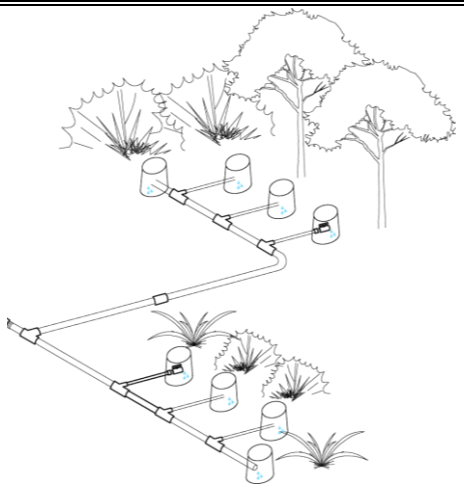

Fig. 2 *Underground irrigation system for grey water application*

Combined system

Combined system is a system for purification, collection and irrigation of grey and well water. Household waste water, including waste water from sinks, showers, bathtubs, sinks, and dishwashers through PVC pipes goes to the sewer, or grey water treatment tank, while the well water reaches the well water treatment tank by pump (Figure 3).

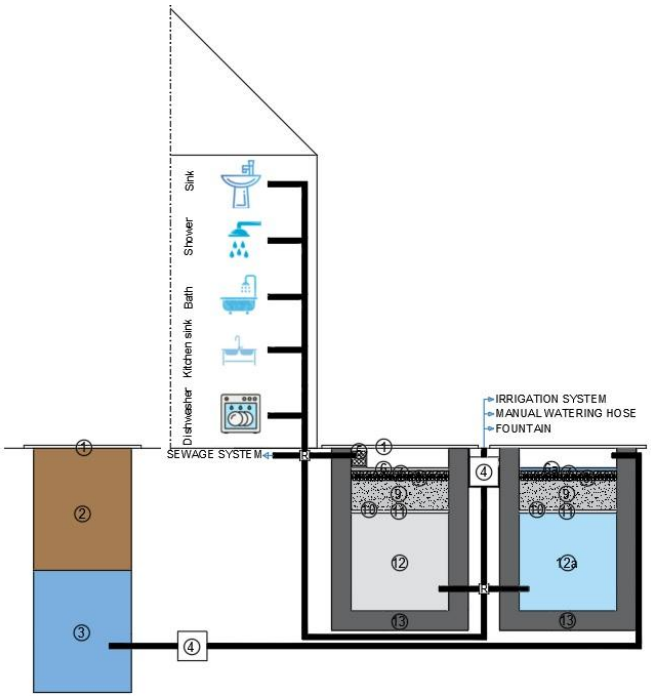

Fig. 3 *Design of the combined system for the treatment, storage and irrigation of grey and well water. 1-Cover; 2-Part of wells without water; 3-Well water; 4-Pump; 5-Sieve; 6-Greywater; 6a-Well water; 7-Large gravel; 8-Small gravel; 9-Sand; 10-Geotextile; 11-Steel construction; 12-Purified greywater; 12a-Purified well water; 13-Concrete; R-Regulator.*

Disinfection with generally applicable disinfectant would avoid biological degradation of grease, small food particles, detergents, etc. Similarly as with the previous system, the automatic controller determines the direction of the waste/well water, depending on the amount of purified grey/well water, or the period of the year. This system consists of two tanks for the purification and collection of grey and well water separately. Both tanks contain the same purification filter, but before the grey water tank, the grey water passes through a mechanical wire filter to collect large waste before filtering. Also, by manually moving the tank lid, it is possible to get a wire filter which needs to be cleaned if necessary. The water purification filter consists of coarse gravel, fine gravel, sand,

geotextile, steel structure that carries the aforementioned materials, and parts of a reservoir for storage of purified grey or well water. The purified grey and well water is pumped in three directions with the help of a pump: (1) into the underground irrigation system (as in the previous system), (2) to the manual watering valve and (3) to a fountain, or other type of water element. This design of the system is suitable not only for households but also for other facilities, for example, touristic recreational and weekend resorts where the inflow of grey water is not continuous. This system proposes alternative irrigation with grey and well water to solve two problems: inadequate quality and inadequate supply of grey water. In general, the system reduces the risk of soil degradation by providing good water quality. Additionally, it saves water by automatic irrigation adequate to plants requirements, by determining soil moisture content using sensors.

Common irrigation problems concerning grey water application

When it comes to the design of irrigation systems, it is first necessary to start by collecting and storing grey water. The common opinion of the authors who have elaborated the issues of grey water storage is that it is difficult, and that there is a danger of an increase in the number of pathogens. Another problem is the depletion of oxygen during the degradation process, which leads to sulfide production and unpleased odor of grey water. However, most authors agree that disinfecting grey water can solve these problems. Also, it was observed that the degradation of organic matter occurs already in the first days of storage (the first 7 days), as well as that the ratio of COD:BOD of water decreased, indicating faster biodegradation of waste. In addition, an increase in the concentration of coliforms was observed during the first 5 days, while after 15 days of storage of grey water, the concentration of coliforms decreased. However, although the number of indicator species is increasing, this does not mean an increase in pathogenic microorganisms as well as risk (Imhof B. & Mühlemann J., 2005). Therefore, the period of storage plays an important role in the quality of grey water, i.e. with a prolonged storage period the quality of grey water decreases. Eriksson et al. (2002) confirm this fact. The cited authors found that storing grey water for up to 24 hours improves its quality, while storing it for more than 48 hours can be a serious problem due to the consumption of dissolved oxygen. However, as long as the storage of grey water is included in the irrigation system, it is essential that storage tanks are available for washing/cleaning (Christova Boal et al., 1996).

In addition to storage, its important role in the use of grey water is its purification. There are numerous problems related to the use of untreated grey water. Exposure to microorganisms in water leads to the risk of disease spread. Due to the fact that it is resistant to water purification processes, Legionella poses a special threat because it can spread through aerosols as well as inhale during irrigation or flushing of toilets (Dixon et al., 1999). Surface spraying of untreated grey water is not recommended because it increases the possibility of coming into direct contact with grey water, which can cause disease to humans and animals. For this reason, it is proposed to use protective equipment when coming into direct contact with grey water, as well as to apply an underground irrigation system (Siggins et al., 2016). However, suspended solids can cause clogging of the distribution system, and grey water to be used for irrigation must be of satisfactory physical quality (Eriksson et al., 2002). Depending on the economic aspect and the quality of grey water required, the degree of treatment before use or storage depends on it. Three levels of treatment are usually defined (Morel, 2002): (1) Primary treatment - the first treatment step that is used to remove most floating or precipitating materials. About 30% of BOD_5 can be removed with this treatment; (2) Secondary treatment - at this stage the bacteria consume organic waste and it is possible to remove about 90% of BOD_5 and suspended matter. Disinfection represents the final stage of secondary treatment; and (3) tertiary treatment - represents the last stage in which nutrients such as phosphorus, nitrogen, BOD_5 and suspended matter are removed. The level of treatment depends on what purposes the grey water will be used for. Grey water intended for surface irrigation must be well filtered and disinfected, while grey water intended for underground irrigation will require only coarse filtration as the risk of human contact is reduced (Finch et al., 2003).

4. Conclusion

According to the above examples of systems for purification and use of grey water, the needs for such systems exists, as well as certain advantages of the system for storage and irrigation of raw grey water, as well as the combined system. The main advantage of these systems is that they are underground and that no odors are spread. In addition, these systems occupy a much smaller area, since all the necessary filters are contained in one tank, compared to the above examples of systems consisting of multiple tanks. Another significant improvement of the combined system is the combination of grey and well water. In addition to well water being an additional alternative water source, it can also dilute grey water by improving its quality. Also, these two systems allow for safe irrigation, meaning, directing excess water into the sewage system reduces the risk of soil wetting and degradation.

5. Acknowledgement

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SURFACE WATER RESOURCES ASSESSMENT METHODOLOGIES APPLICATION IN CASE OF VIT RIVER

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Abstract: The surface water resource determination is an important issue related to most reliable water management, which in some districts of Bulgaria in some periods are not enough. In this aspect, the present work is part of the effort to create an operational tool to assess the annual resource. Annual, because this is one of the periods of planning the water use, on the other hand annual averaging significantly simplifies the water balance equation.

There are several methods in world practice for this purpose: modeling the process *"rainfall – runoff"*; regionalization in typical water quantities depending on physico-geographic factors; balance approach. The first one require a serious resource of information and time, mainly used to analyze the impact of decay factors and climate change rather than on operational purposes. The method of hydrological regionalization is already operational in use, but as far as it is based on registered river flow, it is important to clarify the influence of anthropogenic factors. The water balance method is widely used for the purposes of the Water Framework Directive, both for the assessment of the water bodies' resources influenced by human activity, as well as for analysis of pressure and water stress, for water economic balances, for the management of water abstractions and river basins. It applies to WB category "lake" - large dams; WB with resource dependent on technological input from dams or derivations; WB with additional flow of water transfer, etc. *Vit* is one of the main bays in Northern Bulgaria, combining a mountainous, hilly and plain area, on average in area, presenting relatively well the characteristics of formation of the river flow. There are three significant dams, two irrigation systems, derivations and water transfers and a significant number of smaller consumers. In this sense, the basin is chosen as representative, with the opportunity to demonstrate the methods. The balance method is applied to typical sub-basins for the period 2015 -2017.

As a result, a hydrological evaluation of the surface water resource was made for the selected sub-basins based on the registered flow and the water balance assessment of the surface water resource for the same sub-basins. A comparison was made, conclusions were drawn about the advantages and disadvantages of the methods and their applicability in practice.

KEYWORDS: SURFACE WATER, RESOURCES, WATER MANAGEMENT, BALANCE APPROACH

1. Introduction:

Assessment of water resources is an important task, ensuring efficient and fair water management and ensuring objective long-term planning.

Water management in Bulgaria is carried out by the Ministry of Environment and Water, which maintains the register of consumers and annual gives specific quantities for the three options - normal, dry and wet year. Appropriate resource assessment places this regulation on an objective basis. After the year 2010 the resource assessments are carried out by NIMH/ National Institute of Meteorology and Hydrology/, based on the hydrological method, which will be discussed below. They are prepared on a yearly basis in the light of practical needs and also to avoid seasonal impacts on fluctuations in river flow. Most often estimates are made in the basins, which greatly facilitates calculations from a methodological point of view. Assessments may also be made for districts and administrative units, for example on the territory of Bulgaria, which require additional information on hydrological and meteorological parameters at the border of the area.

2. Methodology:

Three methods for resource assessments are generally used in practice. The first one, currently used in NIMH, is a hydrological method. It is based on statistical links between hydrological observations and other factors that form the river flow, for example: catchment area, average altitude, and others. This method gives assurance in assessments **[1]**, but is based on observations on the recorded runoff, which leads to additional checks on the riverbed with many anthropogenic violation.The second method is the water balance, which assesses the revenue and cost components of the water balance, requires significant amounts of information and, most importantly, for the actually consumed water masses**[2]**. In our country the method is used for individual regions and rivers where it is possible to meet the requirements for the volume and reliability of the input information **[3]**. The third method is quantitative modeling of the drainage process and requires the most information and human resources. It is usually applied in cases where the first two methods can not be used. In this article we will look at the application of the water balance method for the assessment of water resources to some borehole and we will compare the obtained results with those of the hydrological method. The water balance technology is detailed in the **[2]**.

We will use the Physical / Hydrological Balance Technology of formed, used and discharged water. It should be noted that this guideline also details the technology for water balance balancing as well as hybrid hydrological and economic balance linking both types of water information.

In our case, the physical process of surface water formation is described as a result of the balance of the precipitated water revenue and the flow for the formation of the river runoff, underground and groundwater and the cost of evaporation, realized by various mechanisms, by the surface detention plants ***(Ei)*** from the soil and others. Direct determination of evapotranspiration is practically not possible. The rainfall is a feature with large spatial variability, but there are a significant number of measurements in the flatlands, and in the foothills and mountainous parts of the catchments they are insufficient. With relatively good accuracy, the river flow is observed. As far as annual resource assessments are concerned, the influence of sub-surface and underground runoff can be neglected. Our efforts will be focused on the more precise determination of the surface water component - river runoff, by assessing the anthropogenic impact of water users on the change of natural flow regime. This will be done for selected / to the configuration of consumption /, sub-basin from selected river basin.

3. Pilot basin selection

The selection of the pilot basin was realized in view of the following requirements: average for the country area of the catchment (3 - 5 thousand sq. km), various relief, flat, hilly, mountainous, presence of significant consumers whose impact on the water balance on an annual basis the presence of basic hydrometeorological observations of significant duration can be neglected. Pursuant to these requirements, for the purposes of this study, it was selected *Vit* as pilot basin with a catchment area of 3225 km^2. In the valley there are 5 hydrometric stations with a

significant observation period (***Fig.1***), in the figure are shown the three main reservoirs, significant in terms of the annual water balance. **[1]**

It also shows the river network and the main reservoirs, the Sopot reservoir with a catchment area of 76 km and a derivation to *Lesidrenska* River with a similar area; the *Gorni Dabnik* reservoir with a derivative to the *Vit* River from the Boazas water catchment, as well as a smaller *Telisch* reservoir. In the valley, there are other smaller reservoirs, whose impact on the annual water balance is neglected. They are shown at ***Figure 1***.

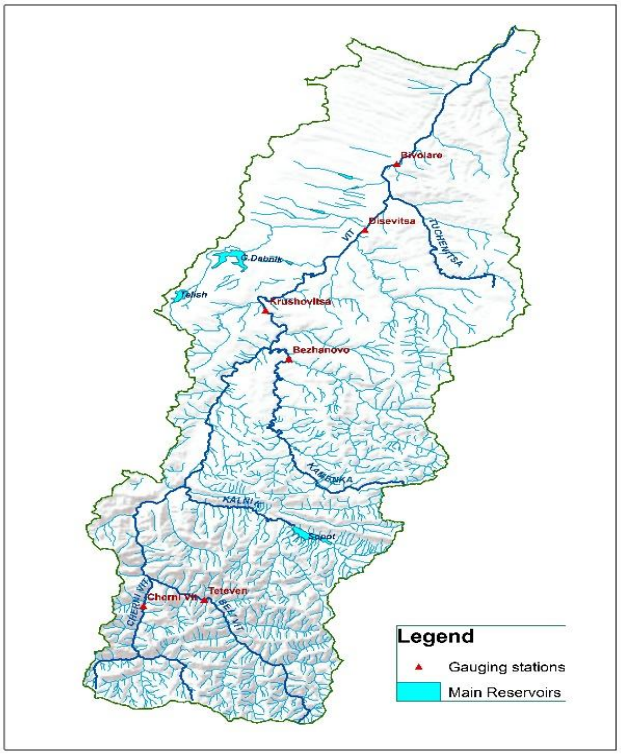

Figure. 1. *Vit River basin, hydrometric network, main reservoirs and derivation, significant for the annual water balance.*

As far as the idea is the application of the water balance approach for surface water assessment and comparison with the results of the hydrological approach, two sub-basins were selected in the *Vit* River where there are direct observations of the river inflow. One is the water catchment area of the Sopot Reservoir at the top of the valley.

The second one is the sub basin of Vit next to gauging station in the village of *Disevitsa*. The period for which the resource assessment has been made is selected in view of the actual of the assessment and the availability of information about the water used by the main users, obtained from Irrigation Systems Co. **[4].** A three-year period 2015-2017 was chosen as representative.

4. Registered users and anthropogenic factors

Information on registered users in the Vit River is received by the MOEW - BDDR **[5]** and IS Co.**[4]**. Information from the BDDR contains a description of the users on certain parameters, an annual limit of the allowed water use. We did not have information about actual water use for 2015-2017. Such information was available only to the sites of the IS EAD.

The information for the different users was merged into ***Table 1*** against the purposes of water use and is shown in ***Figure 2.*** The merger is done according to the classification of the BDDR, and the significance to the annual water balance is assessed according to the type of water consumption.

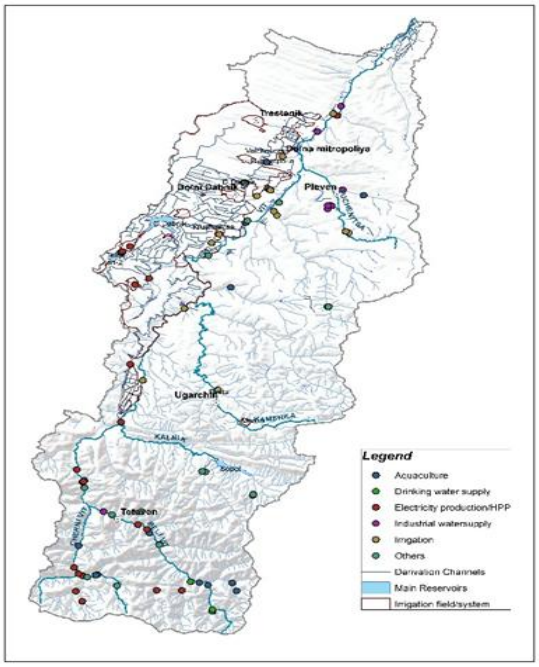

Figure 2. *Registered water use*

There are two main types of users. One has a significant anthropogenic impact on the annual water balance. This is irrigation, where part of the river effluent evaporates from irrigated areas and plants. In the same way we take into account the loss of evaporation from the large reservoirs. Other groups of users have no significant impact on the annual water balance. These are, for example, power stations, aquaculture, water supply - drinking and industrial, etc.. For them we will consider that the water used is transferred instantaneously without loss back to the point of water abstraction. It should also be noted that allowing annual water consumption limits far exceeds actual water consumption. In support of the above we will say that the constructed facilities have a total capacity of about 200 million m3, the annual irrigation limits are about 19 million m^3 and the actual water consumption for irrigation for the period 2015-2017 declared by the IS EAD does not exceed 2 million m^3 per year. As long as the consumed water from smaller users is used for the second and third time by other downstream users, the annual limits shown in Table 1 can only be used as a guide to the scale of consumption. The last one becomes very clear by analyzing the annual sum of the limits for such water consumption purposes as electricity and industrial water supply.

In these two groups, about 50 users have a permitted limit exceeding at least three times the resource of the river basin. It is clear that in the production of electricity, water is used repeatedly, using the differences in altitude in the basin. (For example: In the upper reaches of the Vit River, after the White and Cherni Vit valves, there are seven HPPs that produce the same water.)

Users which influence on the annual water balance might be neglected	**Annual water use limit, [$10^6 m^3$]**	**Numbers in the group**
Aquaculture	6,659	20
Electricity production / HPP	1550,	29
Irrigation	19,196	26
Industrial watersupply	57,089	15
Drinking Water supply	3,200	3
Others	7,667	20

Table 1. Registered water users by purpose of use annual limits

5. Results

For the application of the hydrological method two types of relation are used between the observed water quantities to the selected hydrometric stations and the corresponding water basins areas. For the resource assessment to the *Disevitsa* sub basin, the information from four hydrometer stations in the middle and downstream of the *Vit* and *Osam* Rivers is used. Four regression relations have been created. The first one is with data from 1981-2012 **[1]**, while the other three are for each of the years 2015-2017, the statistical relations have a very high correlation coefficient above 0.95 and are similar in their tendencies, showing stability of the obtained results, ***Figure 3***. Similarly, the regressional dependencies for the assessment of the Sopot sub-basins were created using data from gauging station in the mountainous part of the *Osam* and *Vit* Rivers. The resource estimates identified with these dependencies are listed in the second column of ***Table 2*** as annual water tables. When assessing the resource to this sub-baisn, *Kalnik* area was used, representing the reservoirs own catchment. It should be noted that there is a derivation channel between the *Lesidrenska* River and the Sopot reservoir, increasing the flow to the reservoir, but we do not know when this derivation is used.

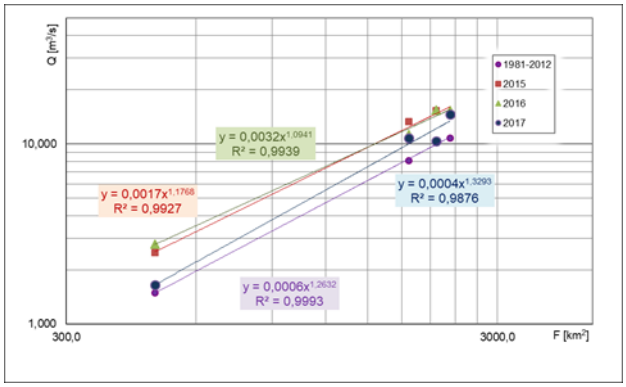

Figure 3. Regression of discharge versus watershed area for gauges downstream *Osam* and *Vit* Rivers

The data on the balance of *Sopot* reservoir and the measurement of the registered runoff from gauging station in the village of *Disevitsa* are used in the application of the water balance method. The following assumptions have been made: for the sub basin *Sopot* we will consider that the resource is equal to the total inflow to the reservoir; we will assume that the resource is equal to the recorded run-off from the gauging plus the evaporation losses from the reservoirs of the main reservoirs plus the irrigation water used, reduced by the return water.

We will consider that the evaporation from the reservoir is a loss of river flow. Similarly, irrigation water is transfer of river flow of evaporation as part of these waters passes through shallow groundwater back into the river network, which we call return water. We will consider that the return water is 30% of the quantity of water for irrigation. **[6]**.

The losses from evaporation of the three dams and the water used for irrigation are from the information of IS Co. **[4]**.

The comparison of the results of the two Sopot sub-basins methods shows significant differences without observing a equal tendency of these differences. A preliminary analysis of the data from 20 rain stations in the area confirms the high water level in 2015 recorded by hydrometric stations. The big difference between the balance and hydrological estimation of 2015 can only be at the expense of the work of the *Lesidrenska* derivation. The additional verification of the accumulated volumes of the Sopot reservoir also shows that it was nearly full at the end of 2014. Probably the *Lesidrenska* derivation was excluded in 2015 to prevent the dam from being overflowed.

The results of the calculations are shown in the last column of **Table2**.

Sub basin	Year	Hidrologic method	Water Balance method
Sopot	2015	60,904	30,527
	2016	39,573	54,108
	2017	52,157	47,132
Disevitsa	2015	492,321	484,003
	2016	488,033	510,595
	2017	377,937	480,246

Table 2. Annual Resources evaluation 2015-2017

This may explain the fact that in the next two years, 2016 and 2017, the water balance method shows values comparable to the hydrological.

For the *Disevitsa* subbasin, the results of the two methods are similar to a noticeable unidirectional trend of higher values of the water balance assessment. Differences between the two methods can be obtained for two reasons: 1) in the case of a poor correlation between the runoff and the area, the value of the recorded runoff in the station could differ significantly from the calculated equation; 2) In case of large losses of evaporation and irrigation, the differences between the recorded and the water balance calculated river flow will be significant.

6. Conclusion

The assessment of water resources in the water balance method is, in principle, preferable because the effect of anthropogenic factors on the river flow is eliminated. The calculations made show that the assessment of the surface water resource by this method is close to that obtained by the hydrological method currently applied in our country. The application of the water balance method requires a considerable amount of information, resources and time, and is more likely to be the case for research tasks. For the application of the water balancing method for operational purposes, it is necessary to provide information on the current water consumption available for a small number of cases.

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THE IMPACT OF LONG ROTATION CYCLE FOREST MANAGEMENT ON SOIL AND WATER PROPERTIES IN HEMIBOREAL REGION

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Abstract: *More than a half of Latvia's territory is covered with forests, and forest sector is important for the national economy. Despite the high economic importance of timber resources, forest utilization in Latvia is moderately intensive, as long rotation cycle (70-100 years for most widespread tree species) is used and strict environmental regulations are in force. Meanwhile, due to the climate change and growing demand for renewable resources, intensification of forest management is ongoing and expected to continue. Studies on the interactions between forest, soil and water are of high importance to ensure sustainably intensified forestry. Forest felling, transportation of logs, collection of slash, stump extraction, drainage system establishment and maintenance, forest road construction, beaver population management, use of water protection structures and riparian bufferzones are apparent components of forestry that may exacerbate, change or improve quality of water, soil and stands, and as such, require research and practical application of relevant protection measures.*

Keywords: SUSTAINABLY INTENSIFIED FORESTRY, LONG ROTATION CYCLE, WATER QUALITY, SOIL DAMAGE, HEMIBOREAL REGION

1. Introduction

In Latvia, forests cover 52% of the country's territory, and the amount of forested areas continues to increase, both by the expansion of the forest in a natural way and by afforestation of non-fertile land as well as land that is no longer used for agriculture. In Latvia, forestry can be described as purposeful and sustainable, as current annual increment exceeds average amount of harvested timber (appr. 11 million m^3) during the last decade [15].

Forestry is one of the most economically important sectors in Latvia, contributing significantly to the overall sustainable development of the economy. In 2017 wood processing, forestry and furniture manufacturing represented 4.8% of GDP and the export volume reached to EUR 2.2 billion that is 30% of all exports [15].

About half of the forests in Latvia are state owned (49%), while majority of the rest belongs to private owners (48%). The remaining 3% belongs to municipalities or are classified as "other forests". The dominant tree species are Scots pine (*Pinus sylvestris*, 33%), birch (*Betula spp*., 30%) and Norway spruce (*Picea abies*, 19%), followed by aspen (*Populus tremula*, 7%), grey alder (*Alnus incana*, 7%), black alder (*Alnus glutinosa*, 3%) and other species (1%); the share of conifers is higher in state-owned forests, while the share of broadleaves is higher in other forests [15].

There are three basic forest management systems in Latvia; the differences generally pertain to the method used to remove the old stand (final felling). The one most commonly used is uniform regeneration felling when trees are removed from the whole area of compartment and regeneration (either natural or artificial) carried out afterwards. The average size of a forest compartment in Latvia is ~2 ha. The second system is gradual regeneration felling when the mature forest stand is removed in several, usually 2-3 approaches. The third system is selective felling when the stand is never entirely removed (continuous cover forestry). The final felling may be carried out or started (in case of latter two systems) when the target age or target diameter of the stand has been reached (Table 1, Table 2) [17, 23].

In all cases tending of the young stand and subsequently, forest thinning is carried out to reach the desired species' composition and to improve the growing conditions for the target species by reducing mutual competition among the trees [15, 17].

Apart from fellings whose aim is to obtain wood and timber for commercial purposes, there are several types of additional fellings with a different primary aim. Sanitary felling is used to improve health condition of the stand by removing trees with diseases, pest-infested trees, trees damaged by animals or other agents, wind-thrown and broken trees. Depending on the scale of the damage, sanitary felling may be uniform or selective. Reconstructive felling is used to replace obviously unproductive stands of low value with stands formed of trees better suited to the specific growing conditions. Landscape felling is used to reveal landscape values, cultural and historical monuments, or nature objects. Deforestation sometimes takes place to establish and maintain forest infrastructure (roads, drainage systems, border trunks) and other types of infrastructure important on national or regional level (e.g., power lines).

Table 1: *The age of the final felling according to the site index [17]*

The dominant tree species	Final felling age [years] according to the site index*		
	≤I	II-III	≥IV
Oak (*Quercus robur* L.)	101	121	121
Scots pine (*Pinus sylvestris* L.), European larch (*Larix decidua* Mill.)	101	101	121
Norway spruce (*Picea abies* (L.) Karst.), Ash (*Fraxinus excelsior* L.), Linden (*Tilia cordata* Mill.), Wych elm (*Ulmus glabra* Huds.), European white elm (*Ulmus laevis* Pall.), Norway maple (*Acer platanoides* L.)	81	81	81
Birch (*Betula* spp.)	71	71	51
Alder (*Alnus glutinosa* (L.) Gaertn.)	71	71	71
Aspen (*Populus tremula* L.)	41	41	41

* The higher the site index, the better the growing conditions

Table 2: *The diameter of the final felling according to the dominant tree species and site index [23]*

The dominant tree species	Site index			
	Ia	I	II	III
	Average diameter of dominant stand [cm]			
Scots pine (*Pinus sylvestris* L.)	39	35	31	27
Norway spruce (*Picea abies* (L.) Karst.)	31	29	29	27
Birch (*Betula* spp.)	31	27	25	22

Only native tree species are permitted in the forests of Latvia (with the exception of larch occurring in very small areas), therefore, Latvia has so far avoided the environmental conflicts associated with large-scale growing of introduced trees. The scope of measures used to intensify tree growth in Latvian forests is rather limited, yet some are applied or tested with good results. The most widely practiced activity in this regard is forest drainage (carried out mainly in the second half of the 20th century, suspended in 1990ties due to environmental considerations; currently only drainage system maintenance is performed). High quality

reproductive material is generally used in forest regeneration in state forests and on increasing scale in private forests as well. Forest fertilization has been carried out in the second half of 20th century, and then suspended, and presently research is again ongoing to quantify possible economic gains and potential risks to the environment from resuming it. Fast-growing tree plantations and agroforestry systems form a separate group and should not be considered as a part of conventional forest management. The given overview and examples confirm that the degree of the intensity of the forest management in Latvia is moderate, however, the situation may change in the near future, and already now several new challenges have arisen that had not been encountered before.

2. Challenges of modern forestry

Due to the global and regional pressures related to climate change and increasing demand for renewable resources, forest management is facing several challenges that are related to the need for improvement of stand productivity and utilization of the logging residues. Forests are important providers of renewable energy in Latvia. Consequently, forestry is under a heavy pressure to reach 40% renewable energy share in total energy used by 2020 set by the directive 2009/28/EC of the European Union [3]. Intensification of the forestry activities is therefore present and expected to continue, but it has to be carried out in a sustainable way.

2.1. Water quality

Establishment of forest drainage systems in waterlogged forests is one of the most effective measures to increase forest productivity in Latvian conditions. Forest drainage activities on large scale were carried out in the second part of 20th century, and currently there are approximately 500 000 ha of drained forestland in the state forests alone [16]. Although new systems are not currently established due to nature conservation reasons, existing ones have to be renovated periodically (every 20-40 years) by ditch cleaning to maintain the productivity [27]. Both establishment and maintenance may alter the water quality in ditches and connected waterbodies.

A threat to cost effective forestry in Latvia is Eurasian beaver (*Castor fiber* L.). Beavers often have preference for forest drainage ditches as suitable places to build dams for habitation. Stands in drained areas are adapted to the optimized water regime, and rapid rise in the water table often leads to mortality of affected forest stands causing severe economic losses.

2.2. Nutrient cycling

Currently dominant uniform regeneration felling is usually supplemented with removal of treetops and branches that are further utilized for energy purposes. In the vicinities of waterbodies, final felling may pose a threat to water quality because the nutrient cycling is significantly altered in a short time period. Leaching of the nutrients into waterbodies may cause eutrophication and ruin habitats for aquatic animals and plants. A properly functional buffer zone is thus essential to retain the nutrients and stabilize the nutrient cycling near the felling area. Different harvesting intensities may require a buffer zone with different parameters.

The most valued forestry product is timber, but logging residues (treetops, branches, stumps) are still a significant renewable energy source that may be used to fill in the energy demand [2]. Different practices are used besides conventional harvesting (CH), where only timber is extracted: whole tree harvest (WTH), where all above ground biomass is harvested; stump biomass (SB) extraction, where stumps are extracted together with major roots; combination of whole tree harvest and stump biomass extraction (WTH+SB). CH is considered to have little impact on site productivity, but, on the contrary, WTH may lead to deterioration of site productivity because of higher content of nutrients in foliage than stems [28].

2.3. Carbon storage

Mineral and especially organic soils store large amounts of carbon and are important carbon pools in the global carbon cycle [4, 26, 29]. The whole carbon cycling in forest ecosystem is not complete if soil carbon is not included. Some of the forestry practices may contribute to climate change mitigation through higher energy wood production, for example, stump removal or removals of logging residues during harvesting. At the same time, they may negatively impact soil carbon storage, as the effects are often site-specific [1, 11].

3. Ongoing research in response to identified challenges

3.1 Forest infrastructure maintenance impact on water quality

Although drainage network maintenance is necessary to support tree growth, it can also cause erosion, resulting in the transport of suspended particles and nutrients to the water bodies. Intensification of sedimentation and eutrophication processes can lead to deterioration of water quality, and it is therefore important to implement effective measures to improve water management practices and guidelines in forestry and water management.

One of the methods used to preserve water quality is the establishment of sedimentation ponds for particulate matter capture. Sedimentation ponds are larger cross-sectional areas on the main ditches before they enter into the waterbody. In Latvia sedimentation ponds are generally built according to standard parameters – pond should be constructed in a 30-50 m long section, creating 0.5-1.0 m recession, the bottom of the pond should be at least 2 m wider than ditch itself [22]. Results of a three-year study by Kalvite et al. [9] showed that sedimentation ponds built by JSC 'Latvia's State Forests' (according to legislation) in six catchments where drainage network maintenance was performed were more effective in reducing the concentration of suspended particles than concentrations of nutrients. In general, concentrations of total suspended solids and nutrients gradually decreased after maintenance (Fig. 1). However, the discharge of nutrients is closely linked to the discharge of particulate matter, and more effective solutions to protect water quality must be considered.

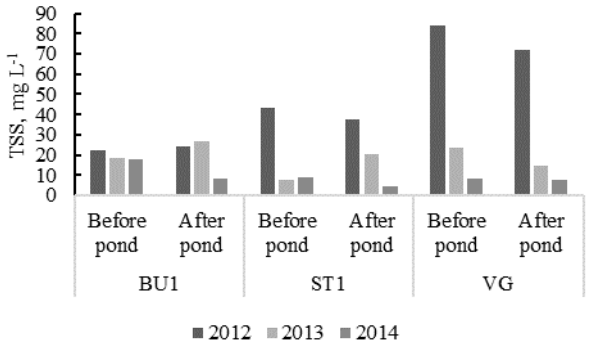

Fig. 1: *TSS concentrations in three study sites (BU1; ST1; VG) before and after sedimentation ponds during drainage network maintenance and during two years following it*

To test whether parameters of water protection structures that are applied in other countries are more effective, a sedimentation pond and a peak flow control structure will be built in 2019 in experimental forests of Kalsnava forest district according to parameters generally used in Finland. In Finland sedimentation ponds are constructed with a surface area of 3-8 m^2 per hectare, with a minimum volume of 2-5m^3 per ha in catchment areas up to 40 ha [7]. The size of the drainage system in our study area is noticeably larger; therefore, a complex solution will be tested by combining a large irregular shaped pond (~3500 m^2) with uncleaned sections of ditches and with sedimentation pits. Peak flow control dams regulate runoff from the drained area during periods of intensive runoff with control pipes, thereby preventing flooding of surrounding areas and extending sediment settling time. The area of the sedimentation pond, which will be located before the peak flow control structure, will be ~468 m^2 (3 m^2 per ha according to the Finnish method). The results will allow to evaluate the efficiency of such water protection structures in local climatic and geographical conditions and to adjust their parameters to increase the efficiency [10].

As beaver activity is multifaceted and complex according to the environmental and ecological impact, further steps have to be considered to reduce the impact of beaver activity on forest productivity and water quality. Kalvite et al. [8] reported that considering N_{tot}, P_{tot}, and DOC concentrations less impact on water quality was detected in a natural beaver site in a protected area comparing to the results from ~3 km distant study site where beaver dams were found in a drainage system established in a potentially highly productive peatland. In addition to higher N_{tot}, P_{tot} and DOC concentrations in the drainage system water, the adjacent forest stand was destroyed due to flooding. During this study also the effects of beaver dam removal were studied. Analyzing the initial effects on the water chemistry, it was concluded that N_{tot}, P_{tot} and DOC concentrations in drainage system water runoff were higher directly after beaver dam removal comparing to the concentrations before dam removal. On the one hand, beaver dam is a structure to retain nutrients on site, but, on the other hand, accumulated nutrients directly after dam removal are released and have a greater impact in a short period of time. Study is being continued to better understand correlations between changes in water quality and the beaver management, besides Hg and MeHg content in water, sediment and biota will be further investigated in beaver populated areas.

3.2 Felling impact on nutrient cycling

Logging residue extraction from final fellings may significantly delay return of equilibrium state in cycling of nutrients. The impact is mainly site specific and dependent on different factors. Some of the main factors are forest site type, fertility of the site and soil properties. In a study by Klavins et al. [12] nutrient concentrations in soil solution were observed for five years in three sites with low, medium and high fertility after different intensities of uniform regeneration felling (WTH and CH). It was detected that nutrient concentrations in soil solution increased with peaks two to three years after the felling and returned to pre-felling levels after three to five years (Fig. 2). It was found that in low fertility site NO_3^--N and K^+ concentrations were higher in CH subplot comparing to WTH showing the importance of logging residue decomposition to aid the growth of the young stand. On the contrary, in high fertility site NO_3^--N and K^+ concentrations were higher in WTH subplot as compared to CH subplot (Fig. 2). PO_4^{3-}-P concentrations did not differ significantly between the subplots of different felling intensity.

To evaluate the site productivity after different intensity fellings in a study by Klavins et al. [13] measurements of the next rotation stands were carried out in the same study sites, as well as five other medium fertility sites where WTH was compared to WTH+SB. In the high fertility site, it was found that productivity of Norway spruce was lower in CH than in WTH subplot. In contrast, productivity of Scots pine in low fertility site was found to be higher in CH subplot than WTH subplot. Comparing WTH and WTH+SB extraction subplots it was found that productivity of Norway spruce and black alder was higher in WTH subplots. In a mixed stand with Norway spruce and black alder no differences were detected regarding spruce productivity, but productivity of black alder was higher in WTH+SB subplot.

In long term WTH (also WTH+SB) may significantly reduce soil nutrient pools [21, 25], but in high fertility sites where risks of extensive leaching are present to nearby waterbodies, logging residue extraction may provide environmental benefits [24]. In a study by Libiete et al. [18] general soil parameters in three of previously mentioned medium fertility WTH vs. WTH+SB sites were analyzed. Acidification of soil and soil solution was not observed. Furthermore, soil C and N stocks where similar in both WTH and WTH+SB subplots.

Previously mentioned WTH vs CH sites are located on shallow slopes, which directs surface runoff and leachates to nearby watercourses/ditches. Between the fellings and water bodies buffer zones are present. To evaluate direct forestry impact on nearby waterbodies and the efficiency of buffer zones soil solution and water in watercourses/ditches are sampled in the framework of an ongoing study. Initial results of the soil solution reflect upslope activities and determines where buffer zones are needed the most [14].

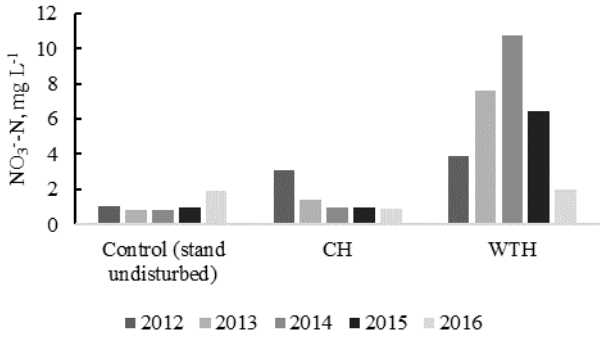

Fig. 2: *NO_3--N concentrations in soil solution during and after different intensity regeneration fellings in high fertility site (CH – conventional harvest, where only stems are removed; WTH – whole tree harvest, where all above ground biomass is removed; felling was performed between 2012 and 2013 sampling (vegetation) seasons)*

3.3 Forest management impact on carbon storage

To estimate soil carbon balance in dry forest site types on mineral soils in Latvia Yasso07 soil carbon model was used. It was determined that under the steady climate scenario, the forest mineral soil is a stable carbon sink. The model showed carbon removals in mineral forest soils for the whole 1990 – 2030 period. The average CO_2 removals for steady climate scenario were ~0.6 t CO_2 ha^{-1} yr^{-1}. Even if the climate change was considered, forest mineral soil still acted as a sink not source of CO_2. Under the most severe climate change scenario (+0.05°C annually), soil was a source of CO_2 only for one year. During the remaining period the forest mineral soil was CO_2 sink (0.1 – 0.7 t CO_2 ha^{-1} yr^{-1}) [1].

Management of organic soils may alter carbon cycling. The main threat for carbon storage is drainage, causing increased CO2 emissions [5, 20]. Results of the study performed in a transitional mire drained for forestry in Latvia showed that in the hemiboreal vegetation zone, drainage of organic soils is not always causing carbon storage reduction. Carbon stock may even increase after the drainage. This is caused by the increase of above and belowground litter production rates. Peat subsidence followed by drainage was caused mostly by physical shrinkage of aerated soil surface not by peat oxidation [19].

4. Conclusions

Historically due to long rotation age of forests, use of only native tree species, small size of compartments and strict environmental considerations forestry in Latvia has been moderately intensive, but currently the forest management intensification is ongoing due to global and regional environmental and economic pressures.

As forestry activities may cause significant impact to connected ecosystems, relevant preventive actions are implemented to minimize the environmental risks. Furthermore, research is being carried out to further investigate possible negative interactions and minimize their impact.

Drainage system maintenance is an integral part of Latvian forestry, and further steps have to be taken to minimize the export of nutrients and suspended particles to connected water bodies.

Eurasian beaver population management has to be considered to balance economic needs and nature conservation.

The disturbance to the cycling of nutrients in felling sites must be further investigated. Export of logging residues should be considered in sites where nutrient stocks will not be exhausted and environmental benefit for nearby waterbodies is possible. Properly functional buffer zones according to felling intensities and topography must be applied.

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MULTI-COMPONENT ADSORPTION OF HEAVY METAL IONS FROM AQUEOUS SOLUTIONS ONTO LOW COST ADSORBENT BASED ON RICE HUSKS

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Abstract: *A novel low cost adsorbent based on rice husks was obtained by slow pyrolysis at temperature 350°C and was characterized by means of SEM, Hg-porosimetry and N2-adsorption. The adsorption properties of the investigated material towards Fe(III), Pb(II), Cr(III) and Cu(II) ions in multi-component aqueous solutions with different concentrations and acidity were studied in a batch system. The adsorption of metals is significantly affected by the pH value. Equilibrium experimental data were fitted to linear Langmuir and Freundlich model and maximum adsorption capacities were calculated. Kinetic of adsorption in multi-component solutions was also investigated.*
KEYWORDS*: RICE HUSKS; PYROLYSIS; ADSORPTION; HEAVY METALS; AGRICULTURAL WASTE*

1. Introduction

During recent years, many researchers have focused their interest on heavy metals due to their known toxicity and carcinogenicity as they are discharged in small quantities by numerous activities such as rapid industrialization, urbanization and anthropogenic sources into the environment [1]. Numerous techniques and treatment technologies have been developed for the clean-up of waters contaminated with metal ions. Traditional methods for water purification such as chemical precipitation, coagulation, ion-exchange and membrane processes are either too expensive or do not allow one to reduce their content to levels dictated by increasingly stringent regulations. Methods based on physical and chemical adsorption have recently found wide application and most studies are concentrated on searching more effective and low cost adsorbents [2].

Rice husks, a by-product from the rice milling industry, are produced in bulk as a waste [3]. The granular structure of the husks and their phase composition, chemical stability, water insolubility, and high mechanical strength render them suitable for preparing valuable materials with different carbon/SiO_2 ratios. A possible application of the husks is as biosorbents for various pollutants from aqueous media, directly or after activation.

The use of biosorbents from numerous lignocellulosic agrowastes is a very constructive approach and has received much attention in sorption of heavy metals, because they are inexpensive and have high adsorption properties resulted from their ion exchange capabilities [4, 5]

Since industrial effluents contain several metals a practical consideration to the problem reveals that most of the effluent solutions represent a case of multi-metal situation rather than mono-metal one. In such a scenario it becomes essential to study the effects of the presence of co-cations on the adsorption capacity of a sorbent for a particle contaminant [6].

The aim of the present investigation is to study the possibilities for simultaneous removal of some heavy metal ions (Fe(III), Pb(II), Cr(III) and Cu(II)) from multi-component solution by hybrid material, obtained from rice husks.

2. Experimental

The rice husks were subjected to slow pyrolysis at temperature 350°C. The hybrid material structure was characterized by scanning electron microscopy (SEM), infrared spectroscopy (IR), intrusion Hg-porosimetry and by low-temperature N_2 adsorption. Before nitrogen adsorption, the samples were degassed at 250°C for 3 h.

The carbon/ash ratio in the solid pyrolysis residues was determined gravimetrically by thermal analysis. The morphology of the investigated material has been studied using scanning electron microscopy.

Adsorption experiments were carried out at room temperature (20°C) in the batch mode [7-9]. 20 mL aqueous solutions containing Cu(II), Fe(III), Pb(II), and Cr(III) ions were sequentially treated with 0.2 g of the investigated material. The variables studied were agitation time interval, pH and concentration of corresponding metal ions. After the desired time of treatment, the samples were filtered to remove the adsorbent, the metal ion concentration in the filtrate was determined by flame AAS. The values of the degree of adsorption i.e. the amount of adsorbed metal ions $\boldsymbol{Q_e}$ were calculated as described in [7,9].

3. Results and discussion

3.1. Material characterization

The porous structure of hybrid material was investigated by SEM and IR spectroscopy, intrusion Hg-porosimetry as well as low-temperature adsorption of N_2. The structural characteristics and the morphology of the investigated material are presented on Figures 1, 2, 3 and 4 and Table 1.

The investigated material is composed of cellulose, hemi-cellulose and lignin. It contains many functional groups such as hydroxyl, carbonyl, and carboxyl with characteristic chemical structures. In order to explore the qualitative adsorption characteristic of surface functional groups, the IR spectrum in the range of 4000–400 cm^{-1} is shown on Figure 2.

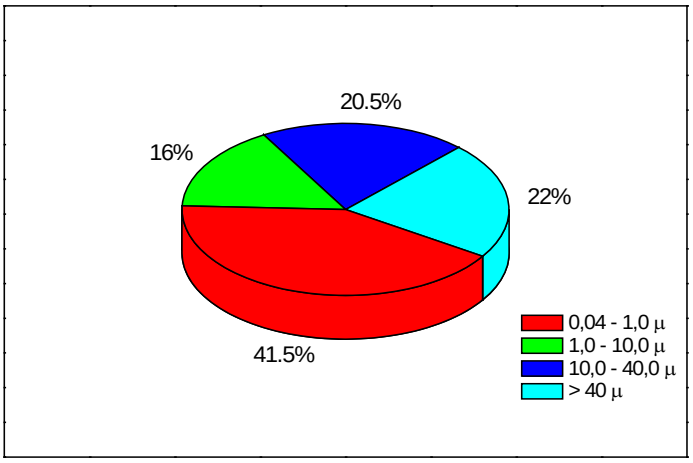

Fig. 1. *Macropore size distribution determined by Hg-porosimetry*

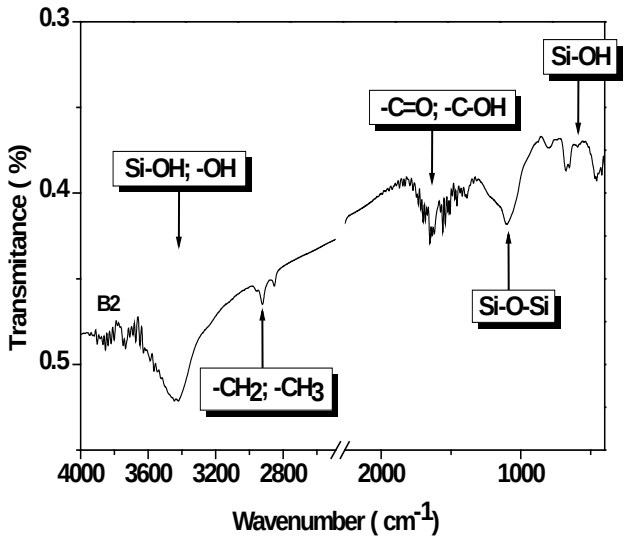

Fig. 2. *IR spectrum of of the investigated material*

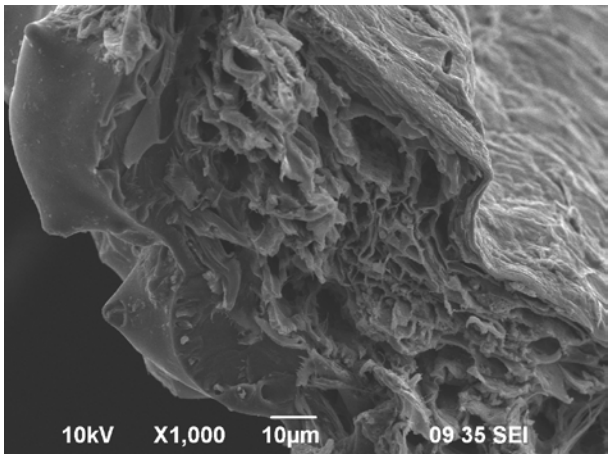

Fig. 3. *Scanning electron micrographs of the surface of the investigated material*

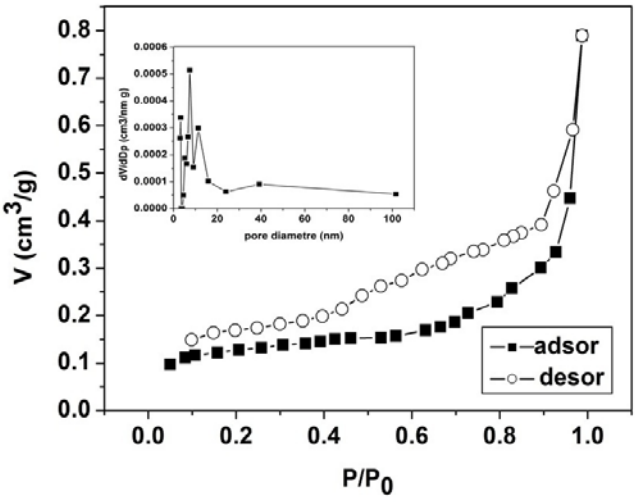

Fig. 4. *Nitrogen adsorption-desorption isotherms and the mesopore size distribution of the investigated material*

It is also obvious that the porous structure of the obtained material in the present study can be defined as multiporous.

Table 1. *Structural characteristics of the investigated material*

Characteristics	Value
Total pore area, $m^2.g^{-1}$	0.82
Average pore diameter **Intrusion data,** μm	0.51
Average pore diameter **N_2 adsorption,** nm	9.7
Bilk density, $g.cm^{-3}$	0.64
Porosity, %	52.04
B.E.T. spec. surface area, $m^2.g^{-1}$	196
V_t,$cm^3.g^{-1}$	$7.522\ x10^{-2}$
pH	6.7
Ratio C:SiO_2	1.08

3.2. Adsorption studies

3.2.1. Effect of contact time

The effect of contact time on the amount of adsorbed Fe(III), Pb(II), Cr(III) and Cu(II) ions in multi-component solutions are presented on Figure 5. The adsorption on the investigated material was found to increase with increasing contact time and reached a maximum value within two hours for Fe(III); about one hour for Cr(III) and Pb(II) and less than 30 min for Cu(II) ions. Nevertheless, all further experiments were performed at a contact time of 12 h.

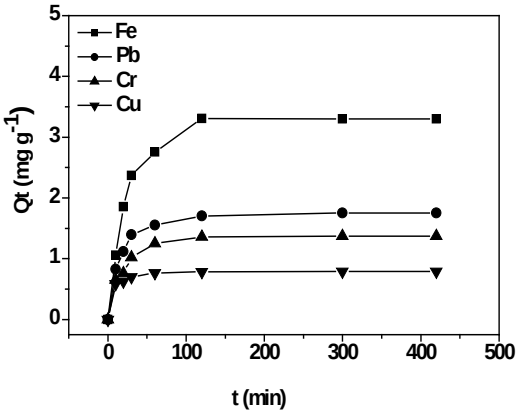

Fig. 5. *Effect of contact time on amount of adsorbed Fe(III), Pb(II), Cr(III) and Cu(II) ions on the investigated material (Co 50 mg L^{-1} at pH 4.5)*

In order to understand the adsorption mechnism, three kinetic models have been applied to the experimental data, namely: pseudo-first-order; pseudo-second-order and intraparticle diffusion as described in [8-10].

The model kinetic parameters and corresponding correlation coefficients are presented in Table 2. The theoretical values obtained from the pseudo-second-order kinetic model are very close to the experimental **Qe** values. Therefore, the adsorption of all investigated ions can be described by the pseudo-second-order kinetic mechanism. On the other hand, the correlation coefficients for the pseudo-second-order kinetic model show the highest values. The obtained results confirmed that the pseudo-second-order mechanism is predominant for the simultaneous adsorption of Cu(II), Fe(III), Cr(III) and Pb(II) onto the investigated material.

The high applicability of the pseudo-second-order rate equation to fit the present kinetic data was generally in agreement with other researchers' results [11].

3.2.2. Effect of pH

The adsorption efficiency of the studied material as a function of pH of initial solutions is presented on Figure 6. As expected, the adsorption of all target metal ions strongly depends on acidity of the initial solutions. Upon increasing the pH values the amounts of adsorbed ions increased and the optimum pH range was found to be about 5.0. Most affected by pH changes is the adsorption of Fe(III).

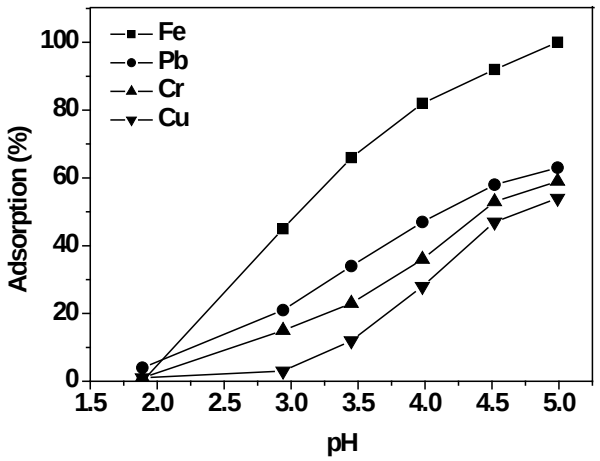

Fig. 6. *Effect of pH on metal adsorption onto the investigated material*

3.2.3. Adsorption isotherms

Experimental adsorption isotherms for multi-component solutions are presented on Figure 7. In all cases an increase of adsorption upon increasing of the corresponding ion concentration in the solution is observed. These results indicated that the energetically less favourable sites also became involved with the increase of ion concentrations [10].

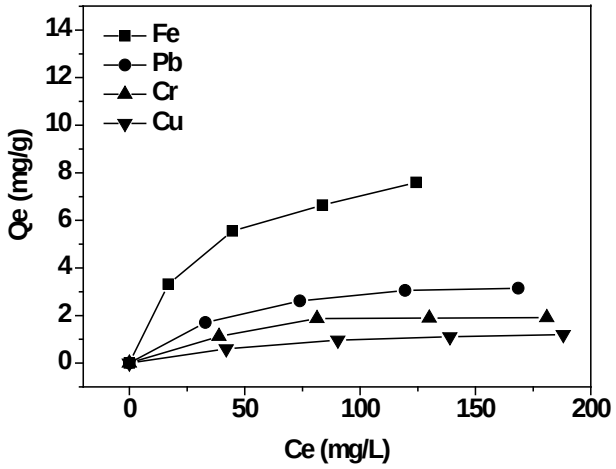

Fig. 7. *Adsorption isotherms for multi-component solution*

The equilibrium isotherms are very important in designing adsorption systems. The adsorption isotherm describes the distribution of the adsorbed molecules/ions between the liquid and solid phases at equilibrium state. The concentration variation method was used to calculate the adsorption characteristic of both adsorbent and process. The elucidation of isotherm data by fitting them to different isotherm models is a substantial step in the adsorption study. There are several isotherm equations available for evaluation of experimental adsorption equilibrium data. In the present study the equilibrium adsorption data are analyzed using Langmuir and Freundlich isotherm models [3-6].

The values of Langmuir and Freundlich parameters and corresponding correlation coefficients are presented in Table 3.

It is obvious from Table 3 that the highest monolayer adsorption capacities (Q_0) were obtained for Fe(III) ions - 7.83 mg g^{-1} (for multi-component solution).

Table 2. Kinetic parameters for the adsorption of Fe(III), Pb(II), Cr(III), and Cu(II) ions from multi-component aqueous solutions onto the investigated material

Metal ions	Pseudo-first order constants			Pseudo-second order constants			Intraparticle diffusion constants			Q_e, exp (mg/g)
	Q_e (mg/g)	k_1 (1/h)	r^2	Qe (mg/g)	k_2 (g/mg h)	r^2	k_{id} ($mg/g.h^{1/2}$)	C (mg/g)	r^2	
Fe(III)	**1.59**	**0.061**	**0.9501**	**3.45**	**0.550**	**0.9888**	**0.25**	**0.309**	**0.9391**	**3.32**
Pb(II)	**1.65**	**0.005**	**0.9932**	**1.80**	**0.101**	**0.9996**	**0.28**	**0.154**	**0.8924**	**1.75**
Cr(III)	**1.25**	**0.004**	**0.9189**	**1.42**	**0.092**	**0.9994**	**0.10**	**0.411**	**0.8941**	**1.38**
Cu(II)	**0.49**	**0.004**	**0.8965**	**0.79**	**0.085**	**0.9998**	**0.23**	**0.066**	**0.8429**	**0.79**

Table 3. *Isotherm constants for multu-component adsorption of metal ions onto the investigated material*

Metal ions	Langmuir parameters			Freundlich parameters		
	Q_0 (mg/g)	K_L (L/mg)	r^2	k_F ($mg^1 L^n g^{-1}$)	n (L/mg)	r^2
Fe(III)	**7.83**	**0.024**	**0.9976**	**1.07**	**2.42**	**0.9789**
Pb(II)	**4.00**	**0.031**	**0.9952**	**0.46**	**2.55**	**0.9483**
Cr(III)	**1.88**	**0.025**	**0.9803**	**0.21**	**2.14**	**0.9910**
Cu(II)	**1.30**	**0.030**	**0.9934**	**0.20**	**2.78**	**0.8853**

According to the correlation coefficients r^2 (values from 0.9803 to 0.9976, Table 3) the fit to this model is excellent. Therefore, the equilibrium adsorption data can be appropriately presented by Langmuir model in the studied concentration range.

The fit of Freundlich model is also very good (correlation coefficients r^2 values from 0.8853 to 0.9910, Table 3), but not as good as the fit of the Langmuir model, especially for Cu(II) and Pb(II). The constants k_F and n calculated for all investigated ions are presented in Table 3. Higher values for k_F indicate higher affinity for adsorption. In our study n-values are in the range of 2.14 to 2.48 (Table 3). Larger value of n (smaller value of 1/n) implies stronger interaction between adsorbent and heavy metal and favourable adsorption onto the obtained hybrid materials [12,13].

However, from data listed in Table 3 it can be concluded that the adsorption isotherms of the ions Cu(II) and Pb(II) exhibit mainly Langmuir behaviour, while for Cr(III) and Fe(III) the mechanism cannot be directly attributed to the Langmuir or Freundlich models (the r^2 values imply that both isotherm models provide good correlations for the adsorption).

4. Conclusions

The present study deals with the adsorption properties of a hybrid material, obtained by slow pyrolysis at temperature 350°C from rice husks, as an effective sorbent with respect to Fe(III), Pb(II), Cr(III) and Cu(II) ions from multi-component solutions.

The effects of contact time, acidity of initial solutions and metal ion concentrations were followed. Contact time of 2 h was sufficient to reach equilibrium. The optimum pH value was found to be about 5.0

The results confirmed that the pseudo-second-order mechanism is predominant for the adsorption of all investigated ions onto the obtained material.

Equilibrium modeling data were fitted to linear Langmuir and Freundlich models. It was established that the adsorption isotherms of the ions Cu(II) and Pb(II) exhibit mainly Langmuir behaviour, while for Cr(III) and Fe(III) the mechanism cannot be directly attributed to the Langmuir or Freundlich models. . The maximum adsorption capacities for multi-component adsorption were calculated. Highest adsorption capacity was achieved again for Fe(II) ions. It was proved that the new hybrid material could be used as effective, low-cost adsorbent for simultaneous removal of Cr(III), Fe(III), Pb(II) and Cu(II) from wastewaters.

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THE INFLUENCE OF PERENNIAL LEGUMES, LEGUME-FESTULOLIUM MIXTURES AND THEIR MULCH ON SOIL MINERAL NITROGEN UNDER ORGANIC CROPPING CONDITIONS

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Abstract: *Legumes are one of the major nitrogen sources in arable organic farms. Often the aboveground mass of perennial legume is used for green manure. The study was aimed to explore the aboveground mass of perennial legumes and their mixtures with festulolium, used as mulch, to estimate soil mineral N variation under organic cropping conditions. The perennial legumes (Trifolium pratense L., Medicago sativa L.) and their mixtures with festulolium (x Festuliolium) and their aboveground mass management methods: removed from the field (cut twice for forage), mixed management (the first cut – removed from the field, the second and third cuts – mulched), mulching (4 times) in organic arable farming system were applied. After ploughing up of mulches, the dynamics of soil mineral nitrogen content depended on the incorporated carbon and nitrogen of mulch, its C/N and meteorological conditions during the whole vegetation period. The compatibility of nitrogen release from incorporated organic matter and cereal nitrogen demand was established not every years. The amount of soil mineral N in the autumn can be controlled by growing mixtures of legumes and festulolium and by incorporating a limited amount of mulch into the soil.*

KEYWORDS: *ABOVEGROUND MASS MANAGEMENT METHODS, FESTULOLIUM, LUCERNE, LEGUME-FESTULOLIUM MIXTURES, MULCH, RED CLOVER.*

1. Introduction

Many scientists in European countries suggest using flexible technological units in organic farms: enriching biodiversity, mobilizing nutrients (nitrogen), incorporating them into the metabolic cycle of biogenic elements within the agro-system, reducing nutrient (especially nitrogen) leaching, halting soil degradation, humus depletion, promoting natural biological processes and effectively balancing organic carbon and nitrogen metabolism in fields [4, 7, 5]. This is very important in crop farms, where most of the nutrients are removed from the farm with the produce sold and the use of legumes is limited. Numerous studies have been carried out using legumes as a green fertilizer, thus enriching the soil with low-cost symbiotic nitrogen [6, 9]. This type of nitrogen is still underutilized and used inefficiently [1, 3, 10]. However, there is considerable amount of data in literature on the rapid mineralization of legume biomass [2, 3, 8] and the potential for nitrogen to leach into groundwater [10, 12]. The more intensively the incorporated organic matter decomposes, the more mineral nitrogen accumulates in the soil [1]. If it is not bound into soil organic compounds at that time or is not absorbed by growing plants, nitrogen losses can occur in early spring or late autumn.

The aim of this study was to examine the chemical composition, the mineralization intensity and the influence on mineral soil nitrogen of aboveground mass mulch of perennial legume herbage and their mixes with festulolium in clay loam soils.

2. Materials and methods

Three similar field experiments were done in the northern part of Central Lithuania's lowland at the Lithuanian Research Centre for Agriculture and Forestry's Joniškėlis Experimental Station (56°21′N, 24°10′E) in 2008-2009 (I experiment), 2009-2010 (II experiment), and 2010-2011 (I experiment). The parental rock of the experimental site is limnoglacial clay on morenic loam, according to the current classification – *Endocalcari Endohypogleyic Cambisol, Cmg-n-w-can* (WRB 2015). The soil texture is clay loam (at a depth of 0–25 cm) on silty clay (at a depth of 26–76 cm) with deeper lying sandy loam (at a depth of 77–135 cm). The topsoil (0–25 cm) pH is close to neutral, medium in phosphorus, high in potassium and moderate in humus.

Experimental designs and details. The experiments were conducted in the following crop rotation sequence: legume and legume-festulolium mixtures → winter wheat *(Triticum aestivum L.).* Design of field experiment: *Factor A.* Legume and legume-festulolium mixtures: 1) festulolium (*x Festuliolium*), Fl; 2) red clover (*Trifolium pratense* L.), RC; 3) mixture of red clover and festulolium, RD+Fl; 4) lucerne (*Medicago sativa* L.), L; 5) mixture of lucerne and festulolium, L+Fl. *Factor B.* Management methods of the aboveground mass of perennial grasses: 1) removed from the field (cut twice for forage), 2R; 2) mixed management (the herbage of the first cut was removed from the field, the herbage of the second and third cuts was mulched), R-2M; 3) mulching (herbage was cut four times and mulched), 4M. Control treatment were Fl, aboveground mass removed from the field. The experimental plots were laid out in a randomised complete two-factor block design in four replicates. In 2008, 2009 and 2010, year of forage grasses cultivation, herbage were cut for forage at flowering stage, for mulching at bud formation stage. Herbage for green manure (mulch) was cut by a self-propelled mower, equipped with a mulching device. In the end of August mulch mass was incorporated by a disk cultivator at 10 cm depth before ploughing at 25 cm depth. In the first year after perennial grasses and their mulch incorporation, winter wheat, was grown. In field experiments, the plants were grown according to organic farming standards.

Sampling and analysis of plant and soil. The aboveground mass of perennial grasses of each cut were measured. After plant mass weighing, the dry matter was determined (dried to constant mass at 105 ° C) and the aboveground mass of perennial grasses was calculated. All plant samples were dried, milled and analysed for: carbon (C) content by wet chemistry dichromate oxidation method spectrophotometrically at wavelength of 590 nm and using glucose as a standard; nitrogen (N) content (by Kjeldahl method). Soil mineral N was measured 3 times during the experimental period: in the first year before ploughing-in of perennial grasses and after ploughing-in – in late autumn; in the second years – in spring when the winter wheat vegetation renewed ($N–NO_3$ by ionometric and NH_4 by spectrophotometric methods). Samples for soil mineral N ($N\text{-}NO_3$ + $N\text{-}NH_4$) analyses – in 1mol L^{-1} KCl extract, w/v ratio 1:5 was collected from 0-60 cm layer. The meteorological conditions of the study periods are presented in Table 1. The data were statistically processed using a two-factor analysis of variance as well as correlation and regression methods [11]. The data of the experiment were analyzed when the factual Fisher criterion ($F_{fact.}$) was higher than the theoretical one ($F_{theor.}$). The significance of differences between the means (control and individual treatments) was estimated according to the least significant difference (LSD) at the 0.05 and 0.01 probability levels.

3. Results and discussion

3.1. Characteristic of herb mulches

Maximum aboveground mass yield was of forage legume-festulolium mixture (I and II experiments) or of lucerne and

Table1. The meteorological conditions of the study periods

Periods	Description of periods
Experiment I 2008-2009	Sum of active temperatures in summer was 1519.3 ºC and in autumn - 305.6 ºC. August and October were months of excess moisture, October and November were unusually warm. Winter did not start immediately, November and early December were changeable. Above zero temperatures (<0 °C) lasted until 13 December, 2008. Winter was warmer than the standard climate rate (average data for 30 years) and December was abnormally humid. Winter had one extended warm (>0 °C) period (21-26 January). March was very changeable, with positive mean daily temperature (>0 °C) stabilizing since 29 March.
Experiment II 2009-2010	Sum of active temperatures in summer was 1429.8 ºC and in autumn - 393.1 ºC. June, July and October were months of excess moisture. September and November were significantly warmer compared to the standard climate rate. Mean daily temperature dropped below 0 ºC on 11 December. Winter was close to the standard climate rate, with more pronounced deviations: December - changeable and humid, January - very cold. The mean daily temperature rose above 0 ºC on 19 March.
Experiment III 2010-2011	Sum of active temperatures in summer was 1767.6 ºC and in autumn - 319.0 ºC. Precipitation during the summer was optimal and mean daily temperatures were significantly higher than the standard climate rate. Autumn was dry except for the humid and unusually warm November. The constant negative mean daily temperature (<0 °C) was recorded on 25 November. Winter was close to the standard climate rate, December and February - unusually cold. Winter had one extended warm (>0 °C) period (1-8 February). March was changeable with very little precipitation. Positive mean daily temperatures (>0°C) were recorded only from 31 March.

lucerne-festulolium mixture (III experiments). This determined the mass of mulch that was incorporated into the soil in late summer (as green manure). It was determined that in case of mixed management of legumes and their mixtures with festulolium, the weight used for mulch was 3532-5749 kg DM ha^{-1} and in case of mulching - 5683-8208 kg DM ha^{-1} (data not show). The amounts of carbon (C) and nitrogen (N) accumulated in herbage mulch are shown in Table 2. The species and management methods of aboveground mass of perennial grasses had significant impact (p <0.01) on changes in these (C and N) indicators. The mixed management of legumes and their mixtures with festulolium resulted in a mulch yield of 1832 to 2987 kg C ha^{-1} for all study periods. In Experiment II (2009-2010) the largest amount of C was accumulated in red clover and red clover-festulolium mulch, in Experiment III (2010-2011) - in lucerne and lucerne-festulolium mixture and in Experiment I (2008-2009) - the amounts varied little between plant species. When applying mulching method to the mass of legumes and legumes-festulolium, the carbon content was from 2969 to 4577 kg ha^{-1}. The largest amount of carbon in herbage mulch was accumulated when applying the mulching method of aboveground mass of red clover and red clover-festulolium. In Experiment III, the amount of carbon was the least and did not differ between species of legumes and legumes-festulolium mulch. The lowest amount of carbon was found in festulolium mulch, regardless of the type of management of the aboveground mass.

In legume and legume-festulolium mulch, nitrogen accumulation was significantly higher than in festulolium mulch. According to mean values, mulching perennial grass mass yields 1.7 times more nitrogen accumulation than using mixed management. This value was lower (1.3) in Experiment III. Most of the nitrogen was accumulated in pure legume mulch, using a combination of mixed management and mulching techniques of aboveground mass (except II experiment). Red clover-festulolium mulch had 34-49 kg ha^{-1} and 31-35 kg ha^{-1} less nitrogen, lucerne-festulolium mulch had 12-35 kg ha^{-1} and 34-71 kg ha^{-1} less nitrogen than pure legume mulch using mixed and mulching management methods, respectively.

Table 2. The amount of carbon and nitrogen in the mulch of perennial forage legumes and their mixtures with festulolium

Legume and legume-festulolium mixture (A)	Management methods of parennial grassses (B)											
	R-2M	4M	R-2M	4M	R-2M	4M	R-2M	4M	R-2M	4M	R-2M	4M
	Carbon (kg ha^{-1})						Nitrogen (kg ha^{-1}) / C and N ratio					
	I experiment 2008-2009		II experiment 2009-2010		III experiment 2010-2011		I experiment 2008-2009		II experiment 2009-2010		III experiment 2010-2011	
Fs	1042	2419	778	2340	933	2237	30/35	55/44	24/32	62/38	28/33	57/39
RC	2703	4367	2357	4082	2460	3424	148/18	254/17	153/15	269/15	149/17	211/16
RC+Fs	2488	4577	2410	4173	2034	3540	114/22	219/21	114/21	238/18	100/20	177/20
L	2483	3634	2141	2969	2987	3446	149/17	250/15	151/14	216/14	172/17	230/15
L+Fs	2500	4039	1832	3455	2840	3472	121/21	195/21	116/16	182/19	160/18	159/22
Mean	2243	3807	1904	3404	2251	3224	112/22	195/23	112/20	193/21	122/21	167/22

Note: Fl – festulolium; RC – red clover; RC+Fl – red clover + festulolium; L – lucerne; L+Fl – lucerne + festulolium; R-2M - mixed management, 4M - mulching.

3.2. Mineralization of herb mulches

The decomposition intensity of herbage mulch applied to the soil surface was determined by the C/N ratio. The highest value of this indicator was in festulolium mulch. The C/N value of herbage mulch decreased while increasing number of mulches (mulching method). Comparison of different legume species showed that C/N value of lucerne mulch was slightly lower than that of red clover mulch. The C/N value of the legume-festulolium mulch increased from 14 to 22. This indicator was slightly lower in Experiment II.

During plant growing period, when spread on the soil surface, the herbage mulch decomposed, its weight, carbon and nitrogen content decreased. According to mean values, mulch has a greater reduction in carbon (from 51.2 to 65.0%) than nitrogen (from 15.8 to 46.8%). After comparing perennial grass aboveground mass utilization methods, it was found that mulching resulted in a significant reduction in carbon and nitrogen content in the mulch in comparison to applying mixed management. Organic nitrogen compounds decomposed the least in festulolium mulch. In red clover mulch, the nitrogen content decreased similarly using both mixed and mulching management. In the lucerne mulch, the decomposition of nitrogen compounds had ambiguous values.

3.3. Soil mineral N

At the end of summer, the amount of soil mineral N in the soil layer of 0-60 cm was determined before the grass plowing and mulch incorporation (Table 3). In different experiments, changes in soil mineral N were ambiguous. In Experiment I, leguminous and their mixtures with festulolium resulted in an increase in the soil mineral N content, and the management methods of aboveground mass had no significant effect. Red clover, red clover-festulolium mixture and lucerne significantly increased soil mineral N compared to festulolium. In Experiment II, the mixed management of aboveground mass significantly increased the soil mineral N content. Legumes tended to increase soil mineral N, and their mixtures with festulolium - to decrease. Most soil mineral N in 0-60 cm layer was in Experiment III. Here, the increase of soil mineral N content was positively influenced by legumes, legume-festulolium mixtures and mulching of their aboveground mass. The most of soil mineral N was found after mixed management of aboveground mass of red clover, lucerne and their mixtures with festulolium.

Table 3. The effect of perennial grasses and their mulches, used for green manure, on mineral N in soil (0-60 layer)

Legume and legume-festulolium mixture (A)	Management methods of parennial grassses (B)								
	2R	R-2M	4M	2R	R-2M	4M	2R	R-2M	4M
	I experiment (2008-2009)			II experiment (2009-2010)			III experiment (2010-2011)		
	Before legume and legume-festulolium mixtures ploughing in late summer								
Fs	27.1	33.6	30.6	20.7	45.4**	33.2	31.8	36.0*	39.1*
RC	40.6*	43.2**	38.1*	34.6	35.3*	37.6*	41.7*	43.5**	38.1
RC+Fs	33.8	41.2**	37.7*	33.3	32.0	29.6	42.5*	45.5**	37.8*
L	34.5	37.8*	38.5*	23.3	49.3**	31.8	35.5*	48.1**	37.3*
L+Fs	33.9	35.3	38.6*	22.9	29.0	30.6	31.8	42.7**	37.1*
LSD_{05}AxB			*10.03*			*14.37*			*3.03*
	After perennial legumes ploughing in late autumn								
Fs	34.1	38.9	45.7	24.5	24.3	21.0	26.3	39.5	44.6*
RC	69.4	50.5	59.1	39.9*	40.7*	36.0	92.1**	56.8*	100.8**
RC+Fs	43.4	69.2	68.7	34.6	38.4	33.8	93.2**	73.4**	78.7**
L	66.5	45.1	77.4*	37.2	33.2	31.3	68.3**	75.7**	120.2**
L+Fs	52.9	49.1	72.6*	30.1	35.9	34.1	76.9**	58.2*	69.7*
LSD_{05}AxB			*35.53*			*14.07*			*17.09*
	In spring								
Fs	37.1	37.0	44.1	41.0	45.6	44.3	39.1	55.3*	53.4*
RC	49.3	60.3**	57.3*	66.5*	66.2*	68.1**	54.3*	65.7**	61.3**
RC+Fs	43.1	46.7	50.5	64.8*	63.8*	67.3**	52.4*	55.6*	60.7**
L	46.4	53.8*	64.2**	67.6*	71.4**	63.5*	53.7*	67.7**	56.2*
L+Fs	43.4	52.7*	70.3**	57.5	62.6*	63.5*	51.5*	61.1**	56.9*
LSD_{05}AxB			*15.20*			*18.37*			*12.26*

Note: Fl – festulolium; RC – red clover; RC+Fl – red clover + festulolium; L – lucerne; L+Fl – lucerne + festulolium; R-2M - mixed management, 4M - mulching.

After plowing the perennial grasses and mulch, winter wheat was sown. In late autumn, at the end of winter wheat growing period, soil mineral N content increased by 54.8% and 79.9% (I and III experiment), respectively, compared with the data before the plowing of perennial grasses. Increase in soil mineral N during non-growing season is a negative phenomenon. According to data collected during Experiment I, the most significant increase in the amount of soil mineral N was influenced by mulching management of whole aboveground mass of perennial grasses and the incorporation of this mulch into the soil. In this experiment, the following patterns of mineral N increase were observed: after the removal of the aboveground mass from the field - after legumes, using mixed management - after red clover and its mixture with festulolium and mulching - after lucerne and its mixture with festulolium. The maximum soil mineral N content was determined during Experiment III. Here, the variation in soil mineral N was significantly influenced by the interaction between perennial grasses and their aboveground mass utilization. Soil mineral N was reduced by the use of mixed management of aboveground mass and the cultivation of legumes in a mixture with festulolium. Soil mineral N was the most abundant when legume mulch was incorporated into the soil (mulching method). Experiment II showed little change in soil mineral N compared to period before grass plowing.

When the growing season started in spring, soil mineral N increased (II experiment), decreased (III experiment) or remained slightly unchanged (I experiment) compared to autumn data (mean data). The soil mineral N content in spring indicates the N reserve for initial growing period of cereals. The soil mineral N content was significantly influenced by both investigated factors and their interaction. In Experiment I, the amount of mineral N decreased the most significantly: after the herbage was removed from the field - after legumes and mulching - after use of all grasses, compared to similar data in late autumn. The largest content of soil mineral N was after red clover, lucerne, their mixture with festulolium, using mixed and mulching management methods of aboveground mass. According to data collected during Experiment II, all leguminous and their mixtures with festulolium, regardless of aboveground mass management methods, increased soil mineral N content. In Experiment III, the amount of soil mineral N increased after festulolium, irrespective of their aboveground mass management. As in Experiment I, the most significant reduction in the amount of

soil mineral N was when the grass was removed from the field and mulching was applied. Aboveground mass management methods had no significant impact.

Statistical analysis showed that soil mineral N correlated directly with C and N accumulated in herbage mulch. As these rates increased, soil mineral N increased in late autumn ($r = 0.73$, $p < 0.05$; $r = 0.73$, $p < 0.05$ Experiment I and $r = 0.72$, $p < 0.05$; $r = 0.85$, $p < 0.01$ Experiment III) and early spring (only in Experiment I $r = 0.66$, $p < 0.05$, $r = 0.75$, $p < 0.05$). According to data collected in Experiment II, nitrogen content in herbage mulch significantly positively correlated with soil mineral N in early spring ($r = 0.77$, $p < 0.01$). The decomposition intensity of herbage mulch incorporated into the soil was demonstrated by the C/N rate in mulch and its influence on the dynamics of variation of soil mineral N. According to data collected in Experiment I, as the C/N value of herbage mulch decreased, the amount of soil mineral N increased in late summer and early spring ($r = –0.79$, $p < 0.01$, $r = –0.69$, $p < 0.05$ respectively). It can be argued that the mineralization of herbage mulch started relatively early. High levels of soil mineral N accumulated in late autumn, which was also influenced by meteorological conditions. In Experiment II, the dependence of soil mineral N on the C/N ratio of herbage mulch was more consistent. As the C/N value of herbage mulch decreased, the amount of soil mineral N increased in late autumn and early spring ($r = –0.83$, $p < 0.01$, $r = –0.95$, $p < 0.01$ respectively). The influence of C/N in herbage mulch on soil mineral N variation was the weakest in Experiment III. Here, the C/N rate in mulch negatively correlated with the soil mineral N only in late fall ($r = –0.70$, $p < 0.05$). Further changes in mineral N content may have been affected by meteorological conditions.

4. Conclusion

Summarizing the data, it can be concluded that high soil mineral N content in late autumn may lead to N losses and decrease of N content in spring. The amount of soil mineral N in the autumn can be controlled (reduced) by growing mixtures of legumes and festulolium and by incorporating a limited amount of mulch into the soil.

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GEOINFORMATION MAPPING FOR PROVIDING THE RATIONAL USE AND PROTECTION OF SOIL

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Abstract: *The approach to design of the system of geoinformation mapping to support making the land management project or management decisions for soil conservation were shown in the study. Developing the conceptual, logical and physical models of geodatabase to provide mapping of arable land condition was shown in the study. A set of thematic maps, designed as combination of relief, climatic and soil conditions, would be very effective to the land management in optimizing the rational use and protection of land.*
KEYWORDS*: GEOINFORMATION MAPPING, SOIL DEGRADATION, LAND CONDITIONS, LAND MANAGEMENT*

1. Introduction

In the modern world, the use of agricultural lands is an important link in the economic activity of humanity. From the economic point of view, implementation of land protection measures is more effective than eliminating the negative consequences of their degradation or total loss of fertile land for agronomy. Therefore, the timely implementation of environmental measures may not only reduce the impact of negative processes on the environment, but also helps to preserve the land for agricultural use.

Determination of the land condition is carried out by assessing the current condition and factors that affect this condition in the spatial-temporal aspect. Knowledge of the land condition is the basis for making decisions on the organization of their rational use and protection, development of the land management projects, planning of crop rotation, etc. In this case, the most important role belongs to the spatial analysis of map data, which requires the practical implementation of territories mapping based on the application of geoinformation technologies and the use of geoinformation modeling. The application of these principles is to determine the condition of soil cover and trends in its change, to take into account the environmental and economic factors of land degradation and provide data to support the decision-making in the field of land use and protection.

Thus, in order to provide appropriate information support for making sound management decisions, an information system is needed that will solve the problems of rational use and protection of soils and will create a complex of complex digital thematic maps reflecting the actual soil condition. Particular role in this regard is played by integration of spatial and time information on land, statistical and cartographic materials in the geographic information system (GIS).

2. Prerequisites and means for solving the problem

2.1. Analysis of recent researches and publications.

The development a problem of evaluation of soil water erosion and conservation practices have been covered in works [1-5]. The article [1] reviewed the estimate and map soil vulnerability to erosion through the Universal Equation of Revised Soil Loss. The paper work [2] considered the factors that have the greatest influence on the formation of water erosion. The article [3] showed substantiates the necessity develop and evaluate a land suitability model for rapeseed farming using topography factors, soil data and remote sensing data in calcareous soils of semi-arid regions northwestern Iran. The research [4] presented the evaluate soil physical properties of long-used cultivated lands. The article [5] deals with the influence increase in the frequency of extreme daily rainfall to erosion process.

The development problems of evaluation of soil wind erosion and conservation practices have been considered in works [6-8]. The work [6] presented prospects about restoration of sod-podsolic and sod-carbonate soils possessing light granulometric composition (texture) regarding local processes of wind erosion. The paper [7] demonstrated how windbreak system planting and plot size and shape planning can influence wind direction distribution and draw attention to the role of preventive agriculture management in controlling wind erosion hazard areas. The study [8] recognized qualitative and quantitative soil loss mechanisms in result of deflation under the conditions of simulated wind at speeds around threshold value.

The article [9] analyzed combined approach based on remote sensing skills and rational equation of soil erosion estimation, to determine the spatial distribution of soil loss and erosion hazard.

The paper [10] demonstrated developing the structure of geodatabase and knowledge base to provide quantitative mapping of land suitability for cultivation the main crops.

Many developed techniques take into account only one type of soil degradation. However, the problem of structuring information of soil state which provides user-friendly display of spatial data and is the basis for making land management project or management decisions for soil conservation was not covered in the works listed.

2.2. Statement of problem.

As many other studies were focused on erosion process modeling, we suggest the geoinformation mapping as the approach to collect, analyze and combine different types of information for making project or land management decisions.

The objective of the study is to substantiate the geoinformation model for increasing the efficiency of the land management in optimizing the rational use and protection of land.

To achieve the objective of the study, the following tasks were used: (i) to determine the general structure and functional model of geoinformation mapping system; (ii) to present an implementation of cartographic modeling of land resources taking into account natural and anthropogenic factors of influence; (iii) to demonstrate physical implementation of the test version of geoinformation mapping system based on the use of attribute and spatial data of the studied area.

2.3. Research methodology.

The geoinformation mapping approach, highlighted in the work [11], provides for the combination of knowledge base with spatial data that expanded the possible applications of geodatabases. The approaches based on the Unified Modeling Language (UML) were used when developing the model. The geoimages in this study are based on the use of such tools as overlay operations, classification methods and reclassification of numerical indices. The information base of the study is ground investigations and thematic land management maps.

The territory of Vasylkiv Raion of Kyiv Oblast was chosen as a modeling object.

3. Solution of examined problem

When studying the issues of rational use and protection of soils, the simulation modeling approach, which expresses the most significant features of real processes and phenomena, was used. On

the one hand, the soils form a certain system, and on the other hand, the soil is an integral part of agrolandscape, which is influenced by the components of this agrolandscape. Soil, in turn, is a complex system, the quality of which is indicated by a large number of indicators: granulometric composition, parent rock, humus content, nitrogen, potassium, phosphorus, pollution level, etc. The development of degradation processes is influenced by the climate, relief, presence of protective forests, human economic activities, etc. All these elements interact with the soil and have a protective or destructive effect (fig. 1).

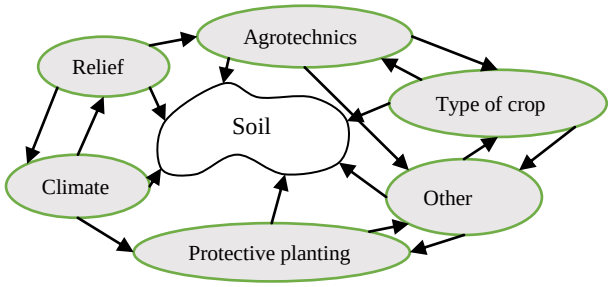


Fig. 1. A set of factors interacting in the studied system.

In this case, in order to achieve the functions of protecting land, in general, and soils, in particular, a set of all interconnected elements and elements of the environment must be taken into account.

The main types of tasks that are necessary to achieve the rational use and protection of lands (soils) in the land management are (Fig. 2): land assessment, protection against degradation and observance of optimum correspondence between types of land.

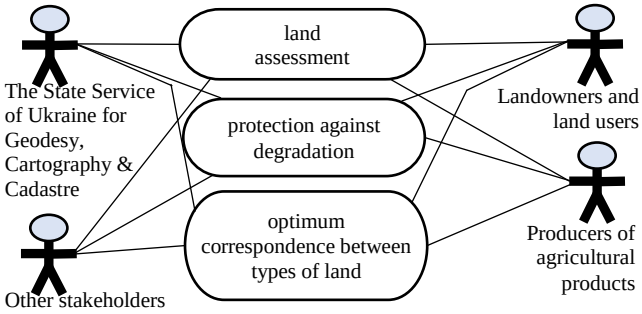


Fig. 2. Classification of task types and users in land management process.

The assessment of land conditions involves defining the indicators that quantitatively and qualitatively characterize the use of land in agriculture. The protection against land degradation involves organizing the crop rotation and soil tillage systems in order to increase its fertility, to protect the soil from water and wind erosion, landslides, flooding, waterlogging, secondary salinization, drying, compaction, soil contamination and to prevent the unjustified removal of agricultural land from cultivation. The optimum ratio of land types allows achieving high productivity of agrolandscapes at the minimum cost of material and energy resources, prevention of erosion processes and contamination of soil and surface water by products of erosion.

The users of such information are: The State Service of Ukraine for Geodesy, Cartography and Cadastre, landowners and land users, including agricultural holdings and other stakeholders, which interested in obtaining the land condition data.

The land-planning task of planning the territory for rational use and protection of land is solved using the geoinformation modeling approach, which is based on the analysis of the set parameters and allows finding the most optimum variant of the ratio of ecological stabilization and economic lands.

The general scheme of the algorithm for geoinformation modeling for rational use and protection of land in planning the land management measures is shown in Fig. 3.

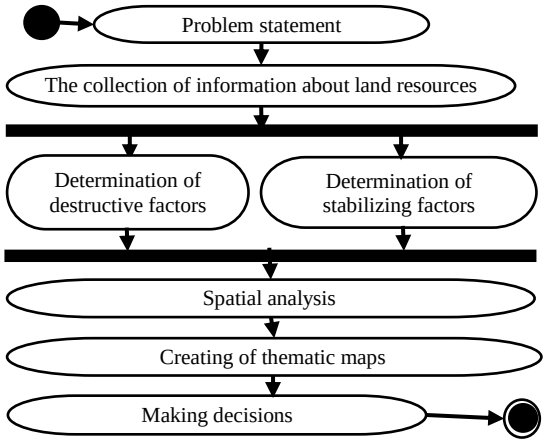


Fig. 3. Functional model of the implementation of actions for solving the problem.

When stating the problem, one should take into account the direction of land protection as an object of nature management and an object of economic activity.

During collection of information on the land resources within the analyzed territory, the incoming data sets and their integration are studied.

In the next stage of the task, two issues are considered in parallel: determination of destructive factors and presence of stabilizing factors. The development of degradation processes is influenced by climate: wind direction and force, precipitation: their intensity and frequency, relief: aspect and slope, presence of protective forest plantations, cultivated crops, presence of field-protective plantations, observance of agrotechnics, etc.

It is proposed to use spatial analysis to assess the land condition, protect soil from erosion and determine the selection of the optimum ratio of land, which allows searching for spatial patterns in the distribution of geographic data and relationships between objects.

The next stage of the functional model is the creation of thematic maps of the study area, which provides a user-friendly display of spatial data and is the basis for making land use or management decisions.

On the basis of the functional model, the plan of action for obtaining maps of justifications is established with the aim of making management decisions on the rational use and protection of land and soils, which requires the processing of heterogeneous attributive and spatial data. In order to process this data, an information system is selected. The geoinformation mapping system was selected, which includes the geodatabase [12-13] for the purpose of collecting, storing, analyzing spatial information and creating a knowledge base containing description rules, methods of definition and rules for submission of mapping materials.

Developing the structure of the geospatial database involves creating the conceptual, logical and physical models. The conceptual model defines the main classes, relation and attributes of the geodatabase, processes for processing and transforming it. At the conceptual modeling stage, the following necessary indicators were identified: (i) to assess the risks of water erosion taking into account the slope, catchment area, slope shape, humus content, granulometric composition of soil, precipitation amount and distribution, crops, etc. [1-5]; (ii) to add the slopes, wind speed and direction, forest cover and other [6-8] to assess the risks of water erosion.

The logical model (Fig. 4) provides support for the processes of registration of agricultural land objects, field research data, climate indicators and their integrated use to assess the agricultural land condition and determine the optimum ratio of land in the GIS. Developed data models and directories implemented in ArcGIS 10.4.

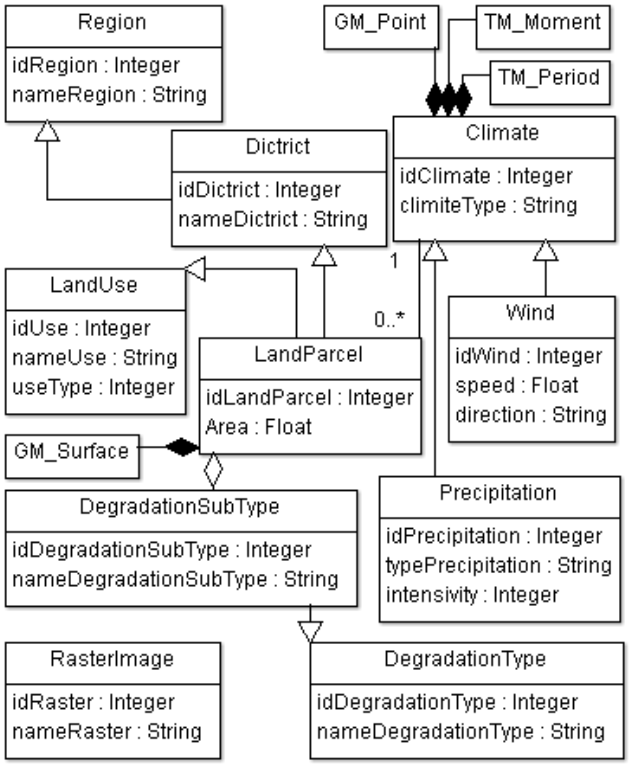


Fig. 4. The fragment of Logical UML-model of geodatabase classes.

The physical implementation of the test version of the geoinformation mapping system was performed based on the use of attribute and spatial data of the studied area.

Systematic and cumulative data were applied to spatial analysis operations: reclassification, overlay, and buffer. The thematic maps were created based on the results of the analysis.

The average coefficient of forest belts of the studied Vasylkiv Raion is 1.06%, which is about 2.5 times less than the optimum forest cover (2.6%) according to the Forest-Steppe of Ukraine [14]. According to the data of studies [14-15], the average height of forest belts in the forest-steppe zone is H = 18 m, and their soil protective effect extends to 25H. Consequently, the area up to 450 m is protected from wind erosion by forest strips. (Fig. 5).

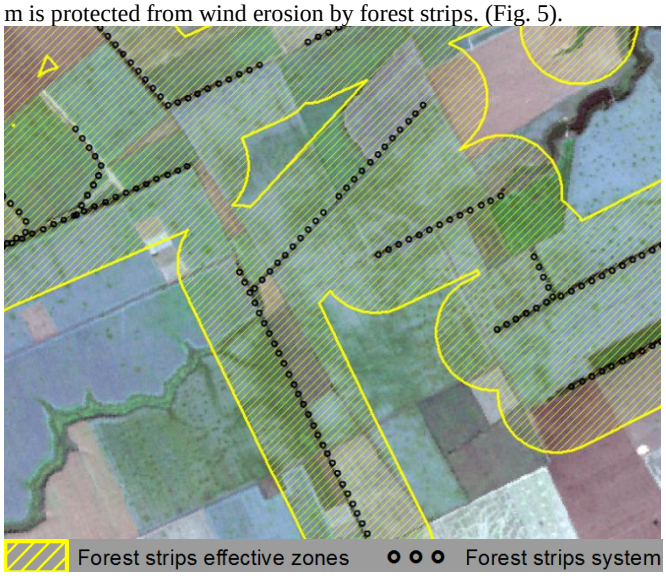
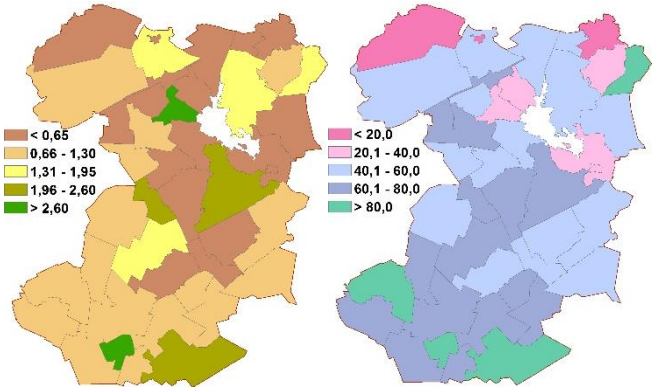


Fig. 5. Fragment of map with forest strips effective zones.

The figure shows that part of the field has an increased risk of wind erosion, which should be taken into account when designing land management measures and should be oriented towards high culture of agriculture, which should be soil-protective.

The map is shown in Figure 6a, which allows to analyze the coefficient of forest belts and compare it with the optimal coefficient of forest belts in the study area. Meanwhile the map is shown in Figure 6b illustrates the percentage of soils that have a protective effect on forest strips.



a b

Fig. 6. Thematic maps of the study area: a – coefficient of forest belts, %; b – percentage of arable land under influence of forest belts protection, %.

The developed maps (see Fig. 6) characterize the insufficient quantity of forest belts for protection of land in the studied area, which requires the development of additional soil protection measures when implementing the land management projects.

The system was clarified and more than 50 indicators of agricultural land mapping were identified. The assessment of condition of these lands is combined into blocks by thematic areas: level of land use, land degradation resistance to wind and water erosion, ecological viability and soil quality. A set of cartographic material were formed to determine the agricultural land condition and support the decision-making on the rational use and protection of land (soils).

4. Result and discussion

When developing the structure of the system for providing adequate information support for making informed management decisions on the rational use of the system and protection of land, a set of factors interacting in the investigated system was identified, the main types of tasks necessary for achieving the rational use and protection of land by land users and stakeholders were identified. On this basis, a functional model of implementation of actions to solve the task of planning the land management measures for rational use and protection of land was developed.

A conceptual model of the geodatabase of geoinformation mapping was developed. A set of attributes of soil cover objects and their temporal and spatial characteristics were established. The geodatabase provides a set of techniques for conducting the study, data processing, mapping and spatial analysis, which is grouped in the library of the knowledge base and rules of the geographic information mapping system, which unify the information, methods of its processing and presentation of results. Based on the conceptual model, a logical model of geodatabase was developed, which includes data on land, type and mechanical composition of the soil, data on slope, exposure and length of slopes, as well as data on climatic indicators - the number of days with wind speed that promotes erosion, availability of protective forest strips and assessment of their impact area.

The application of geoinformation mapping approaches to ensure the rational use and protection of land in the land management provided the development of a set of thematic maps. Thematic maps intended for the study of the soil cover condition, analysis of the factors of influence and manifestations of degradation processes can serve as a basis for assessing, updating, forecasting the soil condition and substantiating the selection of the land management measures aimed at preventing the development of

negative processes of soil destruction. These maps provide information through a color-coding system that improves the perception of information.

The geoinformation mapping system should enable the sharing of data with interested users and systems that require such information.

5. Conclusion.

The study reflects an approach to provide justification for the implementation of the land management measures and increase their efficiency in relation to the rational use and protection of land when planning the land management measures. The data set required for the land management planning was identified.

The structure of the geospatial database in the form of conceptual and logical models was developed and its physical implementation is shown in the test version based on the use of attribute and spatial data in the studied area.

A set of thematic maps that has the potential to visually represent the influence of some factors on soil erosion and land degradation was created.

The methodology and results of the study allow using the new planning guidance for the rational use and protection of land when managing the agricultural development in the region.

The prospect of further study is to develop the algorithms to automate the support for managerial decision-making regarding use and protection of land.

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REDUCTION OF LOSSES FROM DROUGHT BY OPTIMIZING THE USE OF WATER RESOURCES FOR IRRIGATION OF AGRICULTURAL CROPS

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Summary: *Drought is a major problem for plant breeding in the country during dry years. This, in parallel with the increase in the technical capabilities of agriculture, has put more emphasis on overcoming the drought phenomenon. For this purpose, efforts have been made both in the development of relevant technical concepts and in the development of appropriate methodologies and technologies. The most important activity in this direction is the redistribution of water resources mostly over time. The report presents some aspects of overcoming the effects of drought by optimizing the use of water resources.*
KEY WORDS: *WATER, WATER DEFICIT, WATERING, IRRIGATION REGIMES, HYDRO-MELIORATIONS, YIELDS, DROUGHTS, WATER RESOURCES.*

Bulgaria is in the zone of unsustainable humidification. The agro-climatic peculiarities in a number of the regions of the country determine the necessity to carry out irrigation of the crops mainly during the period June-September to compensate for the water deficit forming in order to create suitable conditions for their development.

The role of irrigation in obtaining sustainable yields with high production qualities, with a sharp reduction in the adverse impact of climate factors over the years, is indisputable and scientifically and practically proven.

Achieving the main strategic goal of the state policy in the field of agriculture - creating an efficient and competitive export-oriented sustainable agricultural production is unthinkable without conducting irrigation of the main agricultural crops.

At the same time, the country has limited water resources distributed unevenly over its territory, as well as in seasons and years. Reducing these resources is also associated with climate change in the region in recent years, characterized by long and frequent droughts, which are expected to increase further in the future.

This implies the rational and economical use and increase of the efficiency of water use, and it is essential in this regard to introduce in practice the irrigable agriculture of the country, good practices for irrigation of agricultural crops using appropriate water and energy technologies, irrigation techniques and regimes, organization and management of the irrigation process in accordance with the contemporary approaches and principles of management and protection of water and other environmental components according to European norms and rules in this area.

The natural conditions of an area largely determine the effect of the irrigation of agricultural crops. The effect of watering is greatest where the natural supply of crops with water is insufficient. Such areas in the country are those where average annual rainfall is around 500 mm and rainfall areas that range from 500 to 700 mm but are poorly distributed.

Characteristics of drought and its impact on plant growing

Observations show that intensive drought begins in Bulgaria after the third ten days of June, which continues in July, August, very often in September and partly in October. Almost all the rainfalls that fall in July-August are insufficient to provide a normal vegetation, so artificial irrigation is required.

It should be stressed that the amount of fallen rain can not yet characterize the supply of plants with moisture, because part of it is evaporated from the leaves and stems, another flows on the surface without getting into the soil and using of the plants. These losses are significantly altered in quantitative terms by the falling rainfall. Loss is in direct dependence on soil conditions, precipitation intensity and climate factors.

Taking into account the uneven nature of rainfall, and especially their limitations and irregularities during the summer vegetation months, the need for irrigation in all crops can be assessed even more clearly.

The special features of the rainfall regime and especially the regime during the summer months of July and August show that the rainfall in the country is extremely insufficient to satisfy the requirements of plants from soil moisture. This shows that drought in the country is a regular phenomenon almost all years, and as many researchers claim, drought for our country is climatological normality.

When considering the drought and its influence on the productivity of agricultural crops, the yields obtained in irrigated and non-irrigated conditions also benefit. They, in turn, reflect the impact of meteorological indicators on the development of crops during their vegetation period, depending on the biological and physiological requirements during their individual development phases.

To reduce the drought damage, of particular importance in crop cultivation are the irrigation regimes, which have a significant impact on the ratio of growth and reproduction processes, hence on the formation of yields.

In this case, it is extremely useful to know the yields obtained from multi-year field experiments in optimum irrigation and water deficit conditions, the criticality of the crops to the water during the different phases of their development, the production losses for each phase when water requirements are not met .

For most of the agricultural crops grown in Bulgaria, the rain that falls during the growing season is important. For crops such as corn, sugar beet, tobacco, sunflower and other trenches during vegetation, crops are almost the same as those for vegetables and vegetables, and for the crops of vines, vines, perennial fodder crops, etc., rainfall, which falls during the winter months, also counts.

The temperature affects the normal growth and development of agricultural crops. The temperature conditions for the country are characterized by rapid warming and rising in April. The highest temperatures are in July and August, when relatively the most intense droughts occur. The plants during this period form a large biomass, their water consumption is very high and the drying and exhaustion of easily accessible moisture in the soil has irreparably harmful effects on plant growth. Proper and timely irrigation during this period ensures high and quality yields of all agricultural crops.

Apart from rainfall and air temperature, the relative and absolute humidity of the air, the air saturation deficit with moisture, the wind speed, influence the growth and development of plants.

During the vegetation period, the relative humidity of the air is fluctuating over a wide range, which has an impact on the development of crops. The lowest relative air humidity values ??occur in July and August, during which period most of the crops are in increased growth and development and are subject to high demands on soil and air humidity. The low relative humidity in July and the beginning of August, for example, affects the fertilization and shaping of the corn cobs.

Irrigation as a basis for the development of sustainable agriculture in drought conditions

Overcoming the effects of drought implies a good knowledge of the crop's needs for moisture and the impact on the yield of reduced water reserves, the violation of the irrigation regime. Considerations made in this regard are abstracted from drought as a climatic phenomenon as a hydrological phenomenon and analyzed in the sense of an agronomic phenomenon. Biological and agro-dynamic studies on plant sytem changes and yields related to water stress are addressed.

For the formation of normal crops as well as crop yields, it is necessary to have a certain moisture content in the root soil layer. Given the individual crops and the dynamics of soil moisture in "annual cross-section", crop requirements for moisture under non-irrigated conditions are met in a different way. Because of the climate in our country, the critical minimum is often reached in this respect. This necessitates watering, the number and timing of which are closely related to the stages of crop development and the tensions of meteorological factors.

In cereal crops, seed formation ends at the end of April. Autumn-winter moisture in the soil at that date is usually sufficient for normal plants to germinate. In May, however, with the physiological development of plants and increasing the pressure of the weather factors, these stocks begin to intensely deplete and in the more dry years the yield is decreasing strongly. Irrigation during this period neutralizes the effect of the spring May drought and provides normal yield. As a result of irrigation in years of great drought, yields ranged from 2000 to 3000 kg / ha. In dry and warm years the yield of non-irrigated wheat was only 730 kg / ha. To ensure a normal sowing crop is essential the amount of moisture in the soil in May-June. The soil humidity is decisive for the formation of the yield in these crops during the months of July and the beginning of August. The decrease in moisture during this period leads to a reduction in the yield to varying degrees according to the biology of the crop. In dry years, in individual regions of the country where maize has not been pollinated during these months, mining has not been realized. The conducted in the country experiments in dry years showed unsatisfactory yields of maize - 1030 to 1800 kg / ha.

At the same time irrigation conditions yield three to four times higher yields. Sugar beet is dry-cured. Unlike many other plants, it can suffer significant droughts without perishing. However, for the development of large plant masses, a prerequisite for providing high yields, it needs a great deal of water which, in our conditions, can be ensured mainly by irrigation. The tests performed with sugar beet show an increase in yield as a result of irrigation by 157%. Irrigation on sunflower leads to an increase in the yield from 560 to 1870 kg / ha. In soybeans of non-irrigated areas, 680 kg / ha were obtained, while in the irrigation area 1300 kg / ha. In the humid years the optimal water supply of the plants is realized with 3 to 5 irrigations, but in practice such an irrigation regime is possible only in conditions of unlimited water use and optimized elements of the irrigation process.

Vegetable crops are most demanding for moisture throughout their development and need regular irrigation from planting to harvesting. In the dry years of all agro-technical activities irrigation plays the most important role.

Research on vegetable crops has confirmed the knowledge that water deficit can not be tolerated because of the lower quality of production. Therefore, water-saving technologies must be applied to them.

Multi-annual studies on berry and fruit crops - Agricultural Academy - Sofia prove that there should not be allowed a large water deficit throughout the whole growing season as the yield quality is strongly influenced. That is why they recommend the use of water-saving technologies where the irrigation water savings are about 30%.

When using drip irrigation, it is proved that a reduction of the irrigation norm or respectively irrigation rate can be allowed, which for the apple crops in the Upper Thracian region leads to a decrease of the yield by 13% and a saving of irrigation water of 40%. In combined microirrigations with peaches with reduced irrigation compared to optimal plus over the crown microwatering, where the irrigation water savings are 28%, have proven superior quality characteristics of the fruit production.

At the Institute of Meliorations and Mechanization - Sofia, studies on high yield crops - strawberries and raspberries prove that the reduction in the irrigation rate did not bring significant reductions in yield.

The research work to determine the impact of the water deficit on the quantity and quality of agricultural production in field crops continues with new varieties, lines and hybrids, with newly created drought-resistant forms. Studies are also consistent with the more pronounced drought over the last decade - insoil and atmosphere.

As a new trend in fruit crops, the strategy for regulating biological events through water stress is adopted. It is expressed in the use of reduced irrigation norms through phases of slow growth of fruits coinciding with intense vegetative growth in the respective fruit species, without adversely affecting the size of the fruit and the yield.

The accumulated experimental material to establish an optimal irrigation regime, the enriched knowledge of the dependence of yield on the degree of moisture and the impact of water deficiency in particular phases of the development of the main irrigated crops reveal opportunities for predicting and optimizing the irrigation regime under conditions of optimal and insufficient water supply.

Some guidelines in the hydromeliorative activity to overcome the effects of drought

The main challenges for innovation policy in irrigation are determined by the negative impact of severe climate change, causing major economic losses in agriculture. It is no longer a matter of accidental phenomena, but of permanent trends for prolonged spring and summer droughts. Unfavorable climate change is a prerequisite for assessing the location and role of irrigation under drought conditions.

In view of this, there is an urgent need for more targeted research and practical improvement in irrigation adaptation as an effective means of limiting or preventing the stress impact of water deficit on agricultural crops as a result of the ongoing climate change in the region.

Priority efforts are focused on:

- Clarification of the main ways and measures for limiting the negative effects of droughts and adapting irrigated agriculture and hydro-meliorations in Bulgaria to them;
- Application of good practices for reasonable and economical irrigation of agricultural crops by applying water-saving technologies and irrigation techniques under drought conditions;
- Optimization of water regime irrigation regime according to the sensitivity of individual growth periods. Updating of appropriate irrigation regimes for water shortages for irrigation. Irrigation techniques for water-saving irrigation techniques.
- Development of adapted model schemes for application in irrigation of different crops by water-saving technologies and techniques - for drip irrigation, sprinkling, mist, microwaving, improved gravity irrigation, etc.
- Reconstruction of existing and construction of new irrigation fields and systems, equipped with high-productive and water-saving irrigation equipment;
- Application of new technologies and materials in the construction, preventing filtration and water loss and reconstruction of irrigation facilities: irrigation channels, equalizers, etc.

Conclusions:

1. An analysis of the impact of climate change / rainfall, air temperature, relative and absolute air humidity, air saturation deficit with moisture and wind speed / on plant growth and development is made.

2. The possibilities and effect of using different irrigation technologies and optimization of irrigation regimes to reduce the negative impact of drought were reviewed.

3.The main guidelines for adapting agriculture and hydromeliorations to climate change are outlined.

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