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Aims and Scope

The aim of "Annals of Agrarian Science" is to overview problems of the following main disciplines and subjects: Agricultural and Biological Sciences, Biochemistry, Genetics and Molecular Biology, Engineering, Environmental Science. The Journal will publish research papers, review articles, book reviews and conference reports for the above mentioned subjects.

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Micronutrient mobility in soil under different management practices in organic vineyards

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ABSTRACT

The current study aimed to improve micronutrient mobility in soil using different soil management practices in organic vineyards, where a holistic approach to agricultural production sets a number of limits compared to conventional farming. Therefore, we applied several already well-known practices to monitor changes in micronutrient composition and their potential availability to plant, while assessing them as possible pollutants of the environment if an access amount is mobilised. The study was conducted in three different soil-climatic conditions under established organically managed vineyards, were micronutrients such as Mn, Fe, Cu, Mo, Ni, Zn were observed. The results have shown that cover cropping with grass mixture, mulching with wood chips, and application of organic fertilizer had a positive impact on the increase of mobility and bioavailability of Mn, Fe, and Mo. Although, in some cases reduction in nutrient mobility was observed, especially in the case of Fe and Zn.

Keywords: Micronutrient mobility, Soil fertility management, Organic agriculture, Organic vineyard, Microelements, Bioavailability.

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Introduction

Organic agriculture is one of the fast-growing sectors of agriculture. The global market for organic food and drink has increased from 2000 to 2017 nearly five times and exceeded 92 billion EUROs [1]. According to a recent survey (FiBL, 2019) in 2017 about 69.8 million hectares were managed organically worldwide and compared to 1999 this is a growth by 533 % [1]. Organic agriculture is spread in 181 countries of the world, and its share of agricultural land and farms expanding as the market for organic products is growing, not only in the major markets like Europe, North America, and Japan but also in developing countries [2].

An increasing trend observed in organic agriculture during the last decades indicates the necessity to improve agricultural production and maintain a quality of produce. Among many challenges in organic agriculture, one of the main is to enhance productivity and compete with a conventional agricultural system, as organic farming is often associated will low productivity [3]. Crops productivity directly linked to the maintenance of soil fertility, which mainly relays on organic input due to the restriction of synthetic fertilizers.

There are different soil management practices to ensure an adequate supply of agricultural crops with nutrients. The current study aimed to study micronutrient content and availability through understanding their mobility in soil under different management practices in organic vineyards.

Methods

There were three different sites selected under different soil-climatic conditions. Soil pits were dug on each vineyard plot of the study areas. At least one soil profile was made on each study site and 3 to 6 samples were taken. A detailed field description for each soil profile included site description and a profile description including soil colour (Munsell charts), mottles, coarse fragments, structure, consistence, effervescence (10% hydrochloric acid), roots,

pores, cracks, biological and human activity, etc. were conducted. Soil samples from each pit were taken and analysed in laboratory conditions for basic physical and chemical properties. The soils in study areas, according to WRB (World Reference Base for Soil Resources) classification [4], belong to Kastanozems - Site 1; Cambisols – Site 2 and Site 3.

Treatments and experimental design

There were several treatments under which micronutrient mobility was observed during two years after the establishment of the selected agricultural practice.

Site 1 - Municipality of Sagarejo, Khashmi (latitude: 41.782626; longitude: 45.180690): a) control – cultivation between rows to supress weeds and to prevent crust formation; b) cover cropping with alfalfa; c) organic fertilizer containing microorganisms - lithobionts, actinomycetes and azotobacter, later referred as OF.

Site 2 - Municipality of Akhmeta, Maghrani (latitude: 42.090207; longitude: 45.344527): a) control - cultivation between rows to supress weeds and to prevent crust formation; b) cover cropping with grass mixture; c) OF.

Site 3 - Municipality of Khulo, Maniaketi (latitude: 41.632467; longitude: 42.384846): a) control - cultivation between rows to supress weeds and to prevent crust formation; b) organic mulching with wood chips.

In each vineyard, two rows with a length of 20-30 m were selected for individual treatment as described above.

Soil sampling and processing

Soil samples were collected in the vineyards within rows from 0–20, 20–40, 40-60 cm soil depths using spade before the start of the experiment, at the beginning of vegetation season (April, 2017), and after establishing management practices from 0-20 cm in order to monitor changes in micronutrient composition 2 times per year in May and August during 2017-2018. Two rows were dedicated to each soil management practice, therefore within each row, a composite sample from top 20 cm was prepared by taking samples from 3-5 locations, depending on a length of a row, so finally two composite samples were taken for laboratory analysis per treatment during each sampling period. The soil samples were oven-dried at 40°C, ground to pass through a 1-mm sieve, and stored in plastic containers for laboratory analysis of selected soil physical and chemical properties.

Measurement of soil parameters

Soil textural analysis was performed by following a pipette method. The textural class was determined according to soil textural classification proposed by Kachinsky [5], as the national soil classification system is based on it. Soil bulk density was measured by the core sampling method using 100 ml stainless steel cores by placing the core in the middle of each soil layer in three replications. Soil hygroscopic moisture was determined by a gravimetric method at 105°C using drying oven till constant weight.

Soil pH was studied in soil: water ratio of 1:2.5 by following standard methods as described by Talakhadze [6]. The organic carbon (OC) content of the soils was determined using wet oxidation method according to Walkley and Black [7], calcium carbonate with Scheibler calcimeter, cation exchange capacity and exchangeable bases in barium chloride extraction with final determination using flame atomic absorption spectrometer (AAS). Total nitrogen (N) concentration was estimated by modified Kjeldahl method (ISO 11261:1995) [8], available phosphorus (P) by molybdenum blue method followed after extraction as described by Olsen et al. (1954) [9], available potassium (K) by flame atomic absorption spectrophotometer (AAS) using neutral 1N ammonium nitrate extractant according to DEFRA (Department of the Environment, Fisheries and Rural Affairs, UK) method. Mobile and potentially plant-available micronutrients Fe, Mn, Zn, and Cu of the soil samples were estimated by using atomic absorption spectrophotometer (AAS) following the extraction by 1N ammonium acetate buffer (pH=4.8) solution and final measurements were done on Inductively coupled plasma mass spectrometry (ICP-MS). Ammonium acetate buffer was chosen to ensure comparability to the maximum permissible values established according to legislative norms [10] of Georgia.

The laboratory studies were carried out in the Laboratory of the Soil Research Service of Scientific-Research Centre of Agriculture.

The results obtained were treated statistically to determine the significance of differences before and after treatment compared to control. Student's t-test was used, which is quite robust and can be valid even with smaller sample sizes.

Results and Discussion

General properties of soils under experiments on each site are given in Table 1, showing the main parameters influencing nutrient mobility and potential availability to plants. The results of concentrations of mobile forms of micronutrients such as Mn, Fe, Cu, Mo, Ni, Zn after one year from the start of the field trials are shown in Tables 2, 3, and 4. Sampling was done twice per year in May and August.

Table 1. *General soil fertility parameters for top 0-20 cm layer, at the start of field trials, April 2017*

Parameter	Sagarejo, Khashmi	Akhmeta, Maghraani	Khulo, Maniaketi
pH	8.29±0.29	6.67±0.22	6.42±0.15
Organic matter, %	3.72±0.54	3.69±0.28	6.07±0.35
Total nitrogen, %	0.32±0.02	0.35±0.03	0.56±0.07
Phosphorus (Olsen-P), mg/kg	10.00±5.30	31.90±4.80	144.90±17.80
Available potassium, mg/kg	379.25±34.65	187.75±38.25	326.6±17.70
Exchangeable Ca mg.eqv/100 g soil	43.56±3.19	46.31±6.2	27.46±0.49
Exchangeable Mg mg.eqv/100 g soil	2.22±0.18	4.5±0.48	3.33±0.17
Texture class	Light clay	Light clay	Medium loam

Table 2. *Mobile forms of micronutrients in vineyard soil of Sagarejo, Khashmi, (mg/kg), May-August 2018*

Treatment	Mn	Fe	Ni	Cu	Zn	Mo
Control	3.55±0.26	0.37±0.18	0.12±0.08	0.40±0.01	BDL*	BDL**
Cover cropping, alfalfa	3.46±0.10	0.58±0.27	0.14±0.10	0.36±0.02	BDL	BDL
Application of OF	3.05±0.24	0.51±0.16	0.11+0.08	0.33±0.02	BDL	BDL

* *Below detection limit – 0.09 mg/kg*
** *Below detection limit – 0.9 mg/kg*

Table 3. *Mobile forms of micronutrients in vineyard soil of Akhmeta, Maghraani, (mg/kg), May-August 2018*

Treatment	Mn	Fe	Ni	Cu	Zn	Mo
Control	36.20±3.33	2.24±0.26	0.36±0.06	0.09±0.01	0.32±0.01	BDL*
Cover cropping, grass mixture	44.69±3.61	2.05±0.08	0.50±0.06	0.26±0.02	0.76±0.02	BDL
Application of OF	38.41±3.38	0.42±0.14	0.37±0.05	0.10±0.03	0.17±0.02	3.24±0.47

* *Below detection limit – 0.9 mg/kg*

Table 4. *Mobile forms of micronutrients in vineyard soil of Khulo, Maniaketi, (mg/kg), May-August 2018*

Treatment	Mn	Fe	Ni	Cu	Zn	Mo
Control	40.34±3.18	0.54±0.13	0.13±0.05	0.13±0.02	0.50±0.02	1.57±0.51
Mulching, wood chips	51.05±1.54	0.70±0.10	0.14±0.04	0.16±0.01	0.56±0.03	3.31±0.44

Based on statistical analysis, in the case of Site 1 - Sagarejo, Khashmi, the only concentration of Cu in control and treatment with OF was statistically significant, showing that reduction in Cu mobile fraction was influenced by the application of OF. It seems that organic compounds containing in OF created stable bounds with copper, which has a high affinity to them [11, 12].

On Site 2 - Akhmeta, Maghraani, statistically significant changes were observed in the case of Mn and Zn, plant available pool of these elements was increased probably due to greater vigour of grass mixture to extract them from soil and enhance their mobility after mineralization as a result of incorporation into soil after ploughing. Similar pattern was observed in various studies, where cover cropping enhanced bioavailability of plant nutrients [13]. The mobility of Fe was significantly reduced after OF application, which might be related to the fixation capacities of the fertilizer constituents. On the other hand, OF fertilizer has a noticeable positive impact on the mobility of Mo, which was below the detection limit in control and grass mixture treatment. It can be associated with the activity of various microbial communities introduced into soil [14] via fertilization, although due to the complex composition of OF fertilizer and insufficient data about its performance under different soil-climatic conditions this phenomenon is subject to further studies, as organic matter highly impact metal mobility [15].

On site 3 - Khulo, Maniaketi mobility of Mn, Fe, and Mo was improved by the application of wood chips, which mainly improved water and temperature balance at the soil surface, which is the most active part both for macro- and microorganisms responsible for many biochemical processes taking place in soil [16].

In addition to observation of changes in micronutrients mobility caused enhancements in translocation abilities of some elements, which might be toxic to the environment in high concentrations, were compared to existing legislative norms, where maximum permissible limits for a number of elements including those being subject to our study are set. The comparison shows that none of the micronutrients assessed are in the access amount in the studied soils. All micronutrients at all sites and under each treatment are far below the limits set in Georgia [10].

Acknowledgement

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Draft annotation of stilbene synthase genes of Georgian grape varieties

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A B S T R A C T

In the times of genome-sequencing the bioinformatics is becoming the vital importance for the field of genomics. Here we present draft annotation of stilbene synthase (STS) candidate genes of four Georgian grape varieties - Chkhaveri, Saperavi, Meskhuri Mtsvane and Rkatsiteli by web-based system MEGANTE. It has shown the existence of STSs in the chromosomes 10 and 16. Abundance of STSs candidates is found on chromosome 16. The obtained data is caring significant information for the future gene-expression studies of STSs of Georgian grape varieties.

Keywords: Stilbene synthase genes, MEGANTE, Chkhaveri, Saperavi, Meskhuri Mtsvane, Rkatsiteli.

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Introduction

In the last few decades, genome-based research has become a very popular and accessible approach for studying of the structures and functions of genomes. Identification of the primary genome structure, which involves the detection and analysis of genes and intergenic regions, is crucial for studying the molecular basis of that unique features that causes individuality of each species and also, for the assessment of phylogenetic links between different taxa of living organisms. Much of the data generated by genome sequencing is processed by bioinformatical programs and softweres, that provides scientists with more or less organized information about the nucleotide sequence organizations of the certain genomes. However, it should be noted that bioinformatical data mostly have to be checked and corrected by so called "manual curation" as mistakes/mismatches in machinery annotation is not a rare case.

To date the complete genomes of the numbers of plant species are sequenced and annotated. The amounts of those species are increasing day by day. Among fully sequenced and annotated genomes is the genome of grapevine (*Vitis vinifera* ssp. *vinifera*) – the World's most important agricultural crop [1-5]. According to the data received from the sequence-analyses of firstly fully sequenced grape variety - Pinot noir, *Vitis vinifera* ssp. *vinifera*, is a diploid (2n=38) taxa with 19 chromosomes in karyotype. Genome size in *V.vinifera* is relatively smaller than in other plants - 475-500 Mb. The length of mitochondrial and chloroplast genomes are 750,000 and 160,000 bp respectively [6, 7, 5, 8]. It is shown that the genome carries up to 29.000 genes [1,2].

Tabidze et al., [5] performed whole genome sequencing of well known Georgian grape varieties: Chkhaveri, Saperavi, Meskhuri mtsvane and Rkatsiteli by using Illumina HiSeq. Pinot Noir nuclear, mitochondrial and chloroplast DNA were used as reference. In the frame of the mentioned research among other results, length of chromosomes of Georgian grape cultivars (19 chromosomes for the each grape variety), the amounts of genes and SNPs were detected. Interestingly that in the same work the successful annotation of terpene synthase genes was conducted by using of web-based program MEGANTE – the method which we used in the presented research.

Stilbens represent a small group of phenylpropanoids, which are found in at least 72 non-relat-

ed plant species. Stilbenes are accumulated in cells in response to biotic and abiotic factors (i.e. stress infection, mechanical injury, ultraviolet radiation, chemicals). Well-known resveratrol – stilbene compound, who has the antioxidant activity, can increase resistance to pathogens (e.g., *Botrytis cinerea*, *Eutypa lata*, *Plasformin viticola*). Besides, stilbens are participating in plant-killer relationships, and also have the ability to slow down the progression of some diseases [9].

The major enzymes in the biochemical cascade of phenylpropanoids are stilbene synthases (STS). The main goal of the presented research was detection and annotation of STS genes of four Georgian grape varieties: Chkhaveri, Saperavi, Meskhuri Mtsvane and Rkatsiteli, by using web-annotation system – MEGANTE [10].

Materials and Methods

Web-annotation system MEGANTE (https://megante.dna.affrc.go.jp) was used for annotation of the stilbene synthases (STS) genes of Chkhaveri, Saperavi, Meskhuri mtsvane and Rkatsiteli. The system automatically run different programs and integrates the results to select the consensus exon-intron sites and to predict open reading frame (ORFs) regions. MAGANTE makes possible functional annotation, which includes searches of identities against known proteins and functional domains. The final data generated by the system can be downloaded what makes easy to use it.

Because MEGANTE has some limitations in the sizes of uploaded sequence-files, at the initial stage of the study, the sequences of chromosome 10 and 16 of Chkhaveri, Saperavi, Meskhuri mtsvane, Rkatsiteli and reference Pinot noir were fragmented (cutted) by the program ARTEMIS. For each grape genome ARTEMIS generated 5.000.000 bp long sequences what was corresponded to the MEGANTE's allowed size - 10 Mb. According to the chromosome lengths presented in the Table 1, all five genomes were cut into three fragments of 5.000.000 and one fragment of 3.000.000 bp lengths.

Chromosomal sequence containing nucleotide sequences of stilben synthases - chromosomes 10 and 16 of Georgian grape varieties were obtained from the link provided by Agricultural University of Georgia:

https://drive.google.com/open?id=0B4mIJZ9E-7ht7Q1dDTm9HbGFIR1U.

As reference genome sequences of Pinot noir were used (Genoscope:

http://www.genoscope.cns.fr/externe/GenomeBrowser/Vitis).

The annotation process included the numbers of steps. More concretely: Finding the appropriate consensus exon-intron structures for predicting open reading frames (ORFs) at each locus and making functional annotation, including a similarity search against known proteins and a functional domain search for the predicted ORFs.

Results and Discussion

In our previous work sequence of all 19 chromosomes of four Georgian grape cultivars was determined by resequencing using Pinot noir as a reference genome [5]. Chromosomal lengths of chromosome 10 and 16 where existence of STS candidate genes were found are representing in Tab.1.

49 candidate STS genes were predicted on chromosomes 10 and 16 of all studied Georgian cultivars by web-annotation program MEGANT. Among them, on chromosome 10, only one STS gene was observed in Chkhaveri, Rkatsiteli and Meskhuri mtsvane. At the same time, the presence of two STS genes was detected in Pinot noir, and none was found in Saperavi. Differences in gene number were observed on chromosome 16 of all Georgian grape cultivars. 14 STS genes were found in Meskhuri Mtsvane, 13 in Saperavi, 10 in Chkhaveri and 9 in Rkatsiteli (Table 2).

Table 1. *Chromosomal lengths of Georgian grape varieties according to Tabidze et al., [5].*

Chromosome	Rkatsiteli (bp)	Saperavi (bp)	Meskhuri Mts. (bp)	Chkhaveri (bp)	Pinot noir (bp)
16	22,021,800	22,050,608	22,056,729	22,057,692	22,053,297
10	18,122,339	18,139,422	18,146,577	18,143,602	18,140,952

Table 2. *Numbers of annotated stilbene synthase candidate genes in chromosomes 10 and 16.*

Cultivar	Chromosome 10	Chromosome 16
Chkhaveri	1	10
Meskhuri Mtsvane	1	14
Rkatsiteli	1	9
Saperavi	0	13
Pinot noire	2	12

STS-predictions of Chromosome 10

Single STS gene was detected in chromosome 10 of the tree Georgian grape varieties: Meskhuri Mtsvane, Chkhaveri, Rkatsiteli by system ME-GANTE. Predicted STSs genes were found in the range of 14.203.661 – 14.285.672 bp of chromosome 10. At the same time, the presence of two STS genes was detected in Pinot noir, and none was found in Saperavi (Table 3).

By the maximum-likelihood method phylogenetic tree of stilbene synthase candidate genes on chromosome 10 was built. As seen on Fig. 1, there are two main branches on the tree: one of them (on the bottom of Fig) is represented just with P2 or Pinot noir's STS candidate gene found in the sequence region 14.284.187-14.285.672 bp (Table 3). The second branch (on the top of Fig.) contains all other STS candidate genes which are more closely related to each other.

Table 3. *Genome regions of stilbene synthase candidate genes in chromosome10. Numbers represent bp range of the certain genome region, numbers in brackets indicate the first letter of cultivar and the number of candidate gene, ND - means "not detected".*

Genome Regions on Chromosome 10				
Pinot noir	Meskhuri Mtsvane	Chkhaveri	Saperavi	Rkatsiteli
			ND	14.203.661-14.205.226 (R1)
	14.221.262-14.222.827 (M1)		ND	
14,263,951-14,306,350 (P1)			ND	
		14.266.493-14.312.372 (C1)	ND	
14.284.187-14.285.672 (P2)			ND	

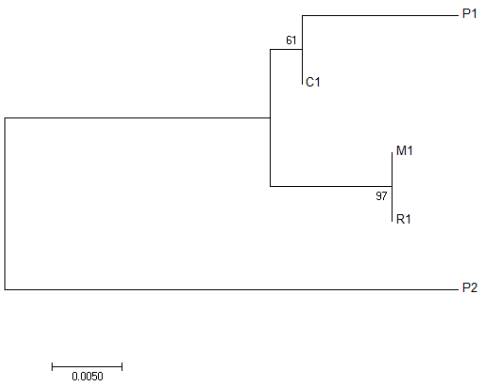

Fig. 1. *Molecular phylogenetic analysis of stilbene synthase candidate genes on chromosome 10 by maximum-likelihood method. Analyses were conducted in MEGA7 [11]*

STS-predictions of Chromosome 16

Table 4 represents positions of predicted Stilbene synthase candidate genes in chromosome16. Differences in gene number were observed on chromosome 16 of all Georgian grape cultivars. 14 STS genes was found in Meskhetian green, 10 in Chkhaveri and 9 in Rkatsiteli and 13 in Saperavi. Position in chromosome also represents the genomic organization of the STS gene cluster, where several additional genes, which are not detected in the Pinot noir reference genome, were identified. Comparative genomics reveals the presence of gene collinearity in a wide range of organisms from different cultivars within a species to genetically distinct genomes. Populations within a species and closely related organisms have extensive regions of gene collinearity. Comparative analysis of Georgian grape samples reflects a high level of similarity among those genes, which are located in similar positions on the chromosome, and confirmed the fact that all these genes are orthologous. The difference in gene number between the analyzed grape cultivars, especially the detection of additional genes that are absent in reference DNA, may help to understand the different volatile profiles in different Georgian grape cultivars.

Conclusion

The presented work represents the first large-scale attempt of STS gene-annotation of Georgian grape varieties. The results offer the new information concerning predicted molecular structures of mentioned genomic regions via providing their STS candidate gene sequences. In the future obtained results can be facilitating for gene-expression studies.

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Table 4. *Genome regions of predicted Stilbene synthase candidate genes in chromosome16: Numbers represent bp range of the certain genome region.*

Genome Regions on Chromosome 16				
Pinot noir	Meskhuri mtsvane	Chkhaveri	Saperavi	Rkatsiteli
				12.622.981-12.624.590
13.636.905-13.638.529				
		16.242.833-16.244.650		
16.268.745-16.270.647		16.272.686-16.290.362	16.267.430-16.285.104	
16.276.509-16.278.378	16.279.101-16.280.970			
16.335.626-16.337.351	16.338.201-16.339.926	16.339.530-16.341.255	16.334.268-16.335.993	16.316.372-16.318.097
				16.378.850-16.380.652
16.385.834-16.387.530	16.388.483-16.390.180		16.384.530-16.386.226	
16.398.235-16.400.037	16.407.841-16.415.954	16.402.185-16.402.362	16.396.933-16.398.735	
				16.447.349-16.459.201
16.466.725-16.478.614	16.469.648-16.471.182	16.470.641-16.482.501	16.465.424-16.467.236	
	16.479.686-16.481.202		16.475.749-16.477.265	16.471.859-16.489.947
16.491.316-16.493.132	16.493.885-16.495.700	16.495.151-16.513.265	16.489.897-16.491.712	
16.503.637-16.509.480	16.506.205-16.512.041		16.502.237-16.508.080	
16.511.156-16.512.830	16.513.717-16.515.391	16.514.941-16.516,615	16.509.756-16.511.430	
	16.528.433-16.530.348	16.529.638-16.531.553	16.524.500-16.526.415	
		16.559.284-16.561.126		16.535.728-16.537,570
16.555.671-16.557.513	16.558.138-16.559.980		16.554.143-16.555.985	
	16.576.448-16.585.497			
	16.589.900-16.591.437	16.590.963-16.592.500	16.585.902-16.587.425	16.587.795-16.604.156
16.607.177-16.608.743	16.609.684-16.611.250		16.605.617-16.607.183	16.607.012-16.608.647
				16.653.181-16.655.099

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One-dimension mathematical model of energy parameters of a hyper concentrated mudflow

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A B S T R A C T

Natural anomalies, mudflows in particular, put many world countries before serious problems trying to develop thorough engineering solutions to combat mudflows. Mudflows are one of the dread natural calamities and relevant regulation measures are associated with the identification of their genesis, dynamics and energetic parameters. The work specifies and assesses the bed processes taking place during the mudflow movement through mudflow channels and the plans to calculate the energetic processes of currents based on the methods and scientific-technical approaches commonly accepted in hydraulics and hydraulic engineering. The problems planned in the article are solved by using classical scientific approaches and experimental study methods. The practice has evidenced that the selection of the models of the regulation measures within the action zones of mudflows needs improvement. The article, by considering the flow rheology and based on the energy equation, deduces the differential equations of uneven flow movement for different values of a bed gradient, in case of permanent and variable mudflow discharges. The obtained results allow predicting the energy parameters of the mudflow motion through non-prismatic beds by considering both, the permanent and variable value of the current discharge.

Keywords: Hyper concentrated mudflow, Rheology, Dynamics, Energetic properties, Mathematical model, Experimental study methods.

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1. INTRODUCTION

An impact of mudflows on the environment, alongside with an ecological destruction, changes the landscape infrastructure. This is a very complex phenomenon and selecting regulatory measures in the zone of a mudflow action is quite difficult. Therefore, despite various control methods used, the efficiency of the environmental protection measures is poor and the prospects to identify adequate control measures are unfavorable. This is because mudflows are anomalous events; they deviate from the dynamic axis in motion less; influence the barriers on their way with full energy; develop the bed during their motion through the channel themselves and have high transportability. Consequently, the innovative methods to assess this phenomenon and adapted models need further improvement.

2. MATHEMATICAL MODEL OF A HYPERCONCENTRATED MUDFLOW

When mudflows are subject to a significant impact of the barriers on their way, their stability is disturbed and their motion develops in form of a wave. When the impact is insignificant, the current shifts from one stationery state into another [1-7]. Consequently, in the former case, the energetic characteristics of the current change in a step-wise manner, while in the latter case, the process takes a smooth course. Therefore, the description of this event is associated with the adaption of different models. It should be noted that a continuous or a step-wise change of such energetic characteristics, as velocity, depth and discharge are, is followed by a significant change of the amplitude of the current moving as a wave and strengthening or weakening of the impact force efficiency. Due to the complex nature of this phenomenon, a mathematical description of this

process and selection of the design parameters of the structural elements of a mudflow control structure on the basis of adapted models is very difficult due to the diversified types of mudflows occurring naturally, and the result is often catastrophic.

Following the existing statistical materials, based on the scientific works [8-13], the development of methods to identify energetic properties and adaption of the models to these phenomena is envisaged by means of analysis of easily recognizable processes first, including identifying the associations between them, and developing the relevant theory later [14-16].

In case of a variable mudflow regime, the current moves with a different shape of its free surface. This is mainly caused by the narrowing and expansion of the channel bed and changing shape of the cross section and base slope. A moving current with such a free surface when its velocity changes in the effective cross-section, is quite common. In this case, an impact of the effective cross-section on the motion must be considered. This parameter is gained by considering the width and the depth of the mudflow [17-21].

The type of the movement model of a hyper concentrated mudflow moving linearly and non-uniformly and its design model are given in Fig.

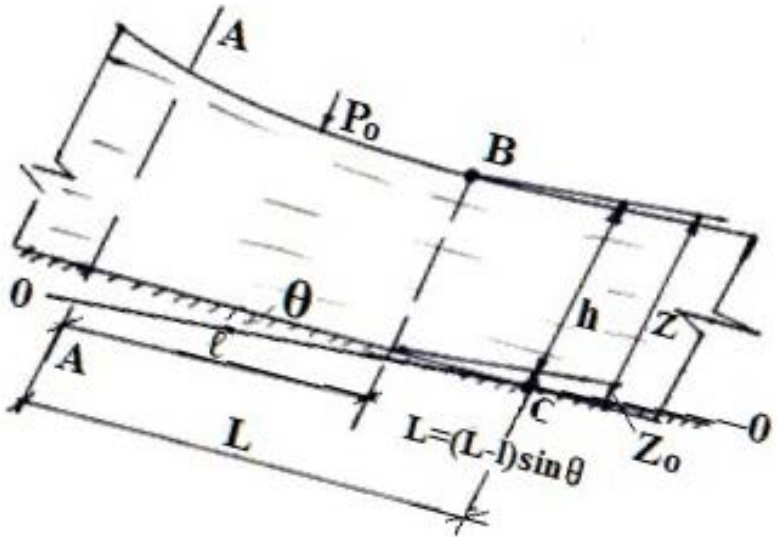

Fig. *Design model of a mudflow motion*

Depending on the longitudinal section of the current, when the mudflow motion is non-uniform, in order to identify the shape of the curve of the free surface, we will consider point B on its surface. The distance from the given point to the reference section *A-A* is l. Besides, the correlation plane is drawn across point C and it is distanced from section A-A by *L*. Consequently, when the distance from point *B* to the correlation plane *O-O* is *Z*, the value of total energy is:

$$\mathrm{E} = \mathrm{Z} + \frac{p}{\gamma} + \frac{\alpha V^2}{2y}. \tag{1}$$

Following the equation of energy of slowly changing motion of the current, the value of pressure loss can be presented as follows:

$$\frac{d\left(\mathrm{Z} + \mathrm{P}_0/\gamma + \frac{\alpha V^2}{2g}\right)}{d\ell} = -I \tag{2}$$

Where: P_0 - is the pressure acting on the surface and equals to atmospheric pressure in case of an open bed (N/m^2); h – is the depth of the mudflow in the design section (m); ω – is the section of the effective cross-

section (m^2); Q – is mudflow discharge (m^3/sec); q – is specific mudflow discharge (m^3/sec); V – is average mudflow velocity; I – is the hydraulic gradient.

Following the equation of energy, coordinate *Z* of point *B* for the mudflow opposite to the correlation plane, is the function of rheological properties, h_0, which is the depth equivalent to cohesiveness and angle of internal friction $\varphi = tg\left(45^0 - \frac{\varphi}{2}\right)$ in particular, i.e.;

$$Z = h(1 - h_0 / h)\varphi + Z_0 . \tag{3}$$

When $Z_0 = (L - l)i$, by considering correction coefficient of mudflow depth *K*, formula (3) will be as follows:

$$Z = Kh + (L - \ell)i , \tag{4}$$

Consequently, the value of a piezometric gradient will be:

$$\frac{dZ}{d\ell} = K\frac{dh}{d\ell} - i , \tag{5}$$

As pressure acting on all points of the free surface of the mudflow channels $p = const$, consequently:

$$\frac{d(P/\gamma)}{d\ell} = 0 \tag{6}$$

For the 3rd member of equation (3), we will have:

$$\frac{d\left(\frac{\alpha V^2}{2g}\right)}{d\ell} = \frac{d\left(\frac{\alpha Q^2}{2q\varpi^2}\right)}{d\ell} \tag{7}$$

When the current moves in the direction of motion with constant discharge:

$$\frac{d\left(\frac{\alpha Q^2}{2g\omega^2}\right)}{d\ell} = \frac{\alpha Q^2 d}{2g}\frac{\left(\frac{1}{\omega_{mud}{}^2}\right)}{d\ell} \tag{8}$$

The association between the area and depth of the effective cross-section can be presented as follows:

$$\omega_{mud} = K\omega . \tag{9}$$

Consequently, dependence (8) will be as follows:

$$\frac{d\left(\frac{\alpha Q^2}{2g\varpi^2 K^2}\right)}{d\ell} = \frac{\alpha Q^2}{2gK^2}\frac{d\left(\frac{1}{\varpi^2}\right)}{d\ell} = -\frac{\alpha Q^2}{g\varpi^3 K^2}\frac{d\varpi}{d\ell} \tag{10}$$

I option

When the bed is not prismatic, the change of the cross section in the direction of motion will be as follows:

$$\frac{d\omega}{d\ell} = \frac{\partial\omega}{\partial\ell} + B\frac{dh}{d\ell} \tag{11}$$

By considering formula (11) in formula (7), we will gain:

$$\frac{d\left(\frac{\alpha V^2}{2g}\right)}{d\ell} = -\frac{\alpha Q^2}{gK^2\omega^3}\frac{\partial\omega}{\partial\ell} - \frac{\alpha Q^2}{gK^2\omega^3}B\frac{dh}{d\ell} \tag{12}$$

By considering formulae (12), (6) and (4) in formula (3), we will gain:

$$\frac{dh}{d\ell}=\frac{i-\frac{Q^2}{K^3\omega^2C^2h}\left(1-\frac{\alpha hKC^2}{g\omega}\frac{\partial\omega}{\partial\ell}\right)}{K-\frac{\alpha Q^2}{gK^2\omega^3}} \tag{13}$$

If dividing the numerator and denominator in formula (13) by K and introducing denotation $i_c = i/K$, we will gain:

$$\frac{dh}{d\ell}=\frac{i_c-\frac{Q^2}{K^4\omega^2c^2h}\left(1-\frac{\alpha Khc^2}{g\omega}\frac{\partial\omega}{\partial\ell}\right)}{1-\frac{\alpha Q^2B}{gK^3\omega^3}} \tag{14}$$

When $dh/d\ell = 0$ and $\frac{\partial\omega}{\partial\ell}=0$,

$$Q = K^2\omega c\sqrt{hi}, \quad \text{m}^3/\text{sec} \tag{15}$$

Average mudflow velocity is:

$$V = K^2c\sqrt{hi}, \quad \text{m/sec} \tag{16}$$

When $K = 0$ and $\varphi = 1$,

$$V = C\sqrt{hi}, \quad \text{m/sec} \tag{17}$$

Formula (14), when discharge is constant, is a differential equation of smoothly changing nonuniform motion of mudflow in open non-prismatic beds and describes the regularity of the change of depth *h* (energetic property) along the motion.

II option

When discharge changes along the motion, equation (8) can be presented as follows:

$$\frac{d\left(\frac{\alpha Q^2}{2gK^2\omega^2}\right)}{d\ell}=\frac{\alpha Q}{gK^2\omega^2}q-\frac{\alpha Q^2}{gK^2\omega^2}B\frac{dh}{d\ell} \tag{18}$$

If considering equation (18) in (2), we will gain:

$$K\frac{dh}{d\ell}-i+\frac{\alpha Qq}{gK^2\omega^2}-\frac{\alpha Q^2B}{gK^2\omega^3}\frac{dh}{d\ell}+\frac{Q^2}{K^3\omega^2c^2h}=0 \tag{19}$$

Following certain mathematical simplification and conversions in equation (19), we will have:

$$\frac{dh}{d\ell}=\frac{i_c-\frac{Q^2}{K^4\omega^2c^2h}\left(1+\frac{\alpha qKc^2h}{gQ}\frac{dQ}{d\ell}\right)}{1-\frac{\alpha Q^2B}{K^3\omega^3g}} \tag{20}$$

When $\frac{dQ}{d\ell}=0$ and $q=0$

$$Q = K^2\omega c\sqrt{hi_c} \quad \text{m}^3/\text{sec} \tag{21}$$

Equation (20) is one-dimensional differential equation of a hyper concentrated current moving through a non-prismatic bed with variable discharge.

III option

When $\frac{dQ}{dx} = q$, it can be presented as follows:

$$\frac{dh}{d\ell} = \frac{i_c - f_c - \frac{Qq}{g\omega^2 K^3}}{1 - \frac{\alpha Q^2 B}{g\omega^3 K^3}} \tag{22}$$

If presenting resistance slope of a cohesive mudflow by Shvedov-Bingham model [6-8]:

$$i_{fc} = \frac{Q\upsilon}{gh^3 bf(\beta)} \tag{23}$$

And when $\beta = h_0/h$, the value of $f(\beta)$ function in formula (23) will be:

$$f(\beta) = (1-\beta)^2\left(1 + \frac{1}{2}\beta\right) \tag{23}$$

The differential equation for the mudflow moving with variable discharge will be:

$$\frac{dh}{d\ell} = \frac{i_* - \frac{Q\upsilon}{gbh^3} f(\beta) - \frac{Qq}{g\varpi^2 K^3}}{1 - \frac{\alpha Q^2 B}{g\varpi^3 K^3}} \tag{24}$$

Equation (24) is a one-dimensional differential equation of a hyper concentrated current moving with a variable discharge through non-prismatic beds.

IV option

When the current moves with a constant speed, i.e. $q = 0$, then:

$$\frac{dh}{d\ell} = \frac{i_{fc} - \frac{Q\upsilon f(\beta)}{gbh^3}}{1 - \frac{Q^2 B}{g\omega^3 K^3}} \tag{25}$$

Equation (25) is a one-dimensional differential equation of a hyperconcentrated current moving with constant discharge through prismatic beds.

3. CONCLUSION

With the aim to solve a regulation and engineering problem of mudflows, the mathematical models were selected as an urgent means.

Differential equations, by considering various options of a hydraulic slope, were developed based on the presented models.

The differential equations were obtained based on mudflow rheology, which accurately describes the mechanism of motion.

The differential equations obtained from the energy equation allow predicting the energetic properties of a mudflow moving through non-prismatic beds – velocity and depth in case of constant or varying discharges.

The differential, equations can be used to evaluate the principal parameters determining the critical state and uniform motion of mudflows.

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Assessment of waterlogging tolerance in mungbean genotypes utilizing morphological traits and SSR markers

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ABSTRACT

Some promising mungbean genotypes were employed to evaluate waterlogging tolerance and molecular characterization using SSR marker. Waterlogging treatment was applied to 25-d old plants maintaining 2-3 cm waterlogging depth for three days with extended seven days saturation period. It significantly reduced the growth and yield but the plants remarkably improved their depressed characters during the recovery period. The early response of waterlogging was the development of adventitious roots which is an important adaptive mechanism of plants under waterlogged situations. Based on waterlogging tolerance index calculated as the percent ratio of relative growth rate (RGR) in waterlogged plants and RGR in non-waterlogged plants of all plant components, the genotypes ACC12890054 and BUmug 4 appeared as the most tolerant to waterlogging. The genotypes ACC12890085 and ACC 12890054 that showed better tolerance to waterlogging gave the highest relative yield of 46% followed by BUmug 4 and VC 6173-A genotypes. Based on the correlation coefficient and relative values, the genotypes were grouped into four clusters using K-means cluster analysis. In SSR analysis, PIC values of the markers were above or almost equal to 0.5 indicating the used primers were effective to differentiate the genotypes at the molecular level. In analysis 16 pairs of mungbean genotypes showed 41.7% maximum dissimilarity. We grouped 12 genotypes into four clusters using unweighted pair group method with arithmetic mean (UPGMA). These four main clusters are distinctly dissimilar to each other on the based of genetic characters. Thus, the findings of this research could be used for envisaging promising mungbean genotypes and developing waterlogged-tolerant mungbean variety(s).

Keywords: Mungbean, Waterlogging tolerance, Genetic variability, SSR marker, Molecular level, Correlation coefficient.

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Introduction

Mungbean (*Vigna radiata* L. Wilczek) is recognized as one of the most promising pulse crops but its large-scale adoption is constrained by many biotic and abiotic stresses. Among abiotic stresses, waterlogging affects more than 1700 Mha of land worldwide [1]. It is anticipated that both the frequency and severity of floods will be increased in many places in the world due to climate change [2]. Possibly flooding or waterlogging will largely affect mungbean cultivation in the future, although some genotypes are found tolerant to waterlogging and capable of recovering from flooding injury [3,4]. Excess water generally causes hypoxia or even anoxia around roots due to the rapid consumption and slow diffusion of oxygen. As a result, plants suffer from devoid of energy [5] and eventually, uptake of water and nutrients is restricted [6]. A greater yield loss has been reported when the young plants are subjected to waterlogging [7]. Therefore, climate change-induced aggravation of waterlogging situations can further promote decreasing of mungbean production which is assumed an extraordinary challenge for its sustainable cultivation [8].

Many researchers conducted studies on the responses of mungbean genotypes to waterlogging and reported several morpho-physiological disturbances

[4, 9-11]. However, such responses are much pronounced in waterlogged-sensitive genotypes because of a slow recovery in photosynthesis and physiological traits, while a high photosynthetic rate and better physiological function were found in tolerant genotypes [10]. Therefore, searching waterlogged-tolerant genotypes and efforts to develop variety(s) capable of withstanding waterlogged situations are underway. Several molecular techniques are followed to develop crop variety(s) tolerant to many abiotic stresses but such techniques are hardly applied in mungbean due to a lack of genetic information of the crop. Developing the sequence of the mungbean genome would probably be an important source of genetic improvement of the crop [12].

DNA markers are needed for creating genetic maps and to locate the exact loci of the targeted gene(s) [13]. Some established molecular DNA markers are RFLP [14], RAPD [15] and SSR [16]. Simple sequence repeats (SSR) are repetitive DNA sequences that can represent the whole genome of an organism [17]. SSR marker is recognized as an influential tool for the evaluation of diverse plant genetic resources [18-19], species identification [20] and gene mapping [21]. Some SSR markers have been developed in mungbean [22] which does not prove to be adequate to fulfill the demand of the scientific community [23]. Moreover, comparatively better polymorphism has been observed between Vigna species, while lower diversity was detected within the species.

Waterlogging for a few days can damage mungbean plants and results in significant yield losses. Therefore, it is important to understand the traits that can improve waterlogging tolerance, and the genes and proteins underlying these traits. Under global waterlogging nature accompanying climate change, it is evident to enhance our knowledge on waterlogging tolerance which will facilitate to development of flood-tolerant varieties [24]. Therefore, this study was undertaken to identify morphological traits for waterlogging tolerance under field conditions towards improvement and sustainable use of mungbean biodiversity and to characterize mungbean genotypes at a molecular level using SSR markers.

Materials and methods

Study location

The experiment was carried out at the Field Research Site and Genetics and Plant Breeding Lab of Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU), Gazipur from February 2015 to June 2016. The experimental site is located at 24°02′15.06″N latitude and 90°23′45.80″ E longitude. The area belongs to high terrace of Madhupur Tracts of Bangladesh.

Experimental layout

Twelve mungbean genotypes and two waterlogging treatments (waterlogging and non-waterlogging control) were the treatment variables. A total of 72 plots were prepared to assign all the treatment combinations. The experiment was a randomized complete block design and replicated three times. The experimental unit size was 1.2×1.2 m. They were surrounded by raised boundaries covered with polythene sheets to prevent water leakage from the waterlogging treated plots.

Plant materials

Twelve mungbean genotypes viz. GK48, GK65, BARI mung 4, BARI mung 6, ACC 12890085, ACC 12890054, BU mug 4, VC 1160-A, VC 6173-A, IPSA-13, GK63 and IPSA-15 were used in this experiment. All the genotypes showed different degrees of tolerance in the previous studies.

Raising of seedlings and treatment imposition

Three seedlings were raised per hill maintaining a distance from the line to line 30 cm and plant to plant 10 cm. To maintain a uniform size of the seedlings, the seedlings were reduced two times keeping vigorous healthy ones. Waterlogging treatment was applied at 25 days after emergence (DAE) maintaining waterlogging depth of 2-3 cm for three days. Thereafter, the excess water was drained out from the waterlogged plots. These three days of waterlogging with seven days prolonged saturated periods (25-35 DAE) were considered as the waterlogging period. The period 35-45 DAE was considered as first recovery period and that of 45-55 DAE as second recovery period. On the contrary, optimal soil moisture was provided to the plant retained as a control. The first sampling was done on the day of waterlogging (25 DAE) and continued the sampling at 10 days intervals up to 55 DAE in both waterlogged and non-waterlogged plants.

Estimation of RGR and WT:

Relative growth rate (RGR) of plant components i.e. root, stem and leaf etc. were calculated accord-

ing to Gardner *et al*. [25]. Waterlogging tolerance (WT) of each plant component was calculated according to Chen and Burton [26]: WT= RGR (waterlogged)/ RGR (control)*100.

Yield attribute and seed yield

The maturity stage, pods were harvested from the plant and data regarding the branches per plant, number of pod per plant, number of seeds per pod, 1000-seed weight and seed yield and harvest index were recorded for waterlogged and control plants in each genotype.

SSR markers and DNA extraction

Four SSR markers (VR 188, VR 225, VR 276 and VR 304) with clear amplifications were selected for genetic diversity analysis of twelve mungbean genotypes. One gram young leaf tissue collected from 2-weeks old seedlings was powdered under liquid nitrogen in a mortar and pestle, and the DNA was extracted employing modified CTAB method [27]. DNA quantification and quality measurement were done as per procedures described by Huda *et al*. [19] and a working concentration of 25 ng/µl was made.

Polymerase chain reaction (PCR) amplification

A 25 µl mixture was prepared for the PCR reaction containing 3 µl template DNA, 2.5 µl of 10x buffer, 2.5 mM dNTPs and 25 mM $MgCl_2$, respectively, 1.25 µl for both forward and reverse primers, and 0.3 µl of Taq polymerase. PCR fragment size was assessed using DNA molecular weight marker. The PCR reaction was performed at 95°C for 5 min and then for 42 cycles of 95°C for 45 sec, 55°C for 45 sec, 72°C for 1 minute and finally 72°C for 5 min. The products were electrophoresed through 1% agarose gel and subjected to photography on a UV transilluminator. Scoring of genomes was done considering the presence or absence of polymorphic bands. A UPGMA method was followed to indexing genetic variation and constructing a dendrogram.

Statistical analysis

The data collected were subjected to analysis of variance (ANOVA) by using Statistix 10 program. Besides, Microsoft Excel was used to estimate standard deviation (SD) and standard error (SE). For cluster analysis, computer software SPSS 16 was used. The Analysis of Variance (ANOVA) was performed for various plant traits and means were separated by the Duncan's Multiple Range Test (DMRT). For molecular characterization,computer software DARwin was used.

Results and discussion

Waterlogging tolerance in root

The relative growth rate (RGR) of the plant roots both waterlogged and non-waterlogged plants of 12 mungbean genotypes during waterlogging, first recovery period and second recovery period have been illustrated in Table 1. Waterlogging affected the RGR of the roots in all the genotypes and showed waterlogging tolerance (WT) values much low. However, most of the genotypes showed higher WT values during 35-45 DAE indicating a remarkable recovery in root growth after the termination of waterlogging. During the period 45-55 DAE, the genotypes ACC12890085, ACC12890054, BUmug 4, VC 1160-A, VC 6173-A, GK 63 and IPSA-15 showed much recovery in root growth and showing WT values more than 100. The greater increase in RGR of waterlogged plant roots indicated the development of adventitious roots after damaging the original ones. A faster formation of adventitious roots at the early stage is a common response of waterlogged-tolerant crop species [28, 29].

Waterlogging tolerance in total plants

Waterlogging affected the RGR of total plants in all the genotypes and showed much low or even negative WT values (Table 2). However, RGR of the waterlogged plant either increased or decreased to some extent depending on the genotypes during the recovery period of 35-45 DAE that indicated the genotypic differences in WT were not pronounced immediately after termination of waterlogging. However, a remarkable recovery in RGR of total plants was found during 45-55 DAE in almost all genotypes. The genotypes BU mug 4 and GK 63 showed the negative FT indexes during 35-45 DAE had the FT indices 200 and 141 respectively during 45-55 DAE. Other genotypes also performed similarly. A plausible explanation of such a rapid increase in RGR can be explained by the fact that the genotypes expended the accumulated dry matter quickly produced through adventitious roots and then eventually utilized that in producing shoot dry matter during the second recovery period.

Yield attributes and seed yield

Yield contributing characters and seed yield of twelve mungbean genotypes as affected by waterlogging are presented in Table 3. The number of branch plant^{-1}, number of pods per plant^{-1}, seed yield plant^{-1}and harvest index was significantly affected by waterlogging, where seed weight was not significantly affected. The number of branches plant^{-1} was more vulnerable to waterlogging and showed 17-64% reduction. There was great variation among genotypes in producing pods plant^{-1} that ranged from 3.03 to 11.58 in waterlogged plants and 5.75 to 21.25 in control plants. The genotype ACC12890054 produced the highest number of pods plant^{-1} under waterlogging situation and control conditions. The variation of seed weight due to waterlogging was not comparable for both waterlogging and non-waterlogged plants. However, genotypes and GK 63 produced bolder seeds in waterlogged situations. 11 Ahmed et al. (2002) found that waterlogging reduced seed yield by reducing the number of pods plant^{-1} rather than reduced the number of seeds pod^{-1} or seed weight.Irrespective of waterlogging treatment, seed yield showed a significant variation across the genotypes. The genotypes produced 0.34 to 1.56 ton ha^{-1} under waterlogged and 2.33 to 3.88 ton ha^{-1} under control condition. Waterlogging induced reduction in seed yield ranged between 54 to 87% depending on genotypes. The genotypes ACC12890085 and ACC 12890054 that showed better tolerance to waterlogging gave the highest yield (46% relative to control) followed by BUmug 4 and VC 6173-A. From Table 3, the harvest index HI was changed remarkably due to waterlogging treatment. The genotype GK 48 had the lowest harvest index which indicates that it had the lowest economic yield due to the negative effect from waterlogging. The genotype ACC12890054 had and the highest HI (90% of control). It means that this genotype showed tolerance to waterlogging and gave the highest economic yield. Therefore, ACC12890054 is the best among the genotypes in respect of yield performance under waterlogging situations.

K-means cluster analysis

K-means non-hierarchical cluster analysis was performed using eight quantitative plant characters i.e. waterlogging tolerance of stem, leaf, root and total biomass, relative root-shoot ratio, pods per plant, harvest index and grain yield for grouping 12 mungbean genotypes. The correlation coefficient values with grain yield were low for other plant characters and they were excluded from multivariate analysis. A dendrogram was prepared on the basis of cluster analysis (Figure 1). The tree was cut at the rescaled distance of 5.0 to produce classes that were maximally related to other specific variables of interest. Thereafter, the genotypes were grouped into four clusters. Cluster 1 is comprised of genotype GK 48 which is characterized by the lowest relative value in all the eight plant characters (Table 4). Cluster 2 contains five genotypes viz. ACC12890085, ACC 12890054, VC 1160-A, VC 6173-A and GK 63 those are characterized by the highest relative root-shoot ratio (47.2) and harvest index (73.5). All other plant characters performed well and the genotypes gave better grain yield relative to control. Cluster 3 includes genotype BU mug 4 having the highest waterlogging tolerance of stem, leaf, root and total biomass as well as pods per plant (65.4) and concurrently gave the highest relative grain yield (41.9). Cluster 4 genotypes viz. GK 65, BARImung 4, BARImung 6, IPSA-13, IPSA-15 were mainly characterized by the moderate plant characters which were higher than that of cluster 1 genotypes. In the clustering pattern, cluster 3 genotype performed better followed by cluster 2 genotypes.

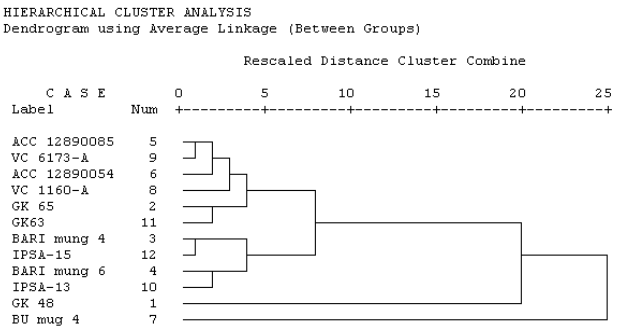

Fig 1. *Graphical illustration of hierarchical cluster analysis of mungbean genotypes using dendrogram*

Table 4. *Comparison profile of the genotypes grouped under four clusters*

Plant traits	Clusters			
	1	2	3	4
No. of genotypes	1	5	1	5
Waterlogging tolerance of stem	22.5	114.8	179.4	79.5
Waterlogging tolerance of leaf	27.1	132.1	161.0	100.2
Waterlogging tolerance of root	2.5	148.3	239.1	66.0
Waterlogging tolerance of total biomass	32.1	129.7	198.6	86.5
Root shoot ratio	28.0	47.2	25.0	41.6
Pods per plant	29.8	57.0	65.4	53.5
Harvest index	31.1	73.5	72.7	70.7
Grain yield	14.5	37.1	41.9	32.2

Molecular characterization through SSR markers

Four SSR markers were used in this study. The details of the used primers and molecular diversity present among mungbean genotypes are presented in Table 5. VR188 and VR 225 primers produced three bands. VR276 and VR 304 primers produced two and four bands, respectively. The selected four primers generated twelve bands in total where all the twelve bands were polymorphic. PIC (Polymorphism Information Content) value indicates primer effectiveness. All PIC values of primers were above or almost equal to 0.5 indicating that the primers were effective. Maximum PIC value was found for VR 276, while the minimum was for VR 225.

A dissimilarity matrix was constructed using the binary data obtained through SSR analysis with a view to observe the genotypic relatedness. The lowest pair-wise estimate of dissimilarity was found to be 0.000 while the highest was 0.417 (Table 6). The highest value was observed for 16 pairs of mungbean genotypes (0.417). Each pair showed 41.7% maximum dissimilarity in their genotypic characters. The lowest dissimilarity (0%) was found for four pairs of mungbean genotypes such as GK 65 and ACC12890085, BARI mung 6 and BARI mung 4, IPSA-13 and VC 1160-A, GK 63 and VC 6173-A. They bear the same genotypic character in each pair of genotypes. A significant amount of genetic divergence was found within the mungbean genotypes as exposed by the dissimilarity matrix.

Genetic similarities served as the source of creating the cluster diagram. Nei's similarity coefficients clustered the 12 genotypes into four different groups (Figure 2). These four main clusters are distinctly dissimilar to each other. Cluster (I) divided into subcluster A and B (Table 7). Subcluster A further divided into subcluster AA and AB. Subcluster AA is also divided into subcluster I and II, which have some similar genotypic characters. Subcluster I involved two mungbean genotypes as IPSA-13, VC 1160-A. Genotypic characters of these genotypes are mostly similar to each other. Subcluster II includes one mungbean genotype IPSA -15. Subcluster AB includes GK 63, VC 6173-A genotypes; they have some similar characteristics but also showed some dissimilar genotypic characters.

Table 5. *List of primers and molecular diversity among the studied mungbean genotypes*

SSR Primers	Sequence	**Total no. of bands**	**Polymorphic bands**		**Monomorphic bands**		PIC value
			No.	**%**	**No.**	**%**	
VR 188	F ATACAAGGGCAGGTGTAGCATC R CAGAAAACTTCATCCCCAGCTA	3	3	100	0	0	0.6287
VR 225	F CAGCAACAGAACTACAATCCCA R CGGCAATCCTCCTATATTCATT	3	3	100	0	0	0.4910
VR 276	F TTGATCCTTGTATTGGATGGTG R GTGGGATTTCTGGTTTTGTTGT	2	2	100	0	0	0.6832
VR 304	F GAAGCGAAGAAGCCATAGAAAA R CCTCACACACAACACAACAGAA	4	4	100	0	0	0.5065

Cluster II has one genotype BU mug 4. Cluster III is divided into subcluster A2 and B2. Subcluster A2 is also divided into subcluster I and II, based on their genotypic characters, which are dissimilar to each other. Subcluster I has two genotypes as BARImung 6, BARImung 4 and subcluster II has two genotypes ACC 12890085 and GK 65, they have same genotypic character. Subcluster B2 in the cluster III has GK 48. Cluster IV has ACC12890054 mungbean genotype. The genotype bear distinctly different character compared to other genotypes.

The distinct clusters were constructed based on morphological and molecular data. Although the total number of clusters is the same the genotypes included in the clusters for morphological and molecular data were not the same. The dendrogram obtained from the SSR markers must be more discriminatory and highly polymorphic and thus, more informative than the one obtained from morphological characterization. Although, the dendrogram generated from the morphological data has provided an overall pattern of variation as well as the degree of relatedness among the genotypes, variation in environmental conditions should be taken into consideration. Moreover, SSR markers are sequence-specific. The targeted region may not control the morphological traits studied. Including more morphological traits and SSR markers representing the whole genome of mungbean may provide a similar dendrogram pattern.

Table 6. *Dissimilarity matrix of mungbean genotypes analyzed using Nei's original measures of genetic identity*

Genotype	GK 48	GK 65	BARI mung 4	BARI mung 6	ACC 12890085	ACC 12890054	BU mug 4	VC 1160-A	VC 6173-A	IPSA -13	GK 63	IPSA -15
GK 48	1.000											
GK 65	0.167	1.000										
BARImung 4	0.250	0.084	1.000									
BARImung 6	0.250	0.084	0.000	1.000								
ACC12890085	0.167	0.000	0.084	0.084	1.000							
ACC12890054	0.167	0.167	0.250	0.250	0.167	1.000						
BUmug 4	0.250	0.250	0.167	0.167	0.250	0.084	1.000					
VC 1160-A	0.417	0.417	0.333	0.333	0.417	0.250	0.167	1.000				
VC 6173-A	0.417	0.417	0.333	0.333	0.417	0.417	0.333	0.167	1.000			
IPSA -13	0.417	0.417	0.333	0.333	0.417	0.250	0.167	0.000	0.167	1.000		
GK 63	0.417	0.417	0.333	0.333	0.417	0.417	0.333	0.167	0.000	0.167	1.000	
IPSA -15	0.333	0.333	0.417	0.417	0.333	0.167	0.250	0.084	0.250	0.084	0.250	1.000

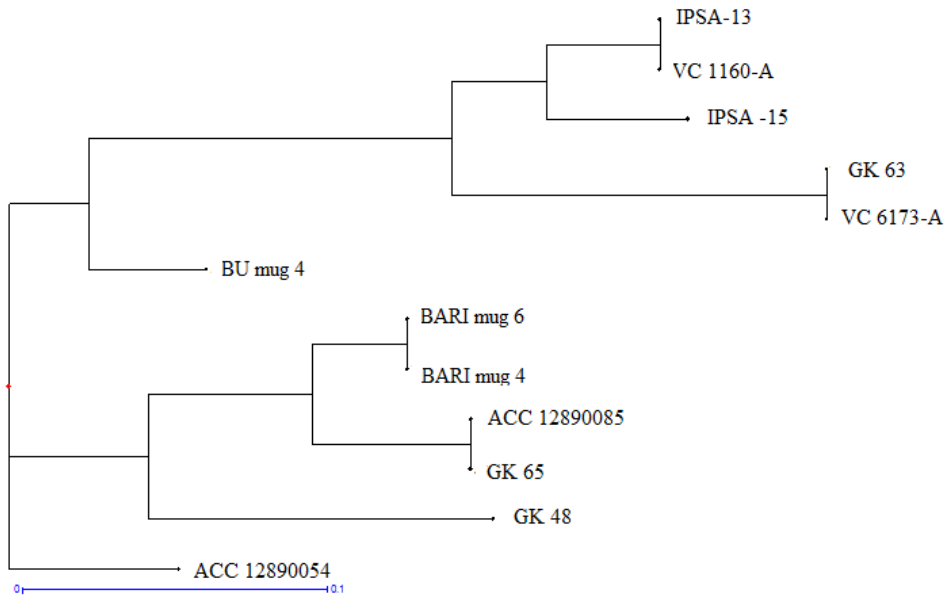

Fig 2. *Dendrogram (UPGMA) pattern of SSR analysis in different mungbean genotypes*

Table 7. *Distribution of twelve mungbean genotypes in different clusters*

Cluster				Genotypes included in different clusters	No. of genotypes in cluster
I	Sub cluster A	Sub cluster AA	Sub cluster I	IPSA -13, VC 1160-A	2
			Sub cluster II	IPSA -15	1
		Sub cluster AB		GK 63, VC 6173-A	2
II				BUmug 4	1
III	Sub cluster A2	Sub cluster I		BARImung 6, BARImung 4	2
		Sub cluster II		ACC12890085, GK 65	2
	Sub cluster B2			GK 48	1
IV				ACC12890054	1

Table 1. *Relative growth rate and waterlogging tolerance of plant root in twelve mungbean genotypes subjected to soil waterlogging*

Genotype	Relative growth rate (RGR, g/g/day)	Root		
		Waterlogging Period (25-35DAE)	Recovery period (35-45 DAE)	Recovery period (45-55DAE)
GK 48	RGR waterlogged RGR control	0.047(27) 0.176	0.065(57) 0.114	0.003(3) 0.122
GK 65	RGR waterlogged RGR control	0.082(55) 0.150	0.053(60) 0.088	0.053(69) 0.07
BARImung 4	RGR waterlogged RGR control	0.019(14) 0.131	0.062(72) 0.085	0.067(94) 0.072
BARImung 6	RGR waterlogged RGR control	0.038(35) 0.109	0.055(45) 0.123	0.004(10) 0.041
ACC12890085	RGR waterlogged RGR control	0.031(30) 0.102	0.105(88) 0.119	0.099(161) 0.062
ACC12890054	RGR waterlogged RGR control	0.079(71) 0.112	0.040(41) 0.099	0.120(157) 0.076
BUmug 4	RGR waterlogged RGR control	0.017(9) 0.184	0.035(32) 0.111	0.110(238) 0.046
VC 1160-A	RGR waterlogged RGR control	0.023(20) 0.115	0.044(37) 0.120	0.165(178) 0.093
VC 6173-A	RGR waterlogged RGR control	0.071(73) 0.097	0.043(63) 0.069	0.087(125) 0.069
IPSA-13	RGR waterlogged RGR control	0.063(61) 0.104	0.058(74) 0.079	0.027(50) 0.054
GK 63	RGR waterlogged RGR control	0.064(51) 0.126	0.020(24) 0.080	0.065(119) 0.054
IPSA-15	RGR waterlogged RGR control	0.080(58) 0.138	0.049(75) 0.066	0.103(108) 0.096

The numerical values in the parenthesis indicate waterlogging tolerance (WT) calculated as the percent ratio of RGR of waterlogged and RGR of control plants.

Table 2. *Relative growth rate and waterlogging tolerance of total plant in twelve mungbean genotypes subjected to soil waterlogging*

Genotype	Relative growth rate (RGR, g/g/day)	Total plant		
		Waterlogging Period (25-35DAE)	Recovery period (35-45 DAE)	Recovery period (45-55DAE)
GK 48	RGR waterlogged	0.074(55)	0.045(45)	0.044(32)
	RGR control	0.135	0.099	0.137
GK 65	RGR waterlogged	0.076(59)	0.040(53)	0.067(122)
	RGR control	0.127	0.075	0.055
BARImung 4	RGR waterlogged	0.079(54)	0.024(36)	0.085(89)
	RGR control	0.145	0.065	0.095
BARImung 6	RGR waterlogged	0.064(52)	0.020(22)	0.036(64)
	RGR control	0.124	0.091	0.056
ACC12890085	RGR waterlogged	0.004(4)	0.077(68)	0.098(114)
	RGR control	0.090	0.113	0.086
ACC12890054	RGR waterlogged	0.081 (65)	0.042(52)	0.118(115)
	RGR control	0.125	0.081	0.102
BUmug 4	RGR waterlogged	0.049(39)	-0.010(-11)	0.141(200)
	RGR control	0.126	0.090	0.071
VC 1160-A	RGR waterlogged	-0.007(-5)	0.025(40)	0.183(153)
	RGR control	0.143	0.062	0.120
VC 6173-A	RGR waterlogged	0.047(47)	0.032(37)	0.101(125)
	RGR control	0.100	0.087	0.081
IPSA-13	RGR waterlogged	0.045(34)	0.046(51)	0.058(79)
	RGR control	0.132	0.090	0.074
GK 63	RGR waterlogged	0.030(26)	-0.004(-5)	0.099(141)
	RGR control	0.117	0.082	0.070
IPSA-15	RGR waterlogged	0.036(33)	0.035(63)	0.083(79)
	RGR control	0.109	0.056	0.106

The numerical values in the parenthesis indicate waterlogging tolerance (WT) calculated as the percent ratio of RGR of waterlogged and RGR of control plants.

Table 3. *Effect of waterlogging on yield and yield attributes of mungbean genotypes*

Genotype	Waterlogging level	Branch Plant^{-1} (no)	Pods Plant^{-1} (no)	1000-Seed Weight (g)	Seed Yield Plant^{-1} (ton ha^{-1})	Harvest Index
GK 48	Waterlogged	0.50(58)	3.33(31)	30.92(93)	0.34(13)	0.14(32)
	Control	0.83	11.17	33.40	2.34	0.45
GK 65	Waterlogged	1.42(64)	7.96(65)	33.86(88)	1.05(30)	0.26(61)
	Control	2.17	14.00	39.33	3.27	0.42
BARImung 4	Waterlogged	0.98(36)	5.23(32)	30.40(94)	0.68(23)	0.20(55)
	Control	2.83	18.92	32.30	3.22	0.37
BARImung 6	Waterlogged	0.92(50)	4.56(55)	48.35(103)	0.97(39)	0.31(88)
	Control	1.92	9.25	47.00	2.48	0.35
ACC12890085	Waterlogged	0.83(53)	5.07(92)	49.59(98)	1.07(46)	0.29(77)
	Control	1.67	5.75	50.87	2.33	0.37
ACC12890054	Waterlogged	1.67(78)	11.58(54)	32.76(96)	1.56(46)	0.33(90)
	Control	2.17	21.25	34.16	3.37	0.37
BUmug 4	Waterlogged	1.25(51)	7.68(72)	36.46(95)	1.12(43)	0.32(72)
	Control	2.33	11.75	38.27	2.67	0.44
VC 1160-A	Waterlogged	1.75(83)	6.84(41)	30.67(99)	1.18(30)	0.30(76)
	Control	2.25	16.75	31.07	3.88	0.40
VC 6173-A	Waterlogged	1.75(80)	7.21(76)	39.24(85)	1.08(42)	0.30(75)
	Control	2.25	10.00	46.65	2.54	0.40
IPSA-13	Waterlogged	0.67(58)	5.06(84)	48.44(84)	0.91(34)	0.31(70)
	Control	1.17	6.58	58.04	2.70	0.44
GK 63	Waterlogged	0.67(61)	3.03(30)	37.26(103)	0.48(20)	0.20(49)
	Control	1.08	10.33	36.48	2.33	0.40
IPSA-15	Waterlogged	1.25(64)	7.06(86)	34.25(96)	1.04(36)	0.33(77)
	Control	2.08	12.42	35.58	2.97	0.42

The values in parenthesis indicate percent relative to control

Conclusion

The different morpho-physiological traits of mungbean were found susceptible to waterlogging, although genotypic variation in improving the waterlogging tolerance during recovery stages was highly evident. The recovery of the depressed plant traits was satisfactory and correlated well with yield and yield contributing characters and hence gave better yield in some genotypes. The dendrogram obtained from the SSR markers was more discriminatory and highly polymorphic and thus, more informative than the one obtained from morphological characterization. Further systematic studies are needed under field conditions to improve waterlogging tolerance of the selected genotypes for sustainable cultivation. A series of molecular lab experiments with more primers representing the wholegenome are essential as a step towards the genetic improvement of mungbean under soils waterlogging environment.

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Participatory policy review: "Supportive Tourism" concept for hand-in-hand rural and mountain development

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ABSTRACT

This article is an attempt to provide an exhaustive review of governmental policy documents for rural and mountain development in Georgia in the context of the local tourism supply chain (LTSC). Mainly, we examine to what extent policy-makers recognize the importance of the interconnectedness between tourism and other economic sectors. The study employs a systematic literature review and participatory workshops with local stakeholders to avoid observing the issue from a single angle. The analysis of strategic documents shows that tourism is considered vital for mountain and rural settlements' economic welfare, in fact, the narrow sense of its capabilities hinder the full effect on allied economic sectors. More precisely, strategies mostly consider tourism's impact on [mountain, rural] communities in terms of its direct consequences such as new constructions in accommodation and catering units, ski trails, etc. This study provides recommendations, which could facilitate improvements in the integration of farming and non-farming activities into the tourism sector. Based on the research, acknowledging the increasing dependency on such a sensitive economic branch as tourism, we suggest the new tourism advancement concept under the title of "supportive tourism". The paper suggests understanding and utilizing tourism as (i) starting point for other local economic actors; (ii) motto to increase demand for local services and products; (iii) supportive platform for the local economy to enter into new markets. Ultimately, supportive tourism could result in weakening dependence of local economic activities on the local tourism supply chain.

Keywords: Supportive tourism, Participatory policy review, Local tourism supply chain, Mountain development, Rural Development, Georgia.

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Introduction

Recent decades have marked mountain and rural tourism as an essential piece of the worldwide tourism economy pie, introducing immense opportunities to highland and peripheral communities [1]. Tourism, due to its multifaceted nature, includes a wide range of economic connections under its umbrella. Such linkages are characterized by tourism's direct (e.g., catering, accommodation, transport) and indirect (e.g., agriculture, manufacturing) effects on other economic sectors. Diversified economic ties position tourism among the economic fields having the distinctive feature of the multiplier effect on local economic areas [2].

Cardinal transformations of the local economy always accompany tourism's introduction into mountain and rural settlements, mainly in the rapid establishment of the previously poorly developed service sector [3]. According to Heng and Low [4],

healthy tourism functioning needs the accompanying development of auxiliary services and manufactures. Thus, a broad array of local supplementary activities can be integrated into the local tourism supply chain (LTSC). As a result, a supportable interrelationship between tourism and the host economy will be a prerequisite for effective mountain and rural development. In particular, sustainable development of tourism throughout the process should ensure the expansion of economic fields that were previously strong, on the one hand, and give the impetus to less-developed branches to move forward, on the other hand [5-7].

A realistic assessment of tourism's benefits and taking the right measures targeted toward local contexts and peculiarities plays a vital role in receiving the anticipated long-term benefits of tourism development. According to the UNWTO [8], tourism in mountain areas should be reinvented in the policy strategies through repositioning the competitive advantages of particular destinations. More precisely, the global campaign should be directed toward encouraging local, traditional, authentic, and innovative production rather than promoting a mass-tourism market with similar product chains in every destination.

Mountainous areas, with their extreme complexity, require more integrated economic development approaches than the lowlands. As suggested by the Food and Agriculture Organization of the United Nations and the International Partnership for Sustainable Development in Mountain Regions [9], it is better to build the mountain economies upon the strengths of their assets, such as traditional knowledge and niche production. Similarly, a Strategic Research Agenda on Mountains for Europe's Future [10] argues that a shift is necessary in the overall understanding of mountains and their capacities: they are unique places with special potential solutions for various pressing challenges, including sustainable mountain tourism. Therefore, as researchers suggest, mountain tourism should be developed based on the local, high-value, competitive products, and services [11,12]. Apparently, such an approach will better ensure the sustainability of tourism development, the diversification of the regional economy, and, importantly, the maintenance of domestic, rooted economic activities.

Based on the assumptions of the UNWTO and the UNDP [13], the power of tourism is crucial for achieving the goals of the 2030 Agenda for Sustainable Development. Developing tourism with strong linkages to allied economic activities is among the pillars of the Sustainable Development Goals. Thus, tourism policymakers should act together with governmental and non-governmental institutes and other relevant stakeholders to harness tourism's multiplier effect through integrated policies. In particular, they must work together to take advantage of tourism's economic interlinkages with, and impacts on, other sectors and activities.

The Association Agreement between the European Union and Georgia 2014–2020 also addresses tourism: Article 9 indicates Georgia's development path in relation to tourism progress. The Georgian government is responsible for increasing tourism's potential and the number of international visitors, as tourism is among the leading sectors of the economy, creating several direct and indirect benefits for host communities. The same article in the Association Agreement states [14] that Georgia should maintain "partnership between public, private, and community interests in the field of tourism, to strengthen the development of competitive and sustainable tourism industry as a generator of economic growth and empowerment, employment, and international exchange."

There is currently high international emphasis on developing tourism with strong linkages to allied economic activities. However, recent research projects carried out in mountainous Georgia have revealed weak interrelations between tourism and other economic sectors. According to Gugushvili et al. [15], the Greater Caucasus experiences weak and non-resilient economic linkages between tourism and agriculture. This significantly hinders the possible benefits and hand-in-hand progress for the local community. It also reduces the stability and sustainability of local tourist markets. Khelashvili [16] observed the lowest emphasis on the consumption of local products. Furthermore, his findings revealed the low multiplier effect from tourism-generated income and high import dependency. Papava [17], in his policy paper, also highlights that only up to 20% of Georgia's consumer basket is produced within the country, whereas the remaining 80% is imported. Such a character of tourism—not consuming local products—contributes instead to the economies of the exporting countries and leads to the leakage of tourism's economic benefits.

Several research projects have apparently been conducted on linkages between tourism and other economic activities. However, few, if any, attempts were made to translate existing scientific evidence into practical solutions and integrate them into the

strategic documents. Based on this gap, the following questions were raised and are answered in this paper: (i) do the strategic documents address issues related to the LTSC? (ii) what kinds of evidence/suggestions do scientific articles offer for tourism development strategies in the mountain and rural areas? and (iii) how do the local people imagine using the immense opportunity of the tourism multiplier effect?

Methodology

The presented study combines a systematic literature review of articles (Georgia's context) and policy documents, as well as applying a participatory workshop. The analysis of the scientific sources and the integration of local perspectives played a decisive role in identifying the current gaps and formulating recommendations for policy documents, which express the needs of the locals.

Systematic Literature Review

The initial phase of the study was conducted based on the principles of the systematic literature review [18]. First, peer-reviewed publications were collected on the study topic using keyword ("tourism" and "Georgia") searches in electronic databases, such as Web of Science, Scopus, ResearchGate, and Google Scholar. Given the scarcity of available literature in the context of tourism in Georgia, the search was not limited to a particular topic. After collection of the relevant articles, pre-defined inclusion criteria, including geographical peculiarities (rural and mountain areas) and the particular topic of tourism study (linkages between the tourism industry and other economic sectors) were used during the systematic analysis of the literature. More precisely, certain parts of the paper, such as the abstract and conclusion, were assessed in compliance with the determined inclusion criteria. The comprehensive literature search resulted in ten articles (Table 1), including conference proceedings and unpublished articles. Our approach allowed synthesis of the research findings to reveal how the LTSC functions in rural and mountainous Georgia and creation of the strategic recommendations.

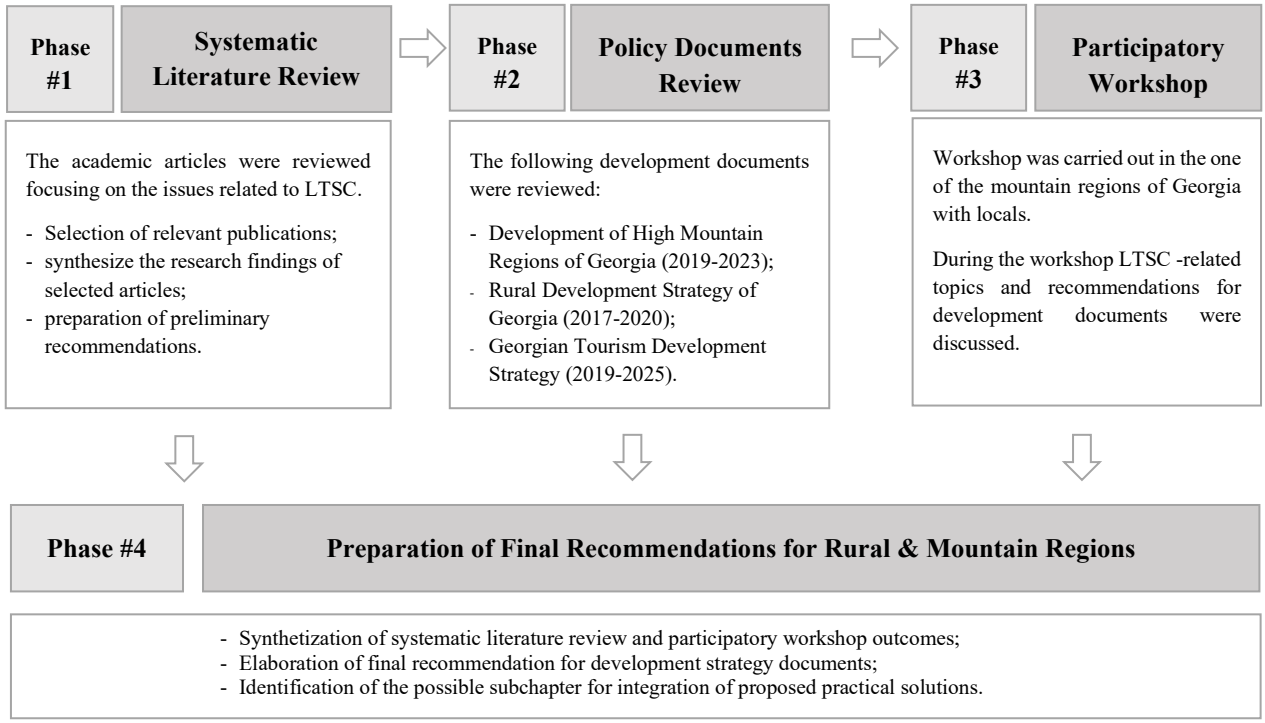

Fig 1. *Phases for Participatory Policy Review*
Source: Figure - Phases for Participatory Policy Review was developed by the authors

Table 1. *Publication collected for Systematic Literature Review*

Publication Title	Author/s	Publication Status	Publication Date
Is Tourism the Beginning or the End? Livelihoods of Georgian Mountain People at Stake	Salukvadze, Gvantsa Backhaus, Norman	published	2020
Spatial Peculiarities of Local Tourism Supply-Chains in High Mountainous Georgia: Challenges and Perspectives.	Salukvadze, Gvantsa Gugushvili, Temur Salukvadze, Joseph	Published	2020
Rural Tourism in Georgia in Transition: Challenges for Regional Sustainability	Khartishvili, Lela Muhar, Andreas Dax, Thomas Khelashvili, Ioseb	Published	2019
Analyzing Tourism Influence on Agricultural Products' Market: A Case Study of the Mestia Municipality, Georgia	Sharia, Mariam	Published	2019
Clustering the Problems of Sustainable Tourism Development in a Destination: Tsaghveri Resort as A Case	Khelashvili, Ioseb Khartishvili, Lela Khokhobaia, Merab	Published	2019
The Role of Tourism in Economic Development of Georgia	Arghutashvili, Valeri	Published	2018
Social and Economic Challenges of Sustainable Tourism Development in Georgia	Khelashvili, Ioseb	Published	2018
Fragmented Development: Tourism-driven Economic Changes in Kazbegi, Georgia	Gugushvili, Temur Salukvadze, Gvantsa Salukvadze, Joseph	Published	2017
Rural tourism as a promising trend of small business in Georgia: Topicality, capabilities, peculiarities	Paresishvili, Otar Kvaratskhelia, Laura Mirzaeva, Valentina	Published	2017
Linking agricultural food production and rural tourism in the Kazbegi district – A qualitative study	Hüller, S. Heiny, J. Leonhäuser, I.-U.	Published	2017

Policy Document Review

The second phase of the study was focused on reviewing policy documents aiming to assess the national perspective on tourism development, particularly regarding the supply side of tourism and its role in mountain and rural advancement. For this reason, we selected and reviewed the following policy documents: (i) Rural Development Strategy of Georgia (2017–2020); (ii) Georgian Tourism Development Strategy (2019–2025); and (iii) Development of High Mountain Regions of Georgia (2019–2023). We applied computer-assisted qualitative data analysis software to analyze the collected materials. The analysis process was focused on reviewing whether the selected strategic documents integrate the findings of recently implemented scientific studies. Furthermore, measures were taken to support scaling up the locally initiated economic activities and their integration in the LTSCs. As a result of the open coding, the primary thematic categories, such as Importance of Tourism, Ecotourism Development, Importance of LTSC, and Data on Tourism Development, were formulated.

Participatory Workshop

The core concept of the presented methodology is to promote active engagement of the local community, who represent final beneficiaries of the analyzed policy documents, in the study. More precisely, the workshop—as an effective participatory

technique—was applied to ensure the integration of the local voices in the process of developing recommendations. The meeting organized for the local stakeholder with cooperation with Local Action Group (LAG) in one of the mountain settlements in Georgia - Mestia Municipality. Around 20 attendees represented different genders, generations and economic fields.

The first part of the workshop was dedicated to the researchers' presentation of the main findings of the systematic literature review regarding the LTSC in the mountain and rural areas of Georgia. The second part consisted of a follow-up teamwork discussion: in small groups, one to three particular topics were selected from the provided issues for further debate. The following topics were discussed: (i) alternative integration strategies in the LTSC; (ii) barriers and possible ways to integrate agriculture in the LTSC; and (iii) challenges with scaling up the economic activities, mainly agriculture. Hence, such an approach revealed the topics that are of primary importance to the local population.

Results

Results of the systematic literature review

The reviewed articles cover a wide range of issues from general questions (the role of tourism in economic development on the national or regional level) to narrower topics (rural tourism and the LTSC). Most of the publications employ qualitative methods, using in-depth interviews, focus groups, and workshops with various stakeholders, such as local community members, representatives of the tourism industry, associations, experts, and practitioners in the study field. A broad representation of different voices is an essential prerequisite for the co-creation of knowledge and the development of inclusive, practical, reliable, and justified solutions.

In the literature discussing tourism broadly, in the context of regional development, scholars outline the multiplier effect of the sector, which is not fully embraced [16]. It has the potential to catalyze, stimulating satellite economic branches in the region and beyond [19].

Some scholars are focused on the challenges and perspectives of the LTSC. The latest studies implemented in the Kazbegi Municipality [15, 20] show that while the advancement of tourism is rapid, the indicators of agricultural activities are significantly decreasing in the region. Based on such a finding, the scholars highlight the crucial importance of integrating local agricultural product supplies into the tourism industry chain [15]. Furthermore, scholars note that the local farmers can improve their livelihoods by supplying the products to tourist facilities (e.g., guesthouses, catering services) [20]; the destination may even create an authentic niche by providing and promoting local, natural agri-food products to tourists [21], which itself is a pillar of sustainable rural tourism development [22,23]. Salukvadze and Backhaus [24] argue that tourism-led fragmentation in the local livelihood system may prevent diversification of economic activities and even increase tourism-dependence of the host community.

Most importantly, the outcomes of several studies (Table 2) mentioned above also include the reasons for the existing weak linkages between agri-food producers and tourism industry representatives. The distinguished triggers cover a wide range of topics that should be addressed in the policy for sustainable rural tourism and healthy LTSC development, as well as in the strategies for rural, mountain, and tourism development.

Table 2. *Triggers and recommendations for developing effective LTSC in terms of agriculture*

Topics	Triggers and recommendations	Authors
Absence of food processing infrastructure Agricultural products' integration in tourism Agricultural extension service for local farmers	The article indicates that in the research region, the absence of professional food processing infrastructure (slaughterhouses and milk collection centers) makes it challenging for local small-scale farmers to deliver agri-food products that fit safety standards. Along with infrastructural shortcomings, an agricultural extension service, especially training in agri-marketing for local farmers, would play a vital role in the process of reaching the tourism market. The authors propose marketization of agri-products, such as honey, herbal tea, potatoes [25], and cheese, which may have the potential to be integrated into the LTSC.	[20]

Ineffective communication between LTSC actors Shortcomings in agriculture	The author argues that even though the development of the tourism sector opened the opportunity for local farmers to sell their agricultural products to the local market, they cannot fully embrace the potential. Sharia points to the leading reasons preventing integration of local agricultural products in the LTSC. This fact is triggered, on the one hand, by the weak communication between the actors from tourism and agriculture businesses, and, on the other hand, the existing challenges faced by the agricultural sector in the region.	[21]
Cooperation between the institutions Institutional development	In the article, scholars draw readers' attention to the project Marani Wine Tours, which is an obvious example of how cooperation between associations and government institutions have succeeded in the valorization of Qvevri[1] wine. Such a practice represents an example of how to stimulate adjoined economic activities—in this case, agri-tourism. The article also outlines the initiated network between between organic farmers and tourism actors supported by NGOs via external funding. Based on the evidence, they argue that the absence of governmental organizations in this initiative has resulted in incomplete development and weak sustainability. The authors foresee that institutional development (institutions for rural tourism development and destination management organizations (DMOs)) will ensure the sustainable development of rural tourism, including hand-in-hand development of agriculture and tourism in the destination.	[23]
Cooperation between the institutions Analyzing existing practices Local context	Similarly to the previously discussed article [23], the author stresses the benefits of strengthened interlinkages between the private sector, governmental and educational institutions. Furthermore, the author highlights the importance of analyzing already existing experience in foreign countries as well as considering the local context with its full advantages, resources, and development prospects.	[19]

[1] Qvevri wine-making is practiced throughout Georgia, particularly in village communities where unique varieties of grapes are grown. The Qvevri is an egg-shaped earthenware vessel used for making, ageing and storing the wine. https://ich.unesco.org/en/RL/ancient-georgian-traditional-qvevri-wine-making-method-00870

The competitiveness of local agricultural products Shortcomings in agriculture Agricultural extension service for local farmers Unstable supply of agri-products	The article pays attention to local products' lack of competitiveness compared to alternative suppliers' distributed goods from outside the region. The authors reveal the reasons in favor of non-local products. The main advantage is the lower price of the mass-produced, low-quality products delivered to the region, which seems to be acceptable for the tourism recipients, especially catering providers. Furthermore, such 'outside' markets have additional advantages, such as broad spatial coverage of product delivery and barter options (e.g., a natural exchange of cheese to vegetables). Altogether, this significantly weakens the competitiveness of local products. Some findings in this article are in line with the perspectives of other scholars [20] and support the view that local farmers' weak marketing skills and lack of enthusiasm to offer their products to tourism recipients are core shortcomings of weak collaboration between farmers and tourism representatives. The article complements Sharia's [21] findings regarding existing shortcomings in agriculture that significantly hinder its integration into the LTSC. Along with the mentioned weaknesses in agriculture, additional shortcomings are observed, such as unstable supply (e.g., seasonality, volatile number of products), outdated infrastructure, and lack of modern technology.	[11]

Recent publications using data from the research project "Linkages between Tourism and Community-driven Economic Activities: Shaping Sustainability in Mountain Regions" provide a new angle for LTSC study. More specifically, the central settlements (e.g., Townlets) in the mountain districts are identified as the primary consumers (e.g., cafes, hotels, guesthouses) of the agri-products delivered from nearby or distant villages [11]. Such a finding indicates the inevitable need for stable connectivity between rural and urban settlements, including road infrastructure, transport, and information flow to pave the way for small-scale farmers' integration within the LTSC.

A recent article by Salukvadze and Backhaus [24] was dedicated to analyzing the tourism-led transformation in mountain and rural areas of the Greater Caucasus. Based on the findings, scholars determined the following main types of livelihood alteration on the household level: (i) developing agri-tourism; (ii) increasing agricultural activities; (iii) reducing agricultural activities; and (iv) expanding non-agricultural activities. The existence of the latter type outlines that the local community's involvement in the tourism supply chain is possible through types of products and services other than agriculture.

Destinations face several tourism-related challenges at the same time, rather than single problem alone. Scholars introduce various scientific tools for sorting out problems to solve them effectively. Khelashvili, Khartishvili and Khokhobaia [26] proposes a system-based methodology, allowing researchers to identify the interrelation between destination's problems to cluster and determine the leverage factors. Ultimately, such an approach enables practitioners to identify problems, which should be addressed on the initial stage of destination development.

The LTSCs and development strategies

Development strategies of rural (2017–2020) and high mountain regions (2019–2023) recognize tourism's essential role in achieving targeted goals, including economic diversification, local development of small and medium businesses, and reducing regional disparities. In documents from both development strategies, nearly the same amount of mentions (number of codes) and similar text lengths (length of the coded text) are dedicated to the 'importance of tourism,' referring to the necessary resources for tourism development (Table 3, Fig. 2).

It is worth mentioning that strategies of high mountain regions and rural development, among

other untapped opportunities, outline issues associated with the LTSC. The particular text segments highlight the regions' potential resources for rural tourism development, increased demand for products alongside tourism development, and weaknesses that prevent such progress. In fact, the Tourism Development Strategy (2019–2025) omitted from its scope these particular fields of tourism. The policy documents obviously lack pragmatic solutions for tackling existing challenges considering existing local resources. The only clear approach for developing sustainable tourism through locally based resources was presented by the Rural Development Strategy through the establishment of thematic villages.

In summary, both strategies fail to sufficiently reflect on existing challenges of the LTSCs. Furthermore, they fall short in showing the local farmers' and entrepreneurs' development path for integrating their products and services within the LTSC and the ways tourism can support the advancement of satellite economic activities.

Table 3. *Number of mentions (codes) in the development strategy documents*

Policy / Codes' Name	Development of High Mountain Regions of Georgia (2019-2023)	Rural Development Strategy of Georgia (2017-2020)	Georgian Tourism Development Strategy (2019-2025)
Development of Eco-tourism	2	0	0
Importance of LTSC	3	6	0
Importance of Tourism (in general)	11	7	Not relevant
Analysis of Tourism Development	7	3	Not relevant

Source: *Table was prepared based on the Policy Documents' Review by the authors*

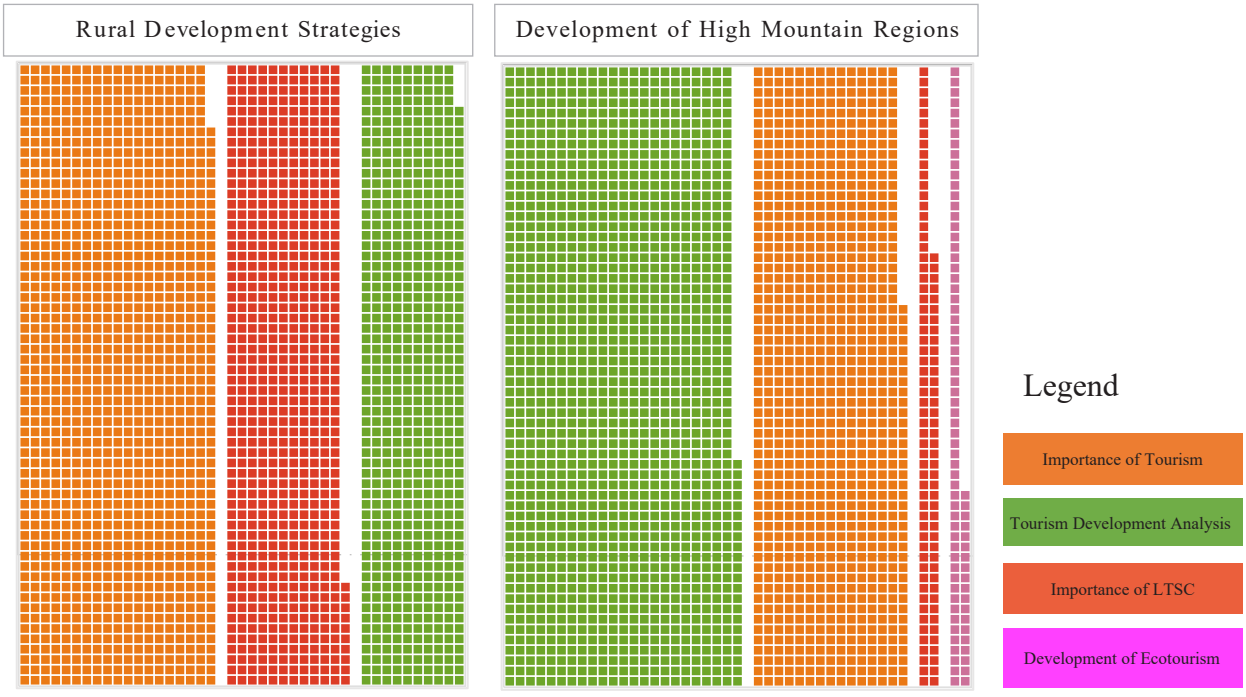

Fig 2. *Document portrait of strategies on high mountain regions and rural development*
Source: *Figure was prepared based on the Policy Documents' Review by the authors*

During the policy documents review several sub-chapters were determined in which the proposed practical solutions should be integrated.

Sub-chapters for Development of High Mountain Regions of Georgia (2019-2023):

- *New subchapter focusing on LTSC (the analysis of current situation);*
- *Internal and external factors (strength, weakness, opportunity, and threats) related to LTSC for SWOT analysis (SWOT analysis of High Mountain Regions);*
- *Strategic goal (strategic goals and objectives).*

Sub-chapters for Rural Development Strategy of Georgia (2017-2020):

- *New subchapter focusing on LTSC (Economic Overview);*
- *Internal and external factors (strength, weakness, opportunity, and threats) related to LTSC for SWOT analysis (SWOT Analysis);*
- *Strategic Objectives (Vision).*

Sub-chapters for Georgian Tourism Development Strategy (2019- 2025):

- *Challenges & Opportunities (Where are we now?);*
- *Our Targets (Where do we want to be in 2025?);*
- *Guiding Principles (How do we get there?).*

Locals' feedback on the recommendations for policy document integration

Proposed topics for discussion with locals during the workshop were broad and flexible enough to allow the participants to choose the particular issues that matter most to them. Such an approach gave a splendid opportunity to observe how they discussed selected crucial subjects for the region with peers and fellow community members (Table 4).

Table 4. *The discussed topics during the workshop with locals*

General Study Topics	Discussed Issues	Proposed Solutions
Challenges of agriculture integration within LTSC	Lack of information between the actors of LTSC	- Digital market, e-platforms for local farmers; - The local, open agi-bazaar, festivals; - Delivery service of the local agri-food; - The open-door market of local agri-food product.
	Non-systematical supply of agri-products triggered by seasonality, poor storage conditions, small amount and limited selection of products, and poor road infrastructure.	- The development of a cold storage facility/fridge (meat, potatoes, etc.); - Greenhouse development (during fieldwork few respondents noted that they actively use greenhouses to produce variety of products, and to store them to overcome seasonality. They noted that the practice of using greenhouses exists in Mestia, Svaneti).
	Lack of price competitiveness of the local agricultural product	Competitiveness rising involves the use of labels by the owners of hotels, cafes, as well as agricultural producers. Through labelling and proper branding, local, ecologically clean products will become distinctive and demanded in the market, which will ensure their recognition by consumers and increase of their competitiveness.

Alternative ways to integrate within LTSC	Lack of economic activities integrated within LTSC	To increase the variety of agri-products
Challenges of scaling-up the agriculture	- Lack of human resources (masculine workforce) in the household - Physically laborious work	- The need to purchase and introduce modern equipment; - Raising awareness about modern equipment.
	- Lack of pastures, remoteness from villages; - Fragmentation of land parcels, scarcity, distance from the residential area;	
	Insufficient knowledge to produce specific agricultural products	
	Lack of information for finding additional funding	

Discussion

A primary concern of this article is to reflect on the current relationship between tourism and allied economic activities through the synthesis of different aspects of the latest studies and local community perspectives. The findings clearly show that knowledge accumulated scientifically and among the locals could tackle existing challenges on the supply side of tourism. Our results are consistent with the position presented in the article published in 2013 [27]. It is evident that nearly a decade later, the lack of marketing skills and labelling of agri-products in compliance with the required standards for rural tourism still need to be addressed. Additionally, another article [28] published in the last ten years highlights the complexity of the tourism industry and, importantly, its reciprocal relationship with the other branches of the economy. The article contains policy recommendations to employ the project management approach [29], namely the Project Integration Management principle for effectively handling a system with various components. The authors [28] suggest considering the stakeholders' expectations and consumers' demands for achieving synergy.

The findings of the presented article support the idea of collaboration between actors from civil society, the private sector, and the government. Additionally, the results of this study indicate that hand-in-hand advancement of economic activities requires strong institutional development, including establishing or identifying an independent (private or public) entity with the specific responsibility of facilitating collaboration around the stakeholders' shared interests. Altogether, this will ensure fulfilling the steps of the development strategies. In one of the latest policy documents, Papava [17] argues that the central premise that tourism is the driving force of the real sector of the economy in Georgia is failing. The reason for this is that tourism's functioning is primarily based on imported products, which creates an illusion of development, but in reality, according to the author, constitutes a "tourist trap." Furthermore, the author suggests that tourism should be amended as a priority focusing more on the knowledge-based economy and the real sector of the economy. The presented article supports the core viewpoint of the mentioned paper, particularly the utilization of tourism's full potential. However, in sharp contrast to Papava [17], we do not suggest that missing a chance to prioritize tourism and redirecting the economic focus cardinally is a good idea. On the contrary, providing recommendations on the ways to embrace tourism's multiplier effect for the benefit of the whole spectrum of economic sectors is of vital importance and the key to tourism's sustainability.

Another scholar [16] shares the main concerns that Georgia has been losing the most valuable advantages of tourism, such as the multiplier effect on the related economic activities. From his viewpoint, tourism should have a positive impact on its satellite sectors through replacing imported goods with locally produced products, increasing the competitiveness of local supply chains and local service providers. Nevertheless, the author does not provide the exact steps for achieving the provided suggestion. In this regard, the presented article is bridging the mentioned gap through different approaches, such as a systematic literature review, workshops

with tourism's host communities, and a review of the official policy strategies. Altogether, this has contributed to the formulation of detailed, practical solutions based on which tourism could unfold with a supportive impact on other economic sectors.

Conclusion

A review of the policy documents sheds light on the urgent gaps that should be bridged according to existing evidence. The study reveals that the development strategies do not integrate the scientific findings of recent investigations and, in turn, neglect the academic viewpoints. The strategies do not integrate the clear ways of maximizing the potential of tourism's multiplier effect on other economic activities. More specifically, the following urgent topics remain unanswered: (i) strengthening the cooperation of local suppliers and tourism representatives; (ii) increasing the competitiveness of local products to become more attractive for tourism recipients; (iii) improving the information flow among the local suppliers and tourism recipients; and (iv) supporting locals' adaptations to the requirements of tourism.

A systematic analysis of the articles and a workshop with the local population revealed the following issues that need to be addressed. The results of the study highlight the importance of improving the information flow among the local actors and tourism recipients. Based on the systematic analysis and locals' participation, more realistic and local-context-oriented measures could be the development of special e-platforms, the establishment of local product festivals, and delivery services of local products within the municipalities.

Most of the studied articles were dedicated to several shortcomings in agriculture, tackling of which will be significantly advance the mentioned field. The agriculture-related challenges were among the topics discussed actively during the workshop. The main conclusion is that the regular supply of agri-products should be ensured, in which the local suppliers will also need support to tackle limitations caused by seasonality. Furthermore, the results point to the need to increase the variety of products for more diversified agricultural production. It seems particularly urgent that all agri-products meet the safety standards. Last but not least, the outcomes suggest increasing the 'visibility' of agri-food through green labels, which will, in turn, increase their competitiveness.

Along with the development of agriculture-related activities, there is a great need to diversify non-agricultural economic practices. The emergence of new economic fields opens avenues for widening tourism's positive impacts beyond the main centers, ensuring spillover effects for nearby and distant villages.

Academic activities highlight the importance of institutional development and cooperation between the stakeholders, including research institutions, NGOs, and private and public sectors. Identifying institution(s) (e.g., national agencies, associations, departments, DMOs, local institutions) responsible for development issues related to the LTSCs would be the first step forward. The they should facilitate effective cooperation between stakeholders.

The authors propose the new concept of "supportive tourism" for hand-in-hand rural and mountain development. Supportive tourism refers to tourism as a means of regional economic diversification, somewhat limiting its development as a final outcome. The upheaval of the tourism industry should have spillover effects of creating a preferable ecosystem for starting new economic activities or scaling up the existing prospective branches. Consequently, promoting supportive tourism will contribute to avoiding anticipated endangerment of the growing tourism dependence and fragility of the sector.

Consistently increasing numbers of local and international visitor flows significantly transforms the demand conditions at the host destinations. Emerging tourism-influenced markets comprise a wide range of customers, including those who demand high-quality goods and services. This process contributes to the growth of regional competitive advantages, which, in turn, provides an opportunity for the local entrepreneurs to innovate and enhance quality. In this environment, since local businesses handle the demand of the domestic market, new doors will be open to other supply chains in other regions and across the borders of Georgia.

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Georgian veterinary manuscripts in Georgian and foreign depositories

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ABSTRACT

The work deals with the veterinary and zootechnical manuscripts (compilations, writings, karabadins) with the newly found manuscripts and their thematic groupings (those of a horse, a dog, birds treatments) among them; the results of the multidisciplinary research and the peculiarities of the manuscripts. The Georgian veterinary manuscripts attract our interest in many ways: as the ones created in the Georgian tradition and tailored to practical needs; marked with the trends of the common cultural area; as the compositions reflecting on the features of the cultural dialogue, the results of the knowledge transformation, and generally, the particular stages of the history of science. The systematic review, characterization and evaluation of these manuscripts and the written sources in terms of the veterinary history, along with the multidisciplinary study, reveal specifically important material. The article gives the analysis of these very lists.

Keywords: Veterinary Manuscript, Foreign Depositories, Karabadin. Sources, Medical texts, Birds treatments.

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Introduction

The manuscripts of Georgian veterinary and zootechnical content, dating from the XVII-XIX centuries, reflect the knowledge and practical experience of the Georgian reality, as well as the influences of the common cultural area. The compositions are about horse, bird, dog care, their treatment, and they give tips on their breeding.

The material is neither fully valued in the field of history, nor widely available for the interested public with foreign scientific circles included; the data is not transmitted electronically. The present research, the planned printed and electronic products will significantly fill the existing gap.

The article presents a general overview and grouping of Georgian veterinary manuscripts by their content and purpose, also their distribution in Georgian and foreign antiquity depositories, and the detailed descriptions of some of the distinguished manuscripts according to the designed specimen.

The challenges of the Georgian medical and veterinary manuscripts research history

Medical manuscripts - the outstanding monuments of Georgian spiritual culture - reflect the achievements of the Hellenistic-Byzantine and the Muslim-oriental civilizations. This connection is apparent in the medieval and later period Georgian manuscripts presented in the general medical, pharmacological or veterinary content monuments, as well as in karbadins, educational-medical and family books. This type of material is accumulated in the depositories of manuscripts of Georgia, as well as in the Georgian manuscript collections preserved abroad. The chronological boundaries of the manuscripts involve 10 centuries.

The systematic scientific study of the medical texts preserved in the Georgian manuscripts began in the 1930s. The works known are by L. Kotetish-

vili [1-3], Iv.Beritashvili [4, 5], M.Saakashvili [6], Il.Abuladze [7], B.Rachvelishvili [8], M.Shengelia [9], R.Shengelia [10], P.Pirpilashvili [11]. In veterinary medicine – studies by L.Leonidze [12] K. Kapanadze [13], K.Jvareshishvili [14]. The recent publications by N. Khelaia [15], D.Kukhianidze [16], L.Samkurashvili [17, 18], L. Shatirishvili [19], T.Abuladze [20,21] are dedicated to certain medical manuscripts and the materials depicting the medical knowledge disseminated in the particular theological compositions. In 2017 the Catalogue of Georgian Medical Manuscripts was published [22].

However, the majority of the medical and veterinary manuscripts have not been studied from the historical perspective of medicine; There is basically no systematic, unified and accessible information available to a wide range of scholars. In addition, with the rare exception, no medication has been made according to the recipes given in the medical manuscripts; The medical knowledge preserved in Georgian manuscript heritage is not fully represented in the curricula of the relevant higher education institutions.

Further research of the manuscripts, their comparative and the multidisciplinary study, searches for parallels and sources are hampered by the lack of a common annotated database of medical manuscripts that would provide baseline data on the Georgian medical manuscripts and their evaluation in terms of medical history.

The medieval Georgian medical manuscripts typologically form the following groups:

- Medical books containing the issues of theoretical and practical medicine, encyclopedic kind of works;
- The materials presented in ecclesiastical literature – in exegetic, homiletic, ascetic, hagiographic works, euchologions;
- The separate works and sections containing medical content included in mixed or thematic compilations (“Chemistry” by Vakhtang VI, collections on precious stones, etc.)
- Small and large karabadins;
- Textbooks;
- Lists of medicines - only lists or lists with descriptions and indications of diseases, sometimes those of curative forms (pills, kursi (tablet), majuni (mixture), jam, powder, balsam, etc.);
- Dictionary material – comprehensive dictionaries including explanatory ones, Latin and / or Oriental matchings; Sometimes add-ons to the existing dictionaries;
- Inscriptions - brief descriptions of diseases, various recipes, etc.
- Later works (mainly those of the nineteenth-century) which are, in fact, the analogues of the modern scientific ones with reference to numerous sources (written - original and translated, folk, physician practitioners’ experience), with added annotations, footnotes, etc.

This group also includes the compositions containing descriptions of any of the diseases with the appropriate diagnoses, treatment methods and remedies.

Veterinary manuscripts create a separate group. The research of the veterinary manuscripts kept in the Georgian and foreign depositories allows us to track over time the domestic animal and bird diseases considered, the illnesses singled out by practicing veterinarians, the medicinal drugs and manipulations tried against the diseases. In the end, there is formed an image of the veterinary medicine development and its clearly cut social role in the society.

Georgian veterinary manuscripts and their distributions in the collections

Various diseases of domestic animals and birds, anti-disease medications, as well as, in part, the methods of their care and breeding exploited by the Georgian people, are presented in the ancient Georgian written veterinary monuments or karabadins. Accordingly, there is a “Horse Karabadin”, a “Bird Karabadin”, a “Falcon Karabadin”, a “Dog Karabadin.” These manuscript compilations provide a rich material on the diseases of domestic animals and birds known in ancient Georgia along with the medicines used to treat them.

Veterinary manuscript books have been found in Georgia since the 17th century. It is feasible that similar compilations existed in earlier centuries, as in this country the knowledge of poultry and domestic animal diseases, their treatment and maintenance were a thing of great importance not only for the elite layers of the society, but for a wider socius as well. However, the number of the preserved karabadins, their translation history or the notes on creating the original sets have been known just since the XIX century (a “Dog Carabadin” written by Ioane Batonishvili (Prince), Q-198 [23].

From the late medieval times the translation of karabadins begins. Vakhtang VI left his indeli-

ble trace on this field. He translated "The Horse" - "this small Karabadin" from Persian into Georgian which, as the manuscript books Q-281 [23] and S-14 [24] announce, had a practical purpose "for young horsemen to get mastery, and for chieftains and herd owners".

The deeds of Vakhtang VI were continued by Ioane and Bagrat Batonishvilis (Princes), Giorgi XII's sons, who made a special mark in the development of the veterinary medicine and considered it necessary to share the knowledge with the Georgians, benefitting the people this way.

Presumably, medical collections were very popular, and therefore, often written and composed, on the hand, they were also frequently damaged, thumbed and torn for their intensive usage. This is the reason why not many of the medical collections have reached us.

The karabadins come up today are mostly without paintings and special decorations. Their embellishments are just the initial letters in cinnabar, ornamented simply. Unfortunately, there are no specimens of medical devices in medical collections, neither in human anatomy.

Instead, European-influenced veterinary karabadins are richly illustrated with medical instruments and animal skeletal imagery, in the analogy to the already discovered and well-known philosophical medical monuments.

Fig 1. *Veterinary manipulation tools with inscriptions. Horse Healing Collection. Translated from French by Bagrat Batonishvili. Autograph. 1817, Petersburg. Kept at Korneli Kekelidze National Center of Manuscripts of Georgia.*

The animal and bird karabadins come from the late medieval times, the number of which is reaching 45. Korneli Kekelidze Georgian National Centre of Manuscripts holds 30 veterinary collections, the remaining 15 are kept in various museums of Georgia and Russia. Six of these 30 manuscripts contain the text of the "Bird Karabadin", 21 manuscripts are the five different works lists dedicated to the horses treatment, two copies contain collections of the same text and present veterinary recipes, and one is a fragment of a "Dog Karabadin" .

Each manuscript has its own origin, adventure and value. They are copied from different originals by the scribes of different literacy background and literary tastes.

There are identified four main groups of manuscript books:

Group I includes horse karabadins, which present the issues of care, treatment and breeding. There are five subgroups marked out:

A) To the first subgroup belongs the oldest H-414 preserved at the National Center of Manuscripts [25]. Written with Nuskhuri it is chronologically the earliest record and its copying dates back to the merge of the first and second halves of the seventeenth century. The text is fragmented, containing 4 pages;

B) Subgroup II contains manuscripts of the same text translated from Persian by Vakhtang VI. The earliest of them is dated with 1763, the latest– with 1874. The extensive edition of this work consists of 114 paragraphs, 43 of which are devoted to zootechnical issues, and 71 - to the veterinary ones.

C) Subgroup III includes a work performed by Ioane Osesdze and ordered by Giorgi Batonishvili (later Giorgi XII). The Karbadin contains 280 paragraphs, 56 of which are devoted to zootechnical issues and 224 - to veterinary ones. According to the colophon, the compiler uses the Armenian language Karabadins and the ones by Vakhtag VI. Thus, the work is a kind of a compilation.

D) Subgroup IV contains texts translated from Russian by Bagrat Batonishvili, which deals with the treatment of horses and cattle. This subgroup combines 5 manuscripts, three of which are autograph manuscripts by Batonishvili. One of them is Q-311 [23] (Fig.1). The manuscript presents two different veterinary works. The first part of the Q-311 is presented at 4r-92v, written in 1817 in Petersburg. The translation is from French, precedeed by a horse picture (3v) (Fig.2). On 5v-6r there are featured veterinary manipulation tools with inscriptions (Fig.1).

E) Subgroup V presents two manuscripts of the "Horse Karbadin": S - 3728 [26] and the manuscript from the Manuscript section of the Russian National Library (St. Petersburg) № 24/20 [27], which deals

with zootechnical and veterinary issues, namely: diseases of the horse skin [scabies], malanders, those of the respiratory tract (cough, breath shortness), digestive system, teeth and gums, etc. In addition, therapeutic and surgical methods used for the treatment of diseases are identified, and medical remedies are indicated.

Group II of the veterinary manuscripts includes a "Dog Karabadin". It is survived as an only manuscript in fragment Q-198 [23]. The fragment of the collection contains six pages, dating with the 18th century. The existing colophon informs us that "it was done by Ioane, the son of the son of the King of Georgia."

Group III contains a "Bird Karbadin". It describes poutry breeding, care and treatment. Most of it is copied in the 17th century. One of the manuscripts (Q-562:2) is led by a physiological introduction [28]. According to Ilia Abuladze, with regard to the linguistic data of the monument, it should be a work of XII-XIII centuries. This setting allows the researchers to think that most of the veterinary manuscripts were created much earlier.

Group IV contains two carabadins with veterinary recipes. The manuscripts consider 117 recipies of the main forms of remedies such as: whey, i.e. extract, ointment, solution, dirt (now: powder), pills, sherbet, etc. The Q-311 veterinary prescription is described in the collection on pages 105r-149r.

Sample of the detailed description of the veterinary manuscript

Within the framework of the project, codicological-textological analysis of the particularly important manuscripts was carried out; A special bulletin scheme was developed to prepare the manuscripts description and their placement in the database.

For illustrative purposes we will present a bulletin containing a description of the veterinary content manuscript - Horse Treatment Collection, Q-311.

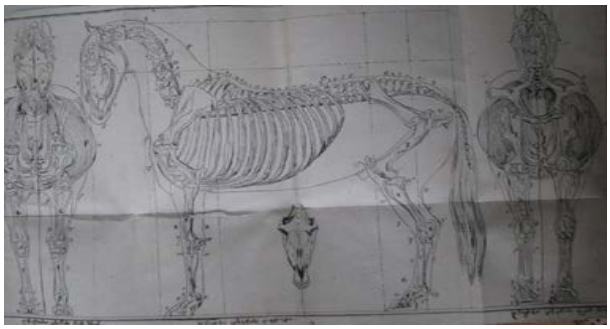

Fig 2. *Horse skeleton. Horse Healing Collection. Translated from French by Bagrat Batonishvili. Autograph. 1817, Petersburg. Kept at the Korneli Kekelidze Georgian National Centre of Manuscripts.*

Table 1. *Georgian Veterinary Manuscripts and the Depositories*

Veterinary Manuscripts kept in the Depositories of Georgia and Abroad

Totally - 45 Manuscripts

Institution	Manuscripts
Kutaisi State	1. №200 2. №220 3. №228 4. №239 5. №243
Sighnaghi Museum of History and Ethnography	1. №721
Telavi Historical Museum	1.№ 2476, 2.№2482
Tbilisi State University Library Funds	1.S-3447
Korneli Kekelidze Georgian National Centre of Manuscripts	1.A-652 16. Q - 198 2.A-671 17. Q - 281 3.A-1127 18. Q - 311 4.A1224 19. Q–562/2 5.S-12 20. Q-1135 6.S-26 21. Q-1187 7.S-225 22. H - 297 8.S-226 23. H - 352 9. S-268 24. H - 414 10.S-325 25. H-956/2 11.S-330 26. H-1255/ბ 12. S-1737 27. H-2156 13. S-2401 28. H-2212 14. S-3467 29. H3260 15. S-3728
National Archive of Georgia	1.№359 2.№619
The National Parliamentary Library of Georgian	1.S-75 2.S-106
National Library of Russia	1.№ 24 (20).
Institute of Oriental Manuscripts (St.Petersburgh)	1.M37 2.C 16

Table 2. *Veterinary Manuscript Bulletin*

Manuscript cipher	Q-311
Place of protection	Korneli Kekelidze Georgian National Centre of Manuscripts
Composition title / Contents	Horses Treatment Compilation
Author / Translator / Compilator	Bagrat Batonishvili (Prince)
Manuscript date	1817
Number of sheets	155
Sizes	19,5 x 15,5
Ink	Black
Handwriting	Mkhedruli
Scribe	The first part of the manuscript is copied by Bagrat Batonishvili. The place of copying: St. Petersburg; The second part scribe: Deacon Bazierov. The place of copying: Moscow.
Owner	-
Manuscript history	-

Ornaments, drawing / graphic drawing /table: horse image - 3v, horse anatomy - 150r

The manuscript consists of two different horse karabadins. Both compositions were translated from Russian by Bagrat Batonishvili, the son of George XIII.

The First Part Colophon „I, Bagrat, the son of the King, translated this karabadin from Russian into Georgian, from different karabadins, the very best and many times tested. I plead those having this karabadin used and read, not to forget me. I have described all- black and white. St. Petersburgh, 1817: 2 May; completed "

The manuscript is preceded by a Zanduki (table of contents) (4r-5r)

For bleeding

Purifying bot caper spurge

For catching cold or running nose of a horse

For a horse fever

For a colic and stretching

For coughing of a horse

For Breath shortness

For a horse tuberculosis ,when a horse is growing thinner and not gaining fat

For giddiness: dizziness, numbness

For sore throat and swollen throat

Eye aching of a horse

For the *makao (Corjza contagiosa eguorum)* a horse disease

For yvatsi of a horse

For worms of a horse

For wounded men and horses

Leaking fluid in a knee or a leg

For swelling of a body and feet

For warts

For Athemak or siraj

For snake biting

For scabies or mange or itching

Enema soluble, great opilation for men and horses

For fever and intense sweating of a horse :

For a horse nose bleeding

Life essence or a life drop

Making opium

For an aching tongue

Horse tail cutting

The medication names in Latin and Georgian;

Horse Treatment, Part II, consists of 117 paragraphs. It refers to the rules for medicine-making. At the end of the second composition there is added a recipe for the "Wounded and Bad Pimple" ointment, written by Bagrati on October 9, 1822.

Part Two Colophon: “This horse treatment book is translated from Russian into Georgian by Bagrati, His Literacy, the son of 13th king of Georgia.”

It has been copied by hand of the sinful priest, deacon Bazierov, in the royal city of Moscow.”

It should be noted that the majority of Georgian veterinary manuscripts, in addition to purely veterinary matters, contain zootechnical issues (compiled and translated by Ioane Osesdze, compilatory work “Horse Karabadin”, H-2156 [29]). It presents the following practical advice for horse breeding and care: for breeding there should be selected a horse with a proper appearance and behavior, thoroughbred; Taking into account the length of the horse pregnancy there is indicated the time of a year when a bull should be let into a herd; Prior to the birth, a skilled and experienced person called “qeshik” should be attached to the pregnant horse. Special tips on bird treatment and care are also provided.

The multidisciplinary study of veterinary manuscripts in terms of the field history and codicology-textology is carried out by the staff of the National Centre of Manuscripts with the direct participation of a veterinary specialist in the frameworks of Shota Rustaveli National Science Foundation funded project “Medical and Veterinary Manuscripts in Depositories of Georgia and abroad”(Grant №HE17-54; 2017-2020).

Conclusion

The article presents the results of a multidisciplinary study of veterinary and zootechnical manuscripts preserved in the depositories of Georgia and abroad (St. Petersburg, Russia): the material listed and grouped by the place of protection; the recent manuscripts; detailed description and evaluation of some outstanding manuscripts on the basis of a special scheme (bulletin).

The results, information and assessments of the study complementing the existing data, are important for the study of veterinary and zootechnical history. It will provide some support to scientific and educational circles interested in the subject.

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Radioactivity in soil samples from the settlements of Tbilisi city (the capital of Georgia)

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ABSTRACT

This study investigated the radioactivity of various types of soil (cinnamonic, cinnamonic calcareous, grey cinnamonic and alluvial calcareous) in suburbs of Tbilisi, Georgia. Soil samples were collected from 11 locations and analyzed using gamma spectrometry. ^{232}Th varied in the range 16.9-34.2 Bq/kg (average 23.8 Bq/kg), ^{238}U – in the range 19.3-50.5 Bq/kg (27.4), and ^{235}U - in the range 0.88-2.3 Bq/kg (1.3). ^{40}K ranged from 291 to 560 Bq/kg (442). Technogenic radionuclide ^{137}Cs was identified in almost all samples and its activity concentration ranged from 3.6 to 27.6 Bq/kg (12.7). Some activity ratios were calculated: ^{238}U/^{235}U, ^{238}U/^{232}Th, ^{226}Ra/^{238}U and ^{210}Pb/^{226}Ra. The radium equivalent activity ranged from 66.1 to 136 Bq/kg (88.7). Annual effective gamma-dose rate varied in the range 0.046-0.083 mSv/y (0.056). Some features of radionuclide distribution are noted, and a comparison was carried out with existing data from the literary.

Keywords: Radioactivity, Gamma spectrometry, Radium equivalent, Gamma-dose, Natural radioactivity, Technogenic radioactivity.

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Introduction

The natural and technogenic radioactivity of soil is one of the main components of the radioactive background of the Earth. Numerous studies have shown that this radioactivity differs considerably in various areas of the globe, ranging from single units up to hundreds of Bq/kg.

Many studies also take into account the activity ratios of various radionuclides, in particular, ^{238}U/^{235}U, ^{238}U/^{232}Th, ^{226}Ra/^{238}U and ^{210}Pb/^{226}Ra as these help understand the various geochemical processes taking place in the rocks and soils [1-4]. Such researches are important for each region.

Soil of various types were studied in different countries [5-9]. Activity concentration of different naturally occurring radionuclides were investigated in these studies. Various activity ratios of the radionuclides were computed by the obtained results.

Here there are presented results of research on the radioactivity of samples of soil collected from 11 locations in the peripheral part of the largest city of Georgia, Tbilisi, and also from 4 locations in the suburbs of the nearby city of Mtskheta.

Materials and Methods

Study area. The territory of Tbilisi is characterized by a complex soil-geological structure. It occupies the eastern end of the Adzharia-Trialeti mountain system and is situated in the territory (Tr) of so-called Tbilisi artesian basin (**I**) – a water pressure system of fissure and fissure-karst waters. Some characteristics of surface waters in this territory, in particular, radon content, have been investigated previously [10], but the radioactivity of soil structures in this area has not been studied. For comparison soil samples from a nearby territory

(approximately 15-20 km to the north of Tbilisi, in the territory of the Kartli artesian basin (**II**) were also studied. Interstitial, fissure and fissure-karst waters can also be found in this basin.

26 samples were collected in territory **I** from 11 locations (2-3 samples per location) near various settlements and sites – Tskneti (Ts), Kojori (Kj), Lilo (Ll), Zahesi (Zh), Avchala (Av), Betania (Bt), Lisi (Ls), and Sololaki (Sl), and 9 samples were collected in territory **II** from 4 locations – settlements Natakhtari (Nt), Misaktsieli (Ms), Bulachauri (Bl), and Bodorna (Bd), in particular, in territory **I**: alluvial calcareous (Al-Cr) – 6 samples; cinnamonic calcareous (Cn-Cr) – 9 samples; cinnamonic (Cn) – 8 samples; grey cinnamonic (GC) – 3 samples; in territory **II**: alluvial calcareous (Al-Cr) – 9 samples (Fig., Table 1).

Sampling. Samples were collected from a deep 0.2-0.4 m. After drying in laboratory conditions samples were ground and dried at 105-110^{0}C, and then sealed in Marinelli beaker and stored for more than 4 weeks.

Measurement of gamma radiation activity. Measurements were carried out using gamma spectrometer Canberra GC2020 with semi-conductor germanium detector with relative efficiency 24%. Gamma spectra acquisition time was 72 h. For the analysis it was used software Genie-2000. There were determined ^{238}U (^{234}Th), ^{226}Ra, ^{214}Pb and ^{214}Bi, ^{210}Pb, ^{235}U, the main radionuclides of ^{232}Th family and others (^{7}Be, ^{40}K, ^{137}Cs). Some geochemical ratios were also determined, in particular, the activity ratios ^{238}U/^{232}Th, ^{226}Ra/^{238}U and ^{210}Pb/^{226}Ra. More detailed description is given in the work [11]. After activity determination for each sample their averaging for each location was carried out.

Assessment of radium equivalent activity Ra_{eq} (Bq/kg), absorbed dose rate *D* (nGy/h) and annual effective dose equivalent AEDE (mSv/y) was carried out according to widely-used formulas [12].

Results

Up to 22 radionuclides were identified: in detail, ^{232}Th family – ^{228}Ac, ^{228}Th, ^{224}Ra, ^{212}Pb, ^{212}Bi, ^{208}Tl (six radionuclides), ^{238}U family – ^{234}Th, ^{234}Pa, ^{230}Th, ^{226}Ra, ^{214}Pb, ^{214}Bi, ^{210}Pb (seven radionuclides), ^{235}U family – ^{235}U, ^{231}Th, ^{227}Th, ^{223}Ra, ^{219}Rn, ^{211}Pb (six radionuclides), and the individual radionuclides ^{7}Be and ^{40}K and the technogenic radionuclide ^{137}Cs.

Tables 2–3 present a number of radionuclide parameters: activity concentration (A), radium equivalent activity (Ra_{eq}), activity ratios of radionuclides ^{238}U/^{235}U, ^{238}U/^{232}Th, ^{226}Ra/^{238}U, ^{210}Pb/^{226}Ra, absorbed dose rate (*D*), annual effective dose equivalent (AEDE), and generalized data – average (av), minimal (mn) and maximal (mx) values – of activity concentration for study samples.

General characteristics. The activity of radionuclides of families varied over a relatively short range: ^{232}Th – from 16.9 to 34.2 Bq/kg (average 23.8 Bq/kg); ^{238}U – from 19.3 to 50.5 Bq/kg (27.4);

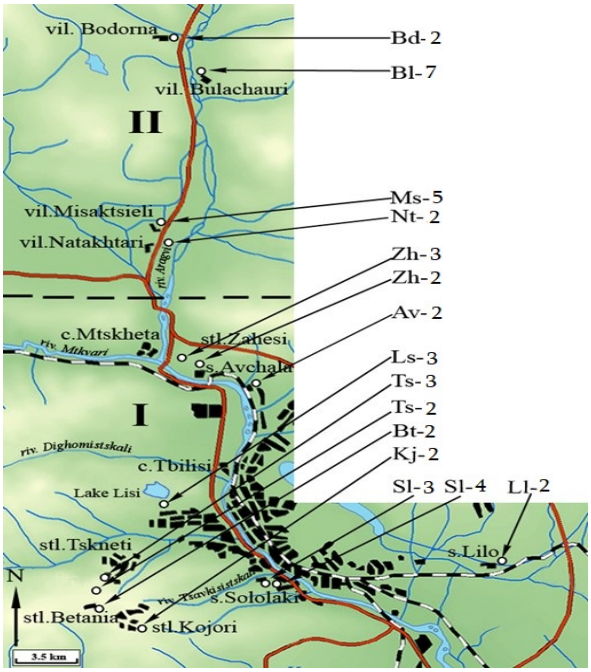

Fig 1. *Objects for investigation*

Table 1. *List of locations (L) and sample types (ST)*

#	Tr	L	Lt(N)[1]; Ln(E)[2]	ST
1	**I**	Ll-2	41.69241; 44.98823	GC
2	-"-	Sl-4	41.68834; 44.79035	Cn-Cr
3	-"-	Sl-3	41.68830; 44.79018	Cn-Cr
4	-"-	Kj-2	41.66133; 44.70335	Cn
5	-"-	Bt-2	41.66809; 44.65187	Cn
6	-"-	Ts-2	41.68028; 44.69153	Cn-Cr
7	-"-	Ts-3	41.68052; 44.69327	Cn-Cr
8	-"-	Ls-3	41.73970; 44.74306	Cn-Cr
9	-"-	Av-2	41.81945; 44.78584	Al-Cr
10	-"-	Zh-2	41.82641; 44.75507	Al-Cr
11	-"-	Zh-3	41.82860; 44.74047	Al-Cr
12	**II**	Nt-2	42.92344; 44.73327	Al-Cr
13	-"-	Ms-5	41.94054; 44.73627	Al-Cr
14	-"-	Bl-7	42.00925; 44.75929	Al-Cr
15	-"-	Bd-2	42.05653; 44.74404	Al-Cr

[1]Lt(N) – latitude (north); [2]Ln(E) – longitude (east).

^{235}U – from 0.88 to 2.3 Bq/kg (1.3) – more than 10 times less in comparison with ^{232}Th and ^{238}U; equivalent activity varied from 66.1 to 136 Bq/kg (88.7).

Note: sample Sl-3 showed relatively high activity (it was collected from a mountain slope) which considerably exceeded (more than half as much again) the activity of sample Sl-4, which was collected from a nearby point, as well as other samples.

Be was observed only in one sample (Kj-2); in other samples values were less than Minimal Detectable Activity (MA) or it was not measured. Activity of ^{40}K was the highest among all radionuclides – from 291 to 560 Bq/kg (442). Technogenic radionuclide ^{137}Cs was measured in almost all samples – from 3.6 to 27.6 Bqkg (12.7). All calculated values of the ^{238}U/^{235}U ratio corresponded (within 10%) to 21.7 (accepted for natural objects). Activities ratio ^{238}U/^{232}Th deviated (more than ±10%) from the average value of 0.81 (for closed systems) basically towards higher values (maximal value of 1.77 for sample Sl-4). For ^{226}Ra/^{238}U ratio appreciable (more than ±10%) prevalence of the daughter product was observed in five samples (Zh-2, Ts-2, Kj-2, Sl-3 and Ll-2), and that of the parent radionuclide in three samples (Ls-3, Bt-2 and Bl-7). For ^{210}Pb/^{226}Ra ratio six samples (Ls-3, Bt-2, Kj-2, Nt-2, Bl-7, Bd-2) showed appreciable prevalence (more than ±20% - the range of limits is expanded because the determination error of Pb-210 reached up to 20%) of the daughter product (the highest value was 2.47); one sample (Sl-3) showed prevalence of the parent radionuclide. The highest values of Ra_{eq}, *D* and AEDE were recorded in the sample collected from location Sl-3, and the least in the sample collected from location Ls-3.

Dependence on the type. The results showed no appreciable dependence on soil type (Table 3). The highest values of Ra_{eq} in territory **I** were found in samples of type Al-Cr – average value of 93.5 Bq/kg (which is sufficiently close to the average value of 95.1 Bq/kg for the samples of the same type in territory **II**); lower values were found for samples of type Cn-Cr (88.0 Bq/kg) and the lowest values were observed for soils of types Cn and GC (75.2 and 79.5 Bq/kg). There was a different picture for the ^{238}U/^{232}Th ratio: almost all samples from territory **I** had a ratio that considerably exceeded the average ratio of 0.81 while soil from territory **II** had a similar ratio to the average. The ^{226}Ra/^{238}U ratio exceeded a little equilibrium value in Al-Cr and GC soils and it was similar to this value in Cn-Cr and Cn soils in territory **I** and in Al-Cr soil in territory **II.** The ^{210}Pb/^{226}Ra ratio was close to the equilibrium value in Al-Cr, Cn-Cr and GC soils and exceeded the equilibrium value in Cn-Cr soil in territory **I** and in Al-Cr soil in territory **II.**

Radiological parameters. The minimal and maximal values of annual effective dose differed between points almost two fold, ranging from 46 to 83 μSv/y (Table 3). The lowest average values (46 μSv/y) were observed for soils of type GC, and the highest (59 μSv/y) for soils of type Al-Cr.

Table 2. *Some main radionuclides parameters of studied soil samples (designations are in the text)*

#	Tr	ST	L	^{232}Th	^{238}U	^{226}Ra	^{210}Pb	^{235}U	^{7}Be	^{40}K	^{137}Cs	Ra_{eq}	^{238}U/^{235}U	^{238}U/^{232}Th	^{226}Ra/^{238}U	^{210}Pb/^{226}Ra	D, nGy/h	AEDE, μSv/y
1	I	Al-Cr	Av-2	19.8	27.6	27.3	33.2	1.3	—	540	<M	89.5	21.3	1.40	0.99	1.22	47.2	58.1
2		-"-	Zh-2	28.8	21.3	31.1	26.9	0.99	-	521	12.2	98.2	21.5	0.74	1.57	0.87	48.9	60.2
3		-"-	Zh-3	22.8	35.3	36.4	29.7	1.6	-	456	20.5	92.9	21.6	1.55	1.03	0.82	49.1	60.4
4		Cn-Cr	Ls-3	16.9	26.4	14.0	27.2	1.2	—	354	9.3	66.1	21.3	1.56	0.53	1.94	37.1	45.7
5		Cn	Bt-2	21.7	24.4	19.8	28.4	1.1	-	425	5.8	78.4	21.7	1.12	0.84	1.42	42.1	51.7
6		Cn-Cr	Ts-2	19.6	19.3	27.3	29.3	0.88	—	403	22.8	73.7	21.8	0.98	1.42	1.07	37.5	46.2
7		-"-	Ts-3	20.4	28.9	25.1	25.7	1.3	-	469	10.0	83.6	21.4	1.41	0.88	1.01	45.3	55.7
8		Cn	Kj-2	17.6	21.9	27.3	46.3	1.02	6.1	418	27.6	71.9	21.6	1.24	1.32	1.71	38.1	46.8
9		Cn-Cr	Sl-3	34.2	50.5	60.9	41.1	2.3	—	559	3.6	136	21.9	1.48	1.21	0.67	67.3	82.8
10		-"-	Sl-4	18.7	33.1	30.9	<M	1.6	<MA	291	<MA	80.3	21.0	1.77	0.93	-	38.8	47.7
11		GC	Ll-2	19.3	25.6	42.2	37.0	1.2	-	345	14.9	79.5	21.5	1.32	1.66	0.98	37.8	46.5
1	II	Al-Cr	Nt-2	33.9	25.5	27.8	24.0	1.2	-	560	14.4	111	21.5	0.75	0.90	1.32	55.6	68.4
2		-"-	Ms-5	31.6	27.0	23.8	26.2	1.2	-	460	5.8	100	22.0	0.87	0.90	1.12	50.7	62.4
3		-"-	Bl-7	23.4	22.2	19.0	46.9	1.03	<MA	370	8.1	77.2	21.5	0.95	0.86	2.47	39.8	48.9
4		-"-	Bd-2	28.5	22.9	25.1	56.6	1.1	-	453	9.6	92.5	21.7	0.81	1.10	2.37	46.7	57.4
			av	*23.8*	*27.4*	*29.2*	*34.2*	*1.3*	*6.1*	*442*	*12.7*	*88.7*	*21.5*	*1.20*	*1.08*	*1.36*	*45.5*	*55.9*
			mn	*16.9*	*19.3*	*14.0*	*24.0*	*0.88*	-	*291*	*3.6*	*66.1*	*21.0*	*0.74*	*0.53*	*0.67*	*37.1*	*45.7*
			mx	*34.2*	*50.5*	*60.9*	*56.6*	*2.3*	-	*560*	*27.6*	*136*	*22.0*	*1.77*	*1.66*	*2.47*	*67.3*	*82.8*

Table 3. *Generalized data for some parameters depending on soil type (designations are in the text)*

#	Tr	ST	Ra_{eq}			$^{238}U/^{232}Th$			$^{226}Ra/^{238}U$			$^{210}Pb/^{226}Ra$			D, nGy/h			AEDE, μSv/y		
			av	*mn*	*mx*	*av*	*mn*	*mx*	*av*	*mn*	*mx*	*av*	*mn*	*mx*	*av*	*mn*	*mx*	*av*	*mn*	*mx*
1	I	Al-Cr	93.5	89.5	98.2	1.23	0.74	1.55	1.20	0.99	1.57	0.97	0.82	1.22	48.4	47.2	49.1	59.5	58.1	60.4
2		Cn-Cr	88.0	66.1	136	1.44	0.98	1.77	0.99	0.53	1.42	1.17	0.67	1.94	45.2	37.1	67.3	55.6	45.7	82.8
3		Cn	75.2	71.9	78.4	1.18	1.12	1.24	1.08	0.84	1.32	1.56	1.42	1.71	40.1	38.1	42.1	49.3	46.8	51.7
4		GC	79.5	-	-	1.32	-	-	1.66	-	-	0.98	-	-	37.8	-	-	46.5	-	-
5	II	Al-Cr	95.1	77.2	111	0.84	0.75	0.95	0.94	0.86	1.10	1.82	1.12	2.47	48.2	39.8	55.6	59.3	48.9	68.4

Discussion

All identified radionuclides, with exception of 137Cs, are naturally occurring. They are characteristic for the region of East Georgia, in particular, for soil in the strip along the river Mtkvari [13].

The content and concentration of naturally occurring radionuclides identified in the samples in general corresponded to those usually observed in various soils [2]. The high activity recorded in sample Sl-3 might reflect the influence of shallow-lying rocks at the locations. The possible migration of their microparticles and mixing with the soil layer could cause hyperactivity in soil collected from this site.

The observed peculiarities of the activity ratios, in particular, the dominance of heightened values of 238U/232Th ratio may be connected with various geochemical processes. So, for example, in works [2,3] it is stated that behavior of Th and U isotopes in aqueous medium considerable differs from each other because of their different solubility, that can cause in some cases appreciable deviations of their ratio from the average value. As noted above the investigated region is characterized by a complex hydrogeological structure. During the circulation of underground waters dissolution of uranium in deep-lying rocks and its carryover into the soil formations located above could cause their enrichment by 238U. The similar picture can take place for Ra too, which is easily leached and washed away by water. This circumstance in view of the other geochemical factors can lead to appreciable variations of the 226Ra/238U ratio causing deviations to a greater or lesser extent from the average and equilibrium values.

The observed differences in concentrations of radionuclide families in samples of various soils in territory I could be connected with the formation conditions of the genetic soil types. The difference in 238U/232Th ratio (and also, to a certain extent, the 226Ra/238U ratio) in territories I and II, appears to be connected with the hydrological processes.

A prominent feature recorded in the majority of samples was the high 210Pb/226Ra ratio – in marked excess of the equilibrium activity value. In previous studies this has been connected with excess 210Pb precipitation from the atmosphere. However, given the complex geological-tectonic structure of the investigated region it is possible that the release of radioactive radon gas from deep layers of rocks and soil could be the cause. This process can lead to the occurrence of a “nonequilibrium” concentration of 210Pb (so-called “allochthonous” 210Pb [14].

Radionuclide 7Be, which is formed in the upper atmosphere as a result of interaction with space radiation and then combines with deposits in the soil, was detected in only one sample. Its absence from the other samples could be associated with the long period of samples storage that could have led to a reduction in concentration to values below MA.

The distribution of radionuclide 40K was similar to values observed in the work [13].

Data for the technogenic radionuclide 137Cs are of special interest. Usually its presence is connected with the Chernobyl accident (1986). For the last period the activity of 137Cs has considerably decreased, due to washing away processes or migration into deeper layers that can provoke the big variations of its activity in samples collected in different locations.

It is also interesting that the value of radium equivalent activity, which varied from 48.6 to 93.1 Bq/kg, was below the recommended limiting value of 370 Bq/kg, while the annual effective dose (29-56 μSv/y) was below limiting value of 1 mSv/y [15-17].

Finally, the results represent doubtless scientific and applied interest in the investigated region, confirming the need for such studies, which should be carried out on a regular basis.

Acknowledgement

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Numerical investigation of meso- and microscale diffusion of Tbilisi dust

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ABSTRACT

Meso- and micro-scale processes of dust propagation in the atmosphere of the city of Tbilisi and its surrounding territory are modelled using 3D regional model of atmospheric processes and an admixture transfer-diffusion equation. Terrain-following coordinate system is used with the purpose of taking into account the impact of very complicated relief on the atmosphere pollution process. It is obtained via modelling that meso-scale propagation of the dust substantially depends on relief form of surrounding territory, background wind speed and its direction. In the second half of the day the mountain-and valley circulation process due to Tbilisi region relief in conditions of background light air causes a change of dust transfer direction in the lower 100m surface layer. The dust dissipated from Tbilisi city in the atmosphere is basically concentrated in lower 600 m of the boundary layer and it is propagated in the narrow zone with length about more than 80 km and width 20-24 km. Modelling of dust micro-scale diffusion process in Tbilisi city shows that the maximum concentrations 1.5-2.0 MAC are obtained from 3.00 p.m.to 9.00 p.m. in vicinity of central avenues and in the southern part of the city. The spatial dust distribution in the lower part of the atmospheric surface layer depends on vehicle traffic intensity, as well as on spatial distribution of highways, and micro-orography of the city and surrounding territories.

Keywords: Atmosphere, Pollution, Dust, Meso-scale, Micro-scale, Numerical Modelling.

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1. INTRODUCTION

In big cities and industrial centers, the human health significantly depends on the atmosphere air purity level [1,2]. According to the World Health Organization “worldwide, ambient air pollution contributes to 7.6% of all deaths in 2016” [3]. Respectively, study of environmental objects pollution and its abatement is very important ecological and human task for healthcare. This problem is especially urgent for industrial centers and big cities that are featured by abundance of pollution sources. Tbilisi – an administrative center of Georgia and one of the biggest cities of the South Caucasus is no exception. Though, Tbilisi is not ranked among the world 500 most polluted cities [4], but according to the data of the Ministry of Environmental Protection and Agriculture of Georgia, dust and microparticle concentrations frequently excess the maximum permissible levels [5]. Tbilisi is the main junction point of Great Silk road connecting Europe and Asia, and it connects Russia with Asia Minor as well. Thousands of heavy and light vehicles move everyday through it. Hundreds of thousands of cars drive on its narrow and compound shaped streets. Microparticles excretion from cars, dust emission from enterprises, pavement surfaces and other objects is the main source of the city pollution. Dust entering the atmosphere under action of variable dynamic fields formed due to complex terrain extends over the city, cultural and recreational zones located at surrounding territories and causes atmospheric air pollution and human health deterioration.

Currently, atmospheric air pollution studies using field measurements [6, 7] mathematical diagnostic and prognostic models [8-14] are carried out for many cities of the world.
In the presented article, for the first time the dust propagation kinematics in the atmosphere of Tbilisi and its surrounding territories will be studied. For these purposes a numerical model of mesoscale and local atmospheric processes in the Caucasus is used [13, 14].

2. STATEMENT OF THE PROBLEM

2.1 Mathematical statement of problem

Tbilisi has a complex terrain. From three sides it is confined by the Greater and Smaller Caucasus Mountain Ranges, while from the south-east side – by lowland. Terrain height in the city and surrounding territories varies from 300 m to 2 km (above sea level). In the city some of the small mountains and valley are located. Therefore, for correct description of the spatial-temporary evolution of the hydrometeorological fields and concentrations of polluting substance in the atmosphere over the complex terrain territory the following system of equations written in the terrain-following coordinate system is used [8]:

(a) For atmosphere:

$$\frac{du}{dt} = -\frac{\overline{P}}{\rho}\frac{\partial \varphi}{\partial x} + lv + g(1+0.61q)\vartheta\frac{\partial z}{\partial x} + \frac{\partial}{\partial x}\mu\frac{\partial u}{\partial x} + \frac{\partial}{\partial y}\mu\frac{\partial u}{\partial y} + \frac{1}{\rho h^2}\frac{\partial}{\partial \zeta}\rho\nu\frac{\partial u}{\partial \zeta},$$

$$\frac{dv}{dt} = -\frac{\overline{P}}{\rho}\frac{\partial \varphi}{\partial y} - lu + g(1+0.61q)\vartheta\frac{\partial z}{\partial y} + \frac{\partial}{\partial x}\mu\frac{\partial v}{\partial x} + \frac{\partial}{\partial y}\mu\frac{\partial v}{\partial y} + \frac{1}{\rho h^2}\frac{\partial}{\partial \zeta}\rho\nu\frac{\partial v}{\partial \zeta},$$

$$\frac{\partial \varphi}{\partial \zeta} = \frac{g}{R\overline{T}}(1+0.61q)\vartheta h,$$

$$\frac{\partial h}{\partial t} + \frac{\partial uh}{\partial x} + \frac{\partial vh}{\partial y} + \frac{\partial \tilde{w}h}{\partial \zeta} + \frac{1}{\rho}\frac{d\rho}{dz}wh = 0, \qquad (1)$$

$$\frac{\partial \vartheta}{\partial t} + u\frac{\partial \vartheta}{\partial x} + v\frac{\partial \vartheta}{\partial y} + \tilde{w}\frac{\partial \vartheta}{\partial \zeta} + Sw = \frac{\partial}{\partial x}\mu\frac{\partial \vartheta}{\partial x} + \frac{\partial}{\partial y}\mu\frac{\partial \vartheta}{\partial y} + \frac{1}{\rho h^2}\frac{\partial}{\partial \zeta}\rho\nu\frac{\partial \vartheta}{\partial \zeta} + \frac{L}{\rho C_p}\phi_{con},$$

$$\frac{\partial q}{\partial t} + u\frac{\partial q}{\partial x} + v\frac{\partial q}{\partial y} + \tilde{w}\frac{\partial q}{\partial \zeta} = \frac{\partial}{\partial x}\mu\frac{\partial q}{\partial x} + \frac{\partial}{\partial y}\mu\frac{\partial q}{\partial y} + \frac{1}{h^2}\frac{\partial}{\partial \zeta}\nu\frac{\partial q}{\partial \zeta} - \varphi_{con},$$

$$\frac{\partial m}{\partial t} + u\frac{\partial m}{\partial x} + v\frac{\partial m}{\partial y} + \tilde{w}\frac{\partial m}{\partial \zeta} = \frac{\partial}{\partial x}\mu\frac{\partial m}{\partial x} + \frac{\partial}{\partial y}\mu\frac{\partial m}{\partial y} + \frac{\partial}{h^2\partial \zeta}\nu\frac{\partial m}{\partial \zeta} + \varphi_{con},$$

$$\frac{d}{dt} = \frac{\partial}{\partial t} + u\frac{\partial}{\partial x} + v\frac{\partial}{\partial y} + \tilde{w}\frac{\partial}{\partial \zeta}, \qquad w = \frac{\partial z}{\partial t} + u\frac{\partial z}{\partial x} + v\frac{\partial z}{\partial y} + \tilde{w}h.$$

(b) For active soil layer:

$$\frac{\partial C}{\partial t} = \frac{\partial}{\partial z}D(C)\frac{\partial C}{\partial z} - \frac{\partial E(C)}{\partial z}, \quad \frac{\partial T_{soil}}{\partial t} = K_{soil}\frac{\partial^2 T_{soil}}{\partial z^2}, \quad \text{at} \quad \delta_0 > z > Z_{soil}; \qquad (2)$$

where t is time; x, y and z are the axes of the Cartesian coordinate directed to the east, north and vertically upwards, respectively; $\zeta = (z-\delta)/h$ is the dimensionless vertical coordinate; $\delta(x, y)$ is the height of the relief; $h = H - \delta$; $H(t, x, y)$ is the height of the tropopause, which height is changed around 9 km; u, v, w and $\tilde{w}$ are the wind velocity components along the axes x, y, z and ζ, respectively; $\vartheta = (T' + \overline{\overline{T}})/\overline{T}$, and $\varphi = (P' + \overline{\overline{P}})/\overline{P}$ are the analogues of temperature and pressure, respectively; $\overline{T} = 300K$; T' and P' are the deviations of temperature and pressure from the standard vertical distributions $P'(t,x,y,z) = P(t,x,y,z) - \overline{P}(z) - \overline{\overline{P}}(t,x,y,z)$; $T' = T(t,x,y,z) - \overline{T} + \gamma z - \overline{\overline{T}}(t,x,y,z)$; T and P are the temperature and pressure of the atmosphere, respectively: $\overline{T} - \gamma z$ and $\overline{P}(z)$ are the standard vertical distributions of the temperature and pressure, respectively; γ is the standard vertical temperature gradient; $\overline{\overline{T}}$ and $\overline{\overline{P}}$ are the background deviations of the temperature and pressure from standard vertical distributions; T_{soil} is the soil temperature; q and m the mass content of the water vapor and cloud water; C is the volume content of soil water; $\rho(z)$ is the standard vertical distribution of the density

of dry air; *g* is the gravitational acceleration; R is the universal gas constant for dry air; C_p is the specific heat capacity of dry air at constant pressure; *S* is the thermal stability parameter; L is the latent heat of condensation; ϕ_{con} is the condensation rate; D is the diffusion coefficient of water in soil; E is the filtration coefficient of water in a soil; K_{soil} is the thermal diffusivity coefficients of soil;

$$\mu = \Delta x \Delta y \sqrt{2\left(\frac{\partial u}{\partial x}\right)^2 + \left(\frac{\partial u}{\partial y} + \frac{\partial v}{\partial x}\right)^2 + 2\left(\frac{\partial v}{\partial y}\right)^2} \quad \text{and} \quad \nu = (0.05\Delta z)^2 \sqrt{\left(\frac{\partial u}{\partial z}\right)^2 + \left(\frac{\partial v}{\partial z}\right)^2 - \frac{g}{\rho}\frac{\partial \rho}{\partial z}}$$

are the horizontal and vertical turbulent diffusion coefficients, respectively [15, 16]. Where Δx, Δy and Δz are the numerical grid steps along the axes x, y, and z, respectively.

For the meteorological fields in the surface layer of atmosphere with thickness of 100 m there is used a parameterization method [17]:

$$\frac{\partial|\vec{u}|}{\partial z} = \frac{u_*}{\chi z}\varphi_u(\varsigma),\ \frac{\partial p}{\partial z} = \frac{p_*}{z}\varphi_\vartheta(\varsigma),\ (p = \vartheta, q),\ \varsigma = \frac{z}{L},\ L = \frac{u_*^2}{\lambda\chi^2\vartheta_*^2}, \tag{3}$$

$$|\vec{u}| = \frac{u_*}{\chi} f_u(\varsigma, \varsigma_u),\ p - p_0 = p_* f_\vartheta(\varsigma, \varsigma_0),\ \varsigma_u = \frac{z_u}{L},\ \varsigma_0 = \frac{z_0}{L},\ \text{if}\quad z \le z_{sur},$$

where z_u – is the roughness; z_ϑ –parameter, which depends on properties of underlying surface and is a known function; z_{sur} and z_0 – known constants; u_* –friction velocity; λ and χ – buoyancy parameter and von Kármán constant; $\varphi_u(\varsigma)$, $\varphi_\vartheta(\varsigma)$, $f_u(\varsigma, \varsigma_u)$ and $f_\vartheta(\varsigma, \varsigma_0)$ are the universal functions of similarity theory.

To describe the diffusion of contaminant in the atmospheric surface layer and in the free atmosphere, the following equation is used

$$\frac{\partial\, Con}{\partial t} + u\frac{\partial\, Con}{\partial x} + v\frac{\partial\, Con}{\partial y} + (\tilde{w} - \frac{W_{sed}}{h})\frac{\partial\, Con}{\partial \varsigma} = \frac{\partial}{\partial x}\mu\frac{\partial Con}{\partial x} + \frac{\partial}{\partial y}\mu\frac{\partial Con}{\partial y} + \frac{1}{h^2}\frac{\partial}{\partial \varsigma}\nu\frac{\partial\, Con}{\partial \varsigma} + \sigma Con\ , \tag{4}$$

where Con is the dust concentration; W_{sed} is an aerosol deposition velocity; σ is parameter of emission of the dust.

Equation systems (1- 4) are solved numerically using initial and boundary conditions, which are selected according to the specific task. Numerical integration of first five equations of (1) is made using scheme [18], the fifth, sixth and seventh equations of (1) and (4) - with the use of Crank-Nicolson scheme and splitting method [8], equations (2) – with the use of Crank-Nicolson scheme, (3) are solved according to method given in [17].

2.2 Conditions of modelling

The two tasks are considered in frame of this work: 1. the mesoscale transfer of Tbilisi city dust; 2. local distribution and temporary variation of the dust in the city emitted into the atmosphere from vehicle traffic. The background hydrometeorological fields, parameters, boundary and initial conditions of the tasks are chosen so, that were possible to simulate the meteorological situation in case of the background stationary light air in June. The background wind speed grows linearly from 1m/s on z = 2 m to 20 m/s on z = 9 km.

In the first task the mesoscale transfer of the dust is simulated in the rectangular domain using calculated grid having $118 \times 90 \times 31$ points with horizontal step 2 km. The concentration Con = 0.59 mg/m^3 is taken as the initial and boundary values at the height of 2 m from the earth surface in the atmosphere of the city [5]. Out of the city the initial concentration of the dust is equal to zero.

In the second task on modelling of the microscale dust distribution process, calculated grid has 103x61x31 points with steps 300 m and 400 m along axes x and y, respectively. The initial dust concentration on the

height 2 m in the populated area is equal to 0.1 mg/m^3, in the unpopulated area – 0. The initial and boundary conditions for the dust concentrations are determined using observational data. It was found that there is almost an linear dependence of dust concentration on the intensity of car traffic. It was also found that in the vicinity of the central motorways and streets, where intesity of car motion is about 1000 cars per hour, the dust concentration is approximately equal to 0.8-1.3 MAC.

In the both tasks 30 levels were taken vertically in the free atmosphere and 16 levels in the surface layer. The time steps were equal to 5 c and 1 c in the first and second tasks, respectively. Calculations were made for the period 72 h.

3 RESULTS OF MODELLING

3.1 Mesoscale transfer of dust

In Fig. 1 there are shown the field of dust concentration and wind velocity over Tbilisi Region for t = 12 and 24 h, at the 2, 100 and 600 m height above the ground surface obtained in case of the background stationary eastern light air. It is seen from Fig. 1 that at t = 12 h under action of the relief a change of directions of the local wind and of transfer of dust in the atmospheric boundary layer take place. Dust is predominantly distributed in north-west direction over the Kartli plain along the Mtkvari River. Pollution cloud has of ellipsoid-shaped form. On 2 m height a dust concentration 0.01-1 Maximum Allowable Concentration (MAC) is obtained at 10 km distance from the city, on 100 m height – at 15-18 km and on 600 m altitude – at 40 km distance.

Distribution of the dust concentration obtained through calculations and analysis of values of corresponding members of equations (4) shows that in the atmospheric surface layer the turbulent diffusion of dust is dominant. Above 100 m an advective transfer of dust grows and on the height 600 m and up from earth surface it becomes predominant. Analysis also shows that at t = 24 h, a local circulation related to daily temperature regime causes wind velocity vertical distribution change in the atmospheric boundary layer. During the evening and night-time, a convective ascension of warm air masses generated in the vicinity of Tbilisi takes place. Ascending warm stream is replaced further by the air cooled during night-time at surrounding mountain slopes. A formed mountain-and-valley circulation along with the local relief form generates north-west wind in 200 m lower atmospheric layer. Described thermodynamic processes lead to dust distribution direction change. In 200 m surface layer the dust is propagated in the direction opposite to background wind along the Mtkvari River valley over the Jeiran plain. Terrain impact on local circulation is gradually reduced with grows of height and in 600-1500 m layer of air the dust is transferred to the west – in the direction of background wind as a 16 km width narrow band. At 2 m height from the earth surface 0.01-1 MAC and 0.01-0.001 MAC concentrations are obtained in 6-10 km, and 20-24 km bands adjacent to city, respectively. In 100 m surface layer of the atmosphere an intensive vertical diffusive dust transfer influenced by vertical turbulence takes place and a dust pollution cloud with 0.1-1 MAC is obtained in the roughly 20 km length ellipsoid-shaped area above the city.

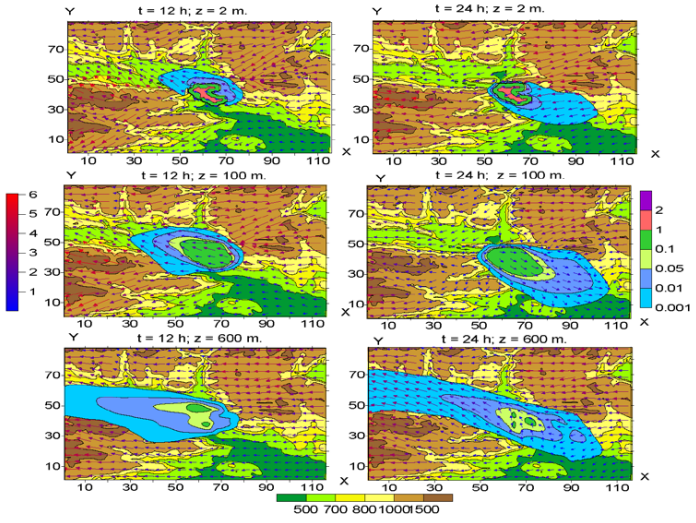
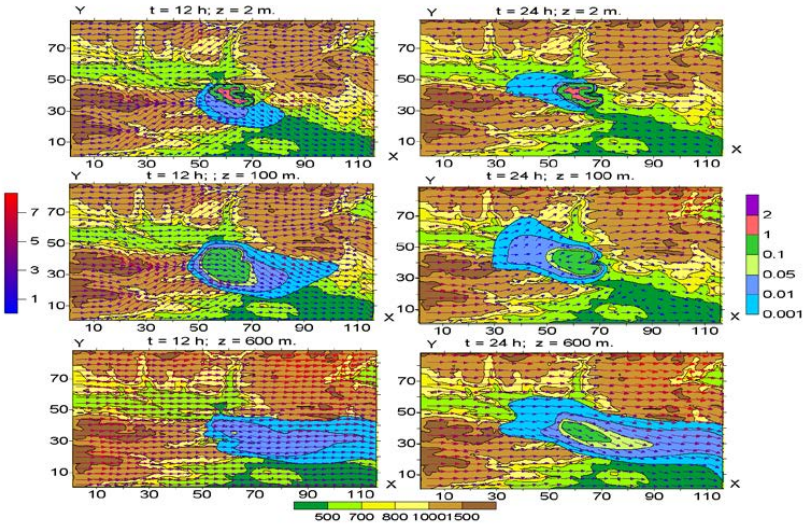


Fig 1. *Terrain height (in m), dust concentration (in MAC) and wind velocity (in m/s) fields at 2, 100 and 600 m height from earth surface in case of background eastern light air, when t =12 and 24 h.*

Throughout the following 24 hours dust diffusion process is repeated quasi periodically, and dust transfer direction in the surface layer of the atmosphere alters from south-east to north-west direction during that time. Dust transfer in the upper part of the surface layer occurs to the west – in the direction of background wind. In case of weak background western wind (Fig. 2), by 12:00, a dust is mainly propagated in the direction of local wind that is formed in the vicinity of Tbilisi - in south and south-east directions. When t = 24 h, dust spreading direction in the surface layer of the atmosphere (z < 100 m) alters. Change in dust transfer direction is related to daily variation of dynamical and thermal meteorological fields in the surface layer of the atmosphere and occurrence of local vertical vortex. Above the surface layer of the atmosphere, wind velocity increases and dust propagation process is getting more intense. As a result, at the height of z = 600 m, 0.01 MAC concentration is obtained in a rectangular-shaped band with 40 km width and more than 100 km length.



3.2 Microscale transfer of dust

For study the micro-scale mechanism of the dust propagation in city the calculations in the 30.6 km x 24.0 km area are made. Tbilisi is located in the center of this area. In Fig. 3 Tbilisi orography and pollution source distribution is shown. Actual geographic coordinates are placed on the axes.

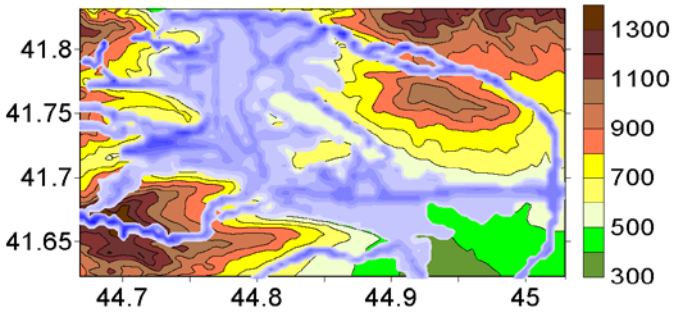


Fig. 3. *Tbilisi relief (in m) and of the pollution sources (blue zone and lines) fields.*

In Fig. 4 the distribution of dust concentration and wind velocity obtained by calculation at the height of z = 2 m from earth surface for 24 hours of the first day are shown. It is seen from the figure that concentration is minimal at the town territory when t = 6 h. At that time the maximum value of concentration varies in interval of 0.3-0.5 MAC at three less populated territories – in vicinity of Tbilisi Sea, south-east and south-west parts of considered area. At the central and densely populated territories of the city, concentration of dust is within 0.1-0.2 MAC. From t = 6 h to t = 12 h in the central part of the city and near the town mains, a concentration rapidly increases with grow of intensity of vehicle traffic.

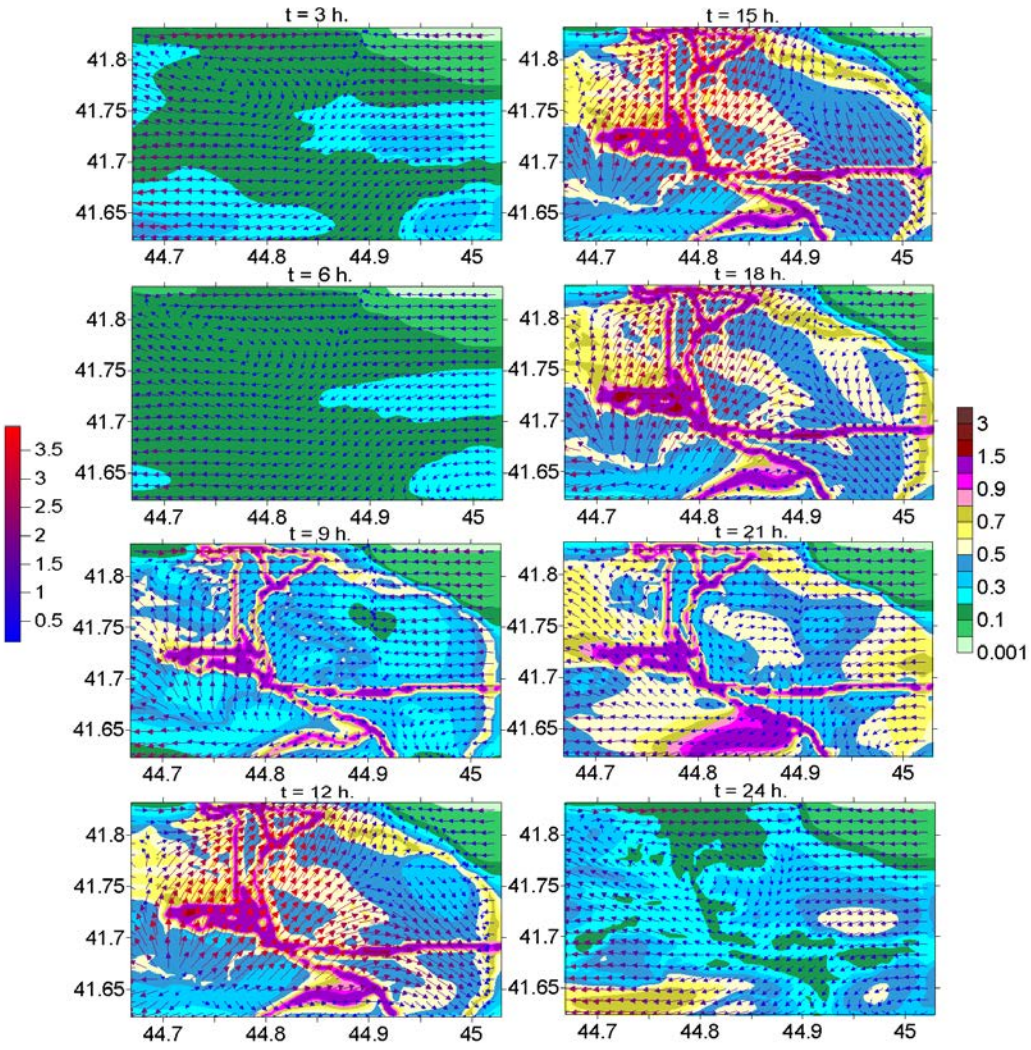


Fig. 4. *Dust concentration (in MAC) and wind velocity (m/s) fields at the territory of Tbilisi at 2 m height from earth surface in case of background eastern light air, when t = 3, 6, 9, 12, 15, 18, 21, and 24 h.*

Maximum values of concentration 1.5-2 MAC are obtained in vicinity of mains and central parts of city from 3 p.m. to 9 p.m. In these parts of city, despite the constant character of vehicle traffic intensity, slow rate of concentration growth and extension of square of relatively severely polluted areas takes place. Areas with severe dust pollution have different forms. Their shape and location depend on the value of surface wind velocity and form of relief (Fig. 4). Closed circulation systems, as well as convergence and divergence areas in the neighborhood of mountains confining separate urban districts are formed. As a result, dust redistribution and accumulation take place in some windward areas of the terrain.

From 9 p.m. to 12 p.m. concentration values are getting smaller. This reduction is non-uniform and is not proportional to vehicle traffic intensity change. Dust pollution drastically falls near the town mains at lowland territories of the central part of the city, and less sharply reduces in the neighborhood of inclined slopes of mountains confining the mentioned territory. Dust accumulation occurs in lowland urban districts. After 12 p.m. hours a quasiperiodic change of dust concentration field takes place.

Calculations had shown that at the height of $z > 2$m a spatial dust distribution in the surface layer of the atmosphere is similar to the distribution shown in Fig. 4. At the same time, concentration slightly falls in 50 m surface layer of the atmosphere. Above 50 m, concentration change is more intense. In the atmospheric boundary layer ($z > 600$ m) a united dust cloud is formed, shape and propagation direction of which depends on local wind velocity. Small concentrations of Tbilisi dust (< 0.001 MAC) reach the upper part of the atmospheric boundary layer and lower layers of free atmosphere.

4. CONCLUSION

Tbilisi dust pollution impact on contamination of surrounding territories in cases of light eastern and western background winds is studied using numerical modeling. Dust propagation area and urban impact zones are determined. Influence of complex terrain on dust migration direction is studied. It is obtained that in case of light wind a local relief form causes daily variations of dust propagation direction.

It is shown, that the vertical turbulent diffusive dust distribution in the surface layer of the atmosphere is predominant compared to advective dust propagation. Above the surface layer the role of advective dust transfer gradually increases. As a result, in the surface layer of the atmosphere dust is propagated to several dozens of kilometers in the form of narrow and long rectangular-shaped stream. It is obtained that in case of light background wind Tbilisi dust creates 0.01-1 MAC and 0.001-0.01 MAC concentrations in zones adjacent to the city with width 6-10 km and 20-24 km, respectively.

Kinematics of distribution of dust generated by motor transport on the territory of Tbilisi is investigated. Diurnal variation of spatial dust distribution is studied. Based on the analysis of wind velocity and concentration fields it is shown that a spatial distribution of severely polluted areas depends on the location of town mains, on one hand and on local atmospheric circulation systems formed due to daily variations of thermal regime, on the other. Comparison of concentration values obtained through modelling with experimental measurement data showed satisfactory correlation.

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Tragacanthic plant communities of Caucasian milk-vetch [Astracantha caucasica (Pall.) Podlech] in Tbilisi environs

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ABSTRACT

Tragacanthic plant communities of Caucasian milk-vetch (*Astracantha caucasica*) of Tbilisi environs are studied for the first time. *Astracantha caucasica* fragmentary spread in Tbilisi environs. Its populations in many cases are not numerous. *A. caucasica* grows on skeleton soils and rocky ecotopes. In Tbilisi environs altitudinal range of *A. caucasica* is from foothills to middle mountain belt (400 to 1000 m a.s.l.). Plant communities of *A. caucasiaca* in Tbilisi environs were discovered on the foothills of Ialno ridge in the vicinities of village Martkopi. They are secondary origin. They are derived as a result of digressive successions of oak forest (Querceta iberici). Typological composition is poor. 2 plant communities were identified by us: (1) Astragaletum gramino-mixtoherbosum and (2) Astragaletum bothriochloosum. Phytocoenological characteristics of plant communities are presented. Principal geo-botanical characterise tics (general projective coverage, sodding degree, density, projective coverage, distribution and average height of each layer, floristic composition, coenetic role of each species – projective coverage, and etc.) and physical-geographical conditions (altitude, relief, exposure, inclination) are given. 63 species of vascular plants, which belongs to 23 families and 57 genera, were recorded. In the floristic spectrum leading families are: *Poaceae* – 12 species (19.1%), *Fabaceae* – 8 (12.7%), *Labiatae* – 8 (12.7%), *Asteraceae* – 7 (11.2%) and *Rosaceae* – 7 (11.2%). The life form spectrum is as follows: hemicryptophytes (including biennials) – 79.9%, phanerophytes – 7.9%, chamaephytes – 7.9%, therophytes – 3.2%, geophytes – 1.6%.

Keywords: *Astracantha caucasica*, Plant community, Phytosociological characteristics, Floristic composition, Life form, Tragacanthic plant.

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Introduction

Tragacanthic shrubberies in Tbilisi environs do not belong to characteristic vegetation. But with its original phytosociological structure take distinguished position in the vegetation cover of Tbilisi surroundings.

Tragacanthic shrubberies in Tbilisi environs are represented by 3 formations: (1) small-headed milk-vetch formation (Astracantheta microcephalae), (2) Caucasian milk-vetch formation (Astracantheta caucasici) and (3) Tana's milk-vetch formation (Astragaleta tanae) [1-3]. Their plant communities are fragmentary distributed and are inserted in the area of various vegetations. From them the first formation is comparatively widespread. Plant communities of other formations have local distributed area.

Phytosociological structure, floristic composition and distributed regularities of small-headed milk-vetch formation (Astracantheta microcephalae) of Tbilisi environs are given in article by Lachashvili and Khetsuriani [3] and literary data about of rest formations are not.

The aim of our research was to establish typological composition, distributed regularities and full floristic composition of *Astracantha caucasica* shrubbery in Tbilisi environs; determine phytosociological structure for each distinguished plant communities.

Objectives and Methods

The object of research is Caucasian milk-vetch tragacanthic shrubbery of Tbilisi environs.
Phytosociological data was obtained by the route method. Geo-botanical surveys were carrying out on 25 m² plots. Number of species was quantifying on 1 m² plots also. During the geo-botanical surveys, studying the structure of plant communities and identification of syntaxa, we were guided by the traditional geo-botanical methods [4-10]. Instead of the term "association" that is observed in Soviet literature, we use the term "plant community" that is recognized through the Europe.
Life forms of the plants are separated on the basis of C. Raunkiaer [11] and I. Serebriakov classifications [12]. Soil types are founded on the modern classifications [13-15].

Results and Analysis

I. Distributed area and short physical-geographical characteristics

Caucasian milk-vetch formation (Astracantheta caucasici) in Tbilisi surroundings is rare and is not appertaining to characteristic and widespread formations. Its plant communities have local distribution area. They are locally spread only in the surroundings of vil. Martkopi on the foothills of Ialno ridge, 900-950 m a.s.l. Territory is located in moderately humid climate zone with moderately warm long summer and moderately cold snowy winter; average annual temperature is 10.3°C, mean annual precipitation – 600 mm, precipitation-evaporation ratio – within the range 1 [16-18]. Climagraph (Fig. 1) is built according to the data of Martkopi meteo station is given below [19, 20]. Plant communities are formed on the skeletal cinnamonic soils.

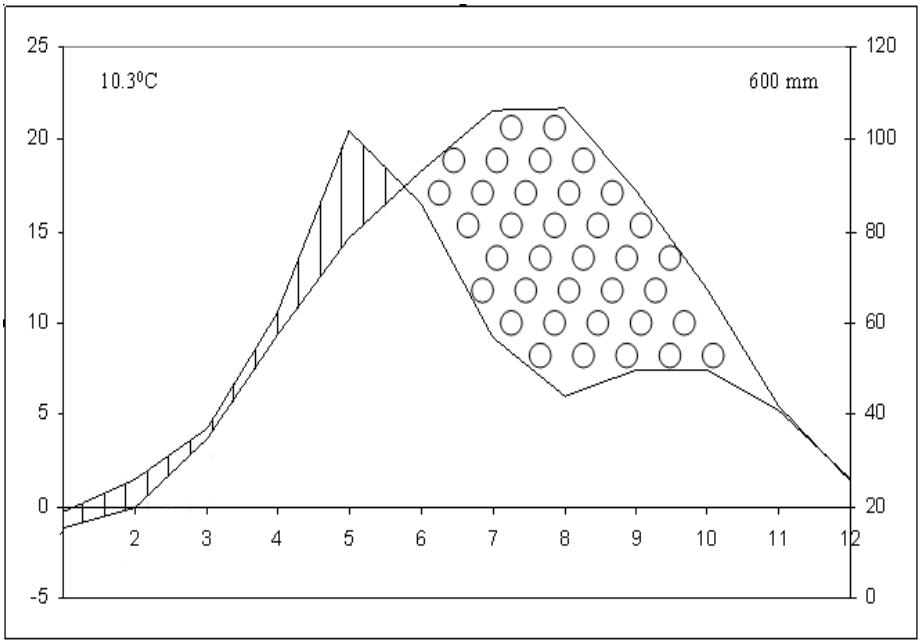

Fig. 1. *Climagraph of study area*

II. Typological composition and geo-botanical characteristic

Tragacanthic shrubberies of Caucasian milk-vetch (*Astracantha caucasica*) in Tbilisi environs are not distinguished by typological variety. Within the formation 2 plant communities were identified by us. They are: (1) Astracanthetum graminoso-mixtoherbosum and (2) Astracanthetum bothriochloosum. From them the second plant community is main.
Consolidated geo-botanical tables, which include main phytosociological characteristics, are given below.

Abbreviations:
m – Meter
cm – Centimeter
s. – Specimen

E – East
N – North
S – South
W – West

Th – Therophyte

H – Hemicryptophyte

G – Geophyte

Ch – Chamaephyte

Ph – Phanerophyte

Table 1. *Astragaletum gramino-mixtoherbosum*

Exposure (macro)	N
Exposure (micro)	N
Inclination	30°
General projective coverage (%)	90-95
Sodding degree (%)	15-20
Shrubs	
Projective coverage (%)	45-47
Distribution	More or less evenly
Average height (cm)	25-27
Maximum height (cm)	35
Grass cover	
Projective coverage (%)	60-65
Distribution	evenly
Average height (cm)	25-30
Maximum height (cm)	80-90
Species richness	
Species richness - 1 m^2	16.8
Species richness - 25 m^2	35
Floristic composition	
Species	**Projective coverage (%)**
Shrubs and trees (Ph)	
Astracantha caucasica	45-47
Carpinus orientalis	+
Cotoneaster saxatilis	+
Quercus petraea subsp. *iberica*	+ (2 growing individes)
Ulmus minor	+ (1 growing individe)

Semishrubs & dwarf semishrubs (Ch)	
Fumana procumbens	+
Scutellaria orientalis	+
Teucrium nuchense	3-4
Teucrium polium	1
Thymus coriifolius	+
Perennial herbs (H)	
Achillea setacea	+
Agrimonia eupatoria	+
Astragalus brachycarpus	+
Bothriochloa ischaemum	+
Brachypodium pinnatum	20
Briza media	5
Calamagrostis epigejos	7
Carex humilis	25
Centaurea ovina	1
Convolvulus arvensis	+ (1 s.)
Securigera varia	+
Dactylis glomerata	+
Dorycnium herbaceum	1
Echinops sphaerocephalus	+ (1 s.)
Echium rubrum	+
Elytrigia intermedium	+
Eryngium campestre	+
Falcaria vulgaris	+
Filipendula vulgaris	+
Fragaria viridis	+
Galium verum	1-2
Hypericum perforatum	+
Inula aspera	+
Jurinea blanda	+
Koeleria macrantha	+
Lotus caucasicus	3-4
Medicago caerulea	3-4
Origanum vulgare	+
Phleum pratense	+
Plantago lanceolata	2-3
Potentilla humifusa	+
Potentilla recta	+
Salvia nemorosa	+
Salvia verticillata	1-2
Scabiosa columbaria	3-4

Stachys atherocalyx	+
Stipa capillata	+
Thalictrum minus	+
Tragopogon serotinus	+
Trifolium ambiguum	+
Perennial herbs (G)	
Allium pseudoflavum	+
Annual plants (TH)	
Filago pyramidata	+
Centaurium erythraea	+

Table 2. *Astragaletum bothriochloosum*

Surveys	1	2	3	4	5
Exposure (macro)	S	S	S	S	S
Exposure (micro)	S-E, S-W	S	S	S	S
Inclination	5	20	15-17	18-20	16-18
General projective coverage (%)	70	70	60	65	75
Sodding degree (%)	15	20	20	18-20	17-18
Shrubs					
Projective coverage (%)	45-50	50	35-40	40	40-45
Distribution	More or less evenly	More or less evenly	More or less evenly	More or less evenly	More or less evenly
Average height (cm)	22-27	25-30	20	25-30	25
Maximum height (cm)	35	35	30	35	35
Grass cover					
Projective coverage (%)	60	60-65	60	60-65	60
Distribution	evenly	evenly	evenly	evenly	evenly
Average height (cm)	10-15	10	10	10	12-15
Maximum height (cm)	60-80	60-80	60-80	70-80	70-75
Species richness					
Species richness - 1 m^2	15	11	14	12	13
Species richness - 25 m^2	24	22	26	25	26
Floristic composition					
Species	**Projective coverage (%)**				
Shrubs (Ph)					
Astracantha caucasica	50	50	35-40	40-45	40-45
Semishrubs & dwarf semishrubs (Ch)					
Fumana procumbens	+	-	-	+	-
Scutellaria orientalis	5	-	8-10	+	+

Teucrium nuchense	+	1	1	+	1
Teucrium polium	2-3	5	3	3-4	4-5
Thymus coriifolius	2-3	2-3	3-4	3-4	4
Perennial herbs (H)					
Astragalus brachycarpus	+	+	+	+	+
Bothriochloa ischaemum	40	35	25	25-27	23-25
Campanula sibirica subsp. *hohenackeri*	-	-	+	+	-
Carex humilis	5-7	4-5	10	6-7	5-6
Centaurea ovina	+	+	-	+	+
Convolvulus lineatus	-	-	+	-	-
Cynodon dactylon	+	-	-	-	-
Dorycnium herbaceum	+	2-3	8	1-2	3
Echium rubrum	-	-	+	-	+
Eryngium campestre	-	+	+	+	+
Falcaria vulgaris	-	-	1-2	-	+
Festuca pratensis	-	+	-	-	-
Festuca valesiaca	2-3	9-10	-	3	3-4
Galium humifusum	-	+ (1 s.)	-	-	-
Galium verum	+	-	+	-	+
Inula aspera	-	+ (1 s.)	-	-	+
Jurinea blanda	-	-	+	+	-
Linum tenuifolium	+	+	1-2	+	+
Lotus caucasicus	+	2-3	1-2	1	+
Medicago caerulea	3	8	1-2	3-4	4-5
Ononis pusilla	-	-	+	-	-
Plantago lanceolata	+	-	1-2	+	+
Polygala transcaucasica	-	+ (1 s.)	+ (1 s.)	-	-
Potentilla humifusa	5	2-3	8	4-5	3-4
Salvia nemorosa	-	+ (1 s.)	-	+	+
Salvia verticillata	+	-	+	+	-
Sanguisorba minor subsp. *balearica*	-	+	-	+	-
Scabiosa columbaria	3	-	+	+	1
Stachys atherocalyx	+	+	-	-	+
Stipa capillata	+	+	-	+	+
Tragopogon serotinus	+	-	+	-	+

Plant communities of *A. caucasica* in Tbilisi environs are secondary origin. They are derived as a result of digressive successions of oak forest (Querceta iberici) and relate to one of the last stage (IV stage) of post-forest vegetation succession [21, 22]. Participation of characteristic species of forest vegetation (*Quercus petraea* subsp. *iberica*, *Carpinus orientalis*, *Ulmus minor*, *Carex humilis*, *Brachypodium pinnatum*) indicates

on this. In this regard participation of some mesophilic plants (*Briza media*, *Calamagrostis epigejos*, *Trifolium ambiguum*) is also interesting.
It is important that weeds almost do not participate in the plant communities.

III. Floristic composition

63 species of vascular plants, which belong to 23 families and 57 genera, were recorded. All species belong to angiosperms. From them dominants are dicotyledons (49 species / 77.8%).
Number of species is disproportionally distributed by families. Most of families (15 families) are represented by only one species and 3 families contain 2 species each. Share of 1-5 leading families accounts 66.7% (42 species) of the total number of species (Fig. 2).

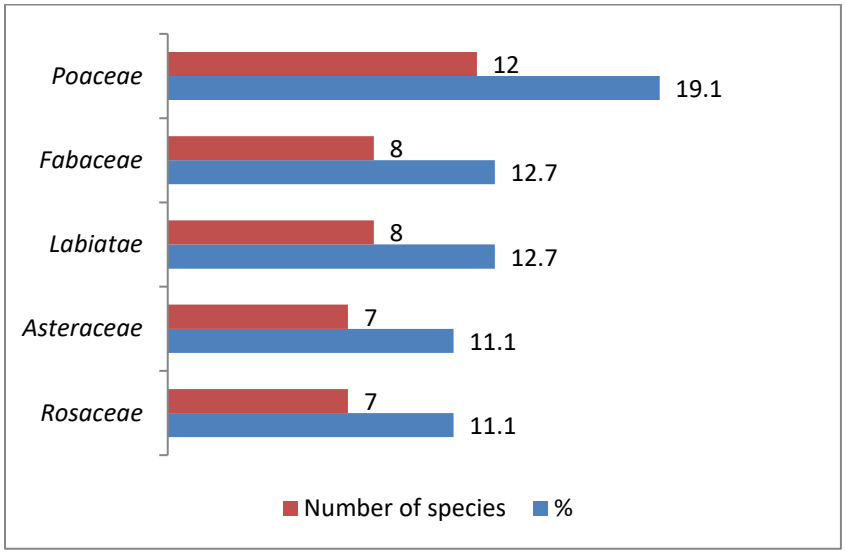

Fig. 2. *Number of species by the leading families*

The same families dominate by content number of genera, though more or less different sequence, are observed (Fig. 3).

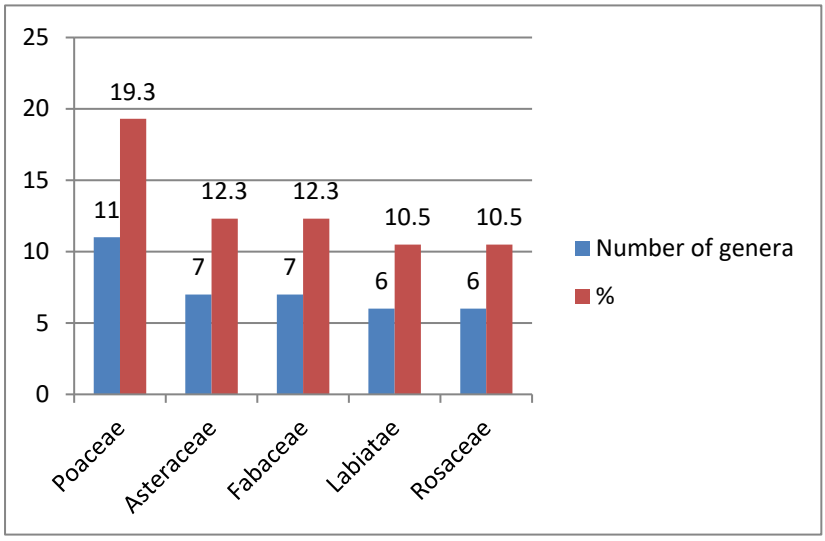

Fig. 3. *Number of genera by the leading families*

Among genera are not leading genera; they are represented by 1-2 species.
Full list of recorded plants is given bellow (Table 3). For each species life forms [11, 12] are indicated.

Table 3. *List of floristic composition*

Family	Species	Life form	
ANGIOSPERMAE			
DYCOTYLEDONEAE			
Apiaceae	*Eryngium campestre* L.	Hemicryptophyte	Perennial herb
	Falcaria vulgaris Bernh.	Hemicryptophyte	Biennial or perennial herb
***Asteraceae* (*Compositae*)**	*Achillea setacea* Waldst. & Kit.	Hemicryptophyte	Perennial herb
	Centaurea ovina Pall. ex Willd.	Hemicryptophyte	Perennial herb
	Echinops sphaerocephalus L.	Hemicryptophyte	Perennial herb
	Filago pyramidata L.	Therophyte	Annual
	Inula aspera Poir.	Hemicryptophyte	Perennial herb
	Jurinea blanda (M.Bieb.) C.A.Mey.	Hemicryptophyte	Perennial herb
	Tragopogon serotinus Sosn.	Hemicryptophyte	Perennial herb
Boraginaceae	*Echium rubrum* Forssk.	Hemicryptophyte	Perennial herb
Campanulaceae	*Campanula sibirica* subsp. *hohenackeri* (Fisch. & C.A.Mey.) Damboldt	Hemicryptophyte	Biennial
Cistaceae	*Fumana procumbens* (Dunal) Gren. & Godr.	Chamaephyte	Dwart semi-shrub
Convolvulaceae	*Convolvulus arvensis* L.	Hemicryptophyte	Perennial herb
	Convolvulus lineatus L.	Hemicryptophyte	Perennial herb
Corylaceae (*Betulaceae*)	*Carpinus orientalis* Mill.	Phanerophyte	Shrub
Dipsacaceae (*Caprifoliaceae*)	*Scabiosa columbaria* L.		Perennial herb
Fabaceae (*Leguminosae*)	*Astracantha caucasica* (Pall.) Podlech (*Astragalus caucasicus* Pall.)	Phanerophyte	Shrub
	Astragalus brachycarpus M.Bieb.	Hemicryptophyte	Perennial herb
	Securigera varia (L.) Lassen (*Coronilla varia* L.)	Hemicryptophyte	Perennial herb
	Dorycnium herbaceum Villar	Hemicryptophyte	Perennial herb
	Lotus caucasicus Kuprian.	Hemicryptophyte	Perennial herb
	Medicago caerulea Less. ex Ledeb.	Hemicryptophyte	Perennial herb
	Ononis pusilla L.	Hemicryptophyte	Perennial herb
	Trifolium ambiguum M.Bieb.	Hemicryptophyte	Perennial herb
Fagaceae	*Quercus petraea* subsp. *iberica* (Steven ex M.Bieb.) Krassiln.	Phanerophyte	Tree
Gentianaceae	*Centaurium erythraea* Rafn	Therophyte	Annual
Hypericaceae	*Hypericum perforatum* L.	Hemicryptophyte	Perennial herb
Lamiaceae (*Labiatae)*	*Origanum vulgare* L.	Hemicryptophyte	Perennial herb
	Salvia nemorosa L.	Hemicryptophyte	Perennial herb
	Salvia verticillata L.	Hemicryptophyte	Perennial herb

	Stachys atherocalyx K.Koch	Hemicryptophyte	Perennial herb
	Scutellaria orientalis L.	Chamaephyte	Dwart semi-shrub
	Teucrium nuchense K.Koch [*Teucrium chamaedrys* subsp. *nuchense* (K.Koch) Rech. f.]	Chamaephyte	Dwart semi-shrub
	Teucrium polium L.	Chamaephyte	Dwart semi-shrub
	Thymus coriifolius Ronniger	Chamaephyte	Dwart semi-shrub
Linaceae	*Linum tenuifolium* L.	Hemicryptophyte	Perennial herb
Plantaginaceae	*Plantago lanceolata* L.	Hemicryptophyte	Perennial herb
Polygalaceae	*Polygala transcaucasica* Tamamsch.	Hemicryptophyte	Perennial herb
Ranunculaceae	*Thalictrum minus* L.	Hemicryptophyte	Perennial herb
Rosaceae	*Agrimonia eupatoria* L.	Hemicryptophyte	Perennial herb
	Cotoneaster saxatilis Pojark.	Phanerophyte	Shrub
	Filipendula vulgaris Moench	Hemicryptophyte	Perennial herb
	Fragaria viridis Weston	Hemicryptophyte	Perennial herb
	Potentilla humifusa Willd. (*Potentilla adenophylla* Boiss. & Hohen.)	Hemicryptophyte	Perennial herb
	Potentilla recta L.	Hemicryptophyte	Perennial herb
	Sanguisorba minor subsp. *balearica* (Nyman) Muñoz Garm. & C. Navarro (*Poterium polygamum* Waldst. & Kit.)	Hemicryptophyte	Perennial herb
Rubiaceae	*Galium humifusum* M.Bieb.	Hemicryptophyte	Perennial herb
	Galium verum L.	Hemicryptophyte	Perennial herb
Ulmaceae	*Ulmus minor* Mill.	Phanerophyte	Tree
MONOCOTYLEDONEAE			
Amaryllidaceae	*Allium pseudoflavum* Vved.	Geophyte	Perennial herb
Cyperaceae	*Carex humilis* Leyss.	Hemicryptophyte	Perennial herb
Poaceae (*Gramineae*)	*Bothriochloa ischaemum* (L.) Keng	Hemicryptophyte	Perennial herb
	Brachypodium pinnatum (L.) P.Beauv.	Hemicryptophyte	Perennial herb
	Briza media L.	Hemicryptophyte	Perennial herb
	Calamagrostis epigejos (L.) Roth	Hemicryptophyte	Perennial herb
	Cynodon dactylon (L.) Pers.	Hemicryptophyte	Perennial herb
	Dactylis glomerata L.	Hemicryptophyte	Perennial herb
	Elytrigia intermedia (Host) Nevski	Hemicryptophyte	Perennial herb
	Festuca pratensis Huds.	Hemicryptophyte	Perennial herb
	Festuca valesiaca Gaudin	Hemicryptophyte	Perennial herb
	Koeleria macrantha (Ledeb.) Schult.	Hemicryptophyte	Perennial herb
	Phleum pratense L.	Hemicryptophyte	Perennial herb
	Stipa capillata L.	Hemicryptophyte	Perennial herb

IV. Life forms

Herbs are basic of floristic composition (53 species / 84.1%) and woody and semi-woody plants are few (5 species each / 7.9% each). Except of *Astracantha caucasica* no one of woody plants belong to characteristic species. They were recorded only in one plant community. In contrast with them, frequency of occurrence of semi-woody plants (*Teucrium polium*, *T. nuchense*, *Scutellaria orientalis*, *Thymus coriifolius and Fumana procumbens*) is high and they belong to characteristic species of plant communities. The core of the floristic composition consists of hemicryptophytes (Fig. 2). Among them characteristic species are: *Bothriochloa ischaemum*, *Carex humilis*, *Astragalus brachycarpus*, *Centaurea ovina*, *Dorycnium herbaceum*, *Eryngium campestre*, *Festuca valesiaca*, *Linum tenuifolium*, *Lotus caucasicus*, *Medicago caerulea*, *Plantago lanceolata*, *Potentilla humifusa*, *Stipa capillata*, *Scabiosa columbaria*. Role of therophytes and geophytes is insignificant.

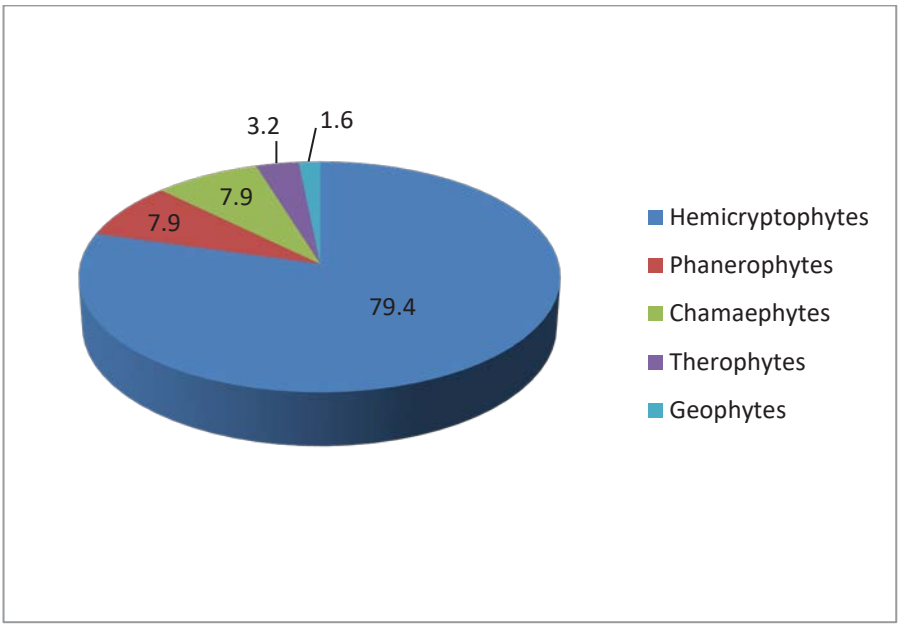

Fig. 4. *Proportion (%) of life forms*

Conclusion

Plant communities of Caucasian milk-vetch formation (Astracantheta microcephalae) in Tbilisi environs have small and local area. They are distributed on the foothills of Ialno ridge in the vicinities of village Martkopi., 900-950 m a.s.l.. Plant communities are developed on slopes with cinnamonic skeletal soils.

In Tbilisi environs tragacanthic plant communities of *Astracantha caucasica* are secondary origin and derived as a result of digressive successions of oak forest (Querceta iberici). Primary plant communities are rare.

Typological composition of formation is poor. 2 plant communities were identified by us: (1) Astragaletum gramino-mixtoherbosum and (2) Astragaletum bothriochloosum.

Layer structure is not well expressed: heights of shrubbery stratum and grass cover are not sharply delimited.

Floristic composition is not rich: 63 species of vascular plants, which belong to 23 families and 57 genera, were recorded. All species belong to angiosperms. From them dominants are dicotyledons (49 species / 77.8%). In the floristic spectrum leading families are: *Poaceae* – 12 species (19.1%), *Fabaceae* – 8 (12.7%), *Labiatae* – 8 (12.7%), *Asteraceae* – 7 (11.2%) and *Rosaceae* – 7 (11.2%). Total share of these leading families is 66.7% (42 species).

Herbs are basic of floristic composition (53 species / 84.1%) and quantity of woody and semi-woody plants is few (5 species each / 7.9% each). The life form spectrum is as follows: hemicryptophytes (including biennials) – 79.9%, phanerophytes – 7.9%, chamaephytes – 7.9%, therophytes – 3.2%, geophytes – 1.6%. Characteristic

species, of which frequency of occurrence is high, belong to chamaephytes and hemicryptophytes. Role of therophytes and geophytes in the structure of plant communities is insignificant.

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Future scenarios of air temperature maximums and minimums for Georgia based on statistical downscaling

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ABSTRACT

In this article monthly maximums and minimums of 2-meter air temperature from three GCMs of CMIP5 [1] database has been statistically downscaled using RCMES [2] package, with four different methods for 27 selected meteorological stations on the territory of Georgia. Stations have been selected all over the territory of Georgia, based on the completeness of their air temperature series throughout the entire period of 1961−2010, their credibility (measured by the number of non-missing data) and to cover as much complex climate features of the territory as possible. The downscaling methods have been trained for the period of 1961-1985 and validated for the period of 1986-2010. Some statistical parameters have been calculated by applying R statistics environment to compare observed and simulated time series and to evaluate temporal and spatial goodness of each method. Downscaling model, driven by the validation study was used for future Tmin and Tmax time series construction for the 2021-2070 period under RCP4.5 and RCP8.5 scenarios. Temperatures time series have been constructed from a multimodel ensemble, with mean and spread. Future change tendencies have been assessed in comparison of the period of 1986–2010 but was also compared with previous 25-years period (1961-1985) to compare future changes with the magnitudes of past tendencies.

Keywords: Statistical downscaling, GCM, Regression, Bias correction, Future projection, Multi-model ensemble.

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Introduction

The climate change signal is not uniform over the globe, contrary to long-term trends and year-to-year variability of the mean meteorological variables and especially extremes considerably varies for different geographical regions [3]. The Global Climate Models (GCMs), or also referred as the General Circulation Models demonstrate a significant skill to simulate climate change information at the continental and hemispheric spatial scales and incorporate a large proportion of the complexity of the global system, but they are far from being perfect even at a global scale. Future climate change information is uncertain due to mentioned complexity and inadequacy of the models in capturing all of its underlying processes, also for unknown amount of future emission and climate internal variability. Careful and systematic evaluation of GCMs from multiple climate modeling centers is widely recognized as critical for improving our understanding of future climate change. The Coupled Model Inter-comparison Project (CMIP), currently in its sixth phase, is an internationally coordinated multi-GCM experiment that has been undertaken for decades to assess global-scale climate change [4-5].

It should be noted that characterizing present climate conditions and providing future climate projections at a regional scale is an extremely difficult task [6] (Mahmood and Babel 2013) as it involves additional uncertainties while reducing, a spatial scale of GCMs simulated climate parameters. GCMs have a very coarse spatial resolution and are unable to simulate sub-grid scale features and physical dynamics [7] and outputs are often too coarse to be effectively used in climate change impacts, adaptation, and vulnerability assessment studies [8]. The decrease in spatial accuracy of GCMs simulated climate variables occurs from continental to local scale using statistical downscaling (SD) or dynamical downscaling (DD) techniques. The last option involves the use of high-resolution Regional Climate Model (RCM) to simulate physical processes at fine spatial scale from the host GCM and is considered as costly and time-consuming one [9-11] (Giorgi 1990; Jones et al. 1995). SD is faster and simpler in use, less computationally expensive and applicable for uncertainty and risk analyses [12].

Using SD a statistical/empirical relationship is established between GCMs simulated large-scale atmospheric variables (predictors) with station (local) scale meteorological variables (predictands) [13-15] A Statistical downscaling method by itself divides into three groups: multiple linear regression, nonlinear regression (e.g. artificial neural networks) and stochastic weather generators, which mostly are used in different sectoral impact studies. Each SD method includes the uncertainties in downscaling result from the concept on which the downscaling models are based and from the data used in the study.

The variability of the results obtained using different types of downscaling models suggest the use of as many statistical downscaling methods as possible in the development of climate change projections at the local scale. These capabilities are necessary to ensure reliable characterization of the future climate, which can lead to conscious decision-making, taking into account the climate characteristics of the region.

There are several studies devoted to the regional climate change projection for Georgia and more widely, for the South Caucasus region. These studies are mostly focused on regional climate modeling approaches and describe how well the regional climate models (RCMs) simulate regional and local climate peculiarities. Mainly two GCMs are mentioned in above-mentioned researches dynamically downscaled by also two different RCMs. Some seldom researches are also available, in which future climate change patterns for Georgia is assessed based on GCM ensemble. There is a gap in studies specifically focused on assessing uncertainty in downscaling results due to different statistical methods, also in a creation of ensembles from different GCMs and SD methods on several sites on the territory of Georgia [16-17].

We have performed statistical downscaling using RCMES - Regional Climate Model Evaluation System (RCMES) package. Mean monthly maximums and minimums of 2-meter air temperature from 3 GCMs of CMIP5 database with four different methods have been downscaled for 27 locations, where Georgian hydro-meteorological stations are located. Models based on SD methods have been trained for the period of 1961-85 and validated for the period of 1986-2010. Different statistical metrics were used to asses models performance, beyond of means and variances comparison. Results of this study discussed and Representative Concentration Pathway (RCP 4.5, RCP 8.5) scenarios constructed for above-mentioned 27 locations in chapter 2.

1. Data and method

1.1. Study area

Georgia's climate conditions are very diverse for a relatively small territory of the country, that is a result of its location on the northern edge of the subtropical zone between the Black and Caspian seas and also because of the complexity of its special topography. Climatic peculiarities in Georgia are mostly conditioned by the Greater Caucasus mountain range from the north and to the Black Sea in the west. The Greater Caucasus range serves as a barrier against cold air from the north. Warm, moist air from the Black Sea easily moves into the coastal lowlands from the west. Climatic zones are determined by a distance from the Black Sea and by the altitude. The Lesser Caucasus range runs parallel to the Turkish and summers and cold winters. Precipitation is comparatively less than at the same heights elsewhere in Georgia.

In the Fig. A.1 maps of annual mean maximal and minimal temperatures averaged over 1961-85 period are presented, where 27 stations of Georgian meteorological network are also marked. Time series from these stations of temperature mean monthly maximums and minimums have been used for this study. Selection criteria of these stations with some additional information is provided below in section 3.1.

1.2. RCMES toolkit

We decided to choose RCMES for performing our study. The Regional Climate Model Evaluation System (RCMES) is an enabling tool of the National Aeronautics and Space Administration to support the United States National Climate Assessment [2]. RCMES is designed to yield information from the various database to import climate models and observations in different formats, also performance metrics are designed to assess and quantify model skill, with plotting and visualization routines. Besides of above-mentioned user-friendly interfaces for quickly configuring is an additional benefit.

RCMES is an open, publicly accessible process enabled by leveraging the Apache Software Foundation's OSS library, Apache Open Climate Workbench (OCW). RCMES provides datasets and tools to assess the quantitative strengths and weakness of climate models, typically under present climate conditions for which we have observations for comparison, which then forms a basis to quantify our understanding of model uncertainties in future projections. OCW also allows users to build their own climate data analysis tools, such as the statistical downscaling toolkit provided as a part of RCMES.

We performed statistical downscaling using RCMES package for near-surface mean maximum and minimum temperature from 3 GCMs - MPI-ESM-MR; HadGEM2-ES; GFDL-CM3 runs exiting in CMIP5 database and available via RCMES.

1.3. GCM data (Baseline and Future scenarios)

RCMES toolkit allowing direct access to CMIP (e.g. CMIP5, CMIP6) global models, through access to the Earth System Grid Federation. Coupled Model Inter-comparison Project (CMIP) was established under the World Climate Research Programme (WCRP) by Working Group on Coupled Modelling (WGCM) as a standard experimental protocol for studying the output of coupled atmosphere-ocean general circulation models (AOGCMs). CMIP provides a community-based infrastructure in support of climate model diagnosis, validation, inter-comparison, documentation and data access [18-21]. The Output from about 60 GCMs with various historical experiment simulations and future emission scenarios are available on this database. We downscaled output temperatures from only three of them. GCM selection criteria was meant to use those models where we plan to have or already got dynamically downscaled results.

Below in the table B.1. Grid Resolutions of selected three GCMs - namely for atmosphere and ocean are presented.

Table B 1. *Grid Resolutions of selected three GCMs for atmosphere and ocean*

Model	Atmospheric Grid		Ocean Grid	
	Latitude	Longitude	Latitude	Longitude
GFDL-CM3	2	2,5	0,3344,1	1
HadGEM2-	1,25	1.875	0,3396	1
MPI-ESM-	1,875	1,875	Orthogonal curvilinear	

The climate model of the Geophysical Fluid Dynamics Laboratory's (GFDL) at NOAA is one of the leading climate models used in the Fifth Assessment Report of the IPCC. It encompasses the predictability and sensitivity of global and regional climate, the structure, variability, dynamics and interaction of the atmosphere and the ocean; and is influenced by various trace constituents. In CMIP5 phase of the project, version 3 of the model is participating. CM3 includes aerosol–cloud and chemistry–climate interactions, and links between the troposphere and stratosphere [22].

CMIP5 set of centennial experiments includes Met Office Hadley Centre's Earth System Model (ESM) HadGEM2-ES which focuses on how the climate system is likely to respond to human-induced disturbances. Model simulations consider greenhouse gas concentrations, aerosol precursors, stratospheric and tropospheric ozone assumptions, as well as an implementation of land-use change and natural forcings for the HadGEM2-ES historical and future experiments following the Representative Concentration Pathways [23].

The new Max-Planck-Institute Earth System Model (MPI-ESM) is used in the Coupled Model Inter-comparison Project phase 5 (CMIP5) in a series of climate change experiments for either idealized CO2-only forcing or forcings based on observations and the Representative Concentration Pathway (RCP) scenarios. MPI-ESM (MPG) is a comprehensive Earth-System Model, in the sense that it consists of component models for the ocean, the atmosphere and the land surface. These components are coupled through the exchange of energy, momentum, water and important trace gases such as carbon dioxide [24].

On the upper panel of the Fig. A.2 maps of the Tmax for 1961-85 period are presented**.** The first plot is constructed from CRU data, the second – from the output of GFDL-CM3, III and IV – from HadGEM2-ES and MPI-ESM-MR, respectively. On the second panel identical maps for Tmin are presented.

1.4. The downscaling methods

Statistical downscaling involves the establishment of empirical relationships between historical and/or current large-scale atmospheric and local climate variables. Once relationships are defined and validated, atmospheric variables are used to predict future local climate variables. However, this approach relies on the critical assumption that the relationship between present large-scale circulation and local climate remains valid under different forcing conditions for future climate [25]. Main disadvantages of this method are: 1) local, small-scale dynamics and climate feedbacks are not simulated, as the GCMs are not able to simulate weather and climate processes at scales smaller than their grid spacing, and statistically downscaled data do not add information at the smaller scale, and 2) assumptions of stationarity between the large and small-scale dynamics are made to downscale future projections. The problem of assuming stationarity is that some of the interactions between the large and small-scale are already changing, so this information is not represented in the downscaled projections.

We Downscaled temperatures from 3 GCMs output with 4 different methods: Delta method (addition); Delta method (bias correction); Quantile mapping; Asynchronous linear regression.

1. Delta method (addition) is the technics, where the difference between present and future simulations are added to the present observation. First, the mean difference between present simulation and future simulation is calculated. The calculated difference is added to the present observation to make a downscaled future prediction. In this method, only the change in mean values in simulations is considered in the future projection and the variance remains unchanged [26]. Distribution of observed and raw Tmin time series from MPI-EMS-MR3 model output for trained (1961-85) and testing/validation periods (1986-2010) for Tbilisi are presented on the Fig. A.3 (a), and Fig. A.3 (b), the bottom plot represents distribution of a downscaled Tmin simulated by MPI-EMS-MR3 model for testing/validation period (1986-2010) for Tbilisi.

2. In Delta method (bias correction), the mean bias of present simulation from present observation is calculated and added to the future simulation [27]. Delta method uses a raw model output for the future period and corrects it using the differences (Δ) between historical reference data from the model and observations. If we assume the variability as equal for both GCMs and observations, the monthly data is simply shifted by the mean bias in the reference period. On the Fig. A.4 (a) results of using bias correction method for the same time series are presented.

3. The other methodology is quartile mapping method fitting cumulative distribution functions of observed, training and testing data [28] Li et al. (2010). Quantiles for observed (XO), as well as GCM (XGCM) simulated data are first calculated. Then linear transformation to each quantile from GCM data to adjust its range is applied to match the quantile with observed data. The Same correction to the quantiles in the future data should be used. Downscaling results using quantile mapping method are shown on the Fig. A.4 (b).

4. Statistical Asynchronous Regression (SAR) method is a technique for determining a relationship between two-time varying quantities without simultaneous measurements of both quantities [29]. It requires that there is a time invariant, monotonic function $Y = u(X)$ relation between the two quantities, Y and X. In order to determine $u(X)$, we only need to know the statistical distributions of X and Y. $u(X)$ converts the distribution of X into the distribution of Y, while conserving probability. Downscaling results using Statistical Asynchronous Regression method are shown on the Fig. A.4 (c).

In the next chapter goodness and weakness of each method is discussed and some metrics are analyzed to prove some conclusions.

2. Validation results and discussion

2.1. Performance of model downscaling and validation

Prior to future scenario construction, the results of the observed data of mean monthly maximum and minimum temperature are compared with the simulated data during the training and validation periods using some statistical parameters (metrics).

Twenty-seven sites broadly scattered throughout Georgia were selected based on the completeness of their temperature series throughout the entire period of 1961−2010 and their credibility measured by the number of non-missing data, as well as to cover as much complex climate features of the country as possible. The locations and summary information for the 27 stations selected are shown in Fig. A.1 and Table B.1, respectively.

The study carried out the downscaling process for every 27 stations feeding three GCMs outputs

using four downscaling methods, which produced 27*3*4 time series for each parameter, and the study then took the best matching method for constructing future climate scenarios.

The models were trained (downscaled) using observations of 25 years of data (1961–1985, termed the base period) and the remaining 25 years of data (1986–2010, termed the validation period), respectively.

Model evaluation has been performed using R-Instat - open source menu driven statistical software, powered by R - programming language and free software environment for statistical computing and graphics, supported by the R Foundation for Statistical Computing [30].

2.2. Indicators of performance assessment

The Pearson's correlation coefficients (CC) and plots of squared CC values contributed to the identification and selection of the most valuable methods for developing the downscaling model. Except the CC to evaluate the quality of the model predictions, following metrics were used as measures of the statistical agreement between the predicted values and observed data, including the mean bias, mean absolute error (MAE), the root mean square error (RMSE), as well mean (μ), median (Med), standard deviation (SD), median absolute deviation (MAD), coefficient of variation (CV) and standard error of mean (SE_μ). They were calculated for all three models and four downscaling methods separately.

The value of CC is indicative of strength between observed and simulated values whereas mean bias, MAE and RMSE are used to determine the accuracy of the model. However, μ, median and SE_μ are exercised to test how well the model predicted the mean values, while SD, CV and MAD are used to investigate the variability of data simulated by the model.

The last Indicator, chosen as the criteria for evaluating the performance of downscaling methods, was the assessment of an effect of each downscaling method on trends in seasonal and annual mean minimum and maximum temperatures for the validation period in comparison with the behavior of observed data series temporal variability. Spearman's Rho rank correlation was used to determine the statistical significance of trends for maximum and minimum temperature on seasonal and annual timescales. This statistic is a non-parametric measure of correlation, adapted to data sets with strong autocorrelation (temperature). It makes no assumptions about the probability of the distribution of the investigated data and it is less affected by outliers or by any form of data discontinuity [31]. The statistical significance was determined at the 95% confidentiality level. The magnitude of the trend was calculated by the slopes of the linear trends using ordinary least square fitting and expressed in °C decade^{-1}.

2.3. Evaluation of downscaling methods

Table B.3(a) shows the mean CCs between modeled and observed minimum temperatures for 3 GCMs using 4 candidate methods during the validation period (1986-2010) for each season over all 27 stations and Table B.3(b) shows the same for maximum temperature. Seasons are defined as follows: as the following: winter-DJF (December–February), spring-MAM (March–May), summer-JJA (June–August) and autumn-SON (September–November).

Overall, it is evident that both the simulated maximum and minimum temperatures were closely consistent with observations. CC between simulated and observed temperature exceeded or equaled to 0.8 in the validation period. Also, it could be seen that the minimum temperature is modelled slightly better than the maximum. There are some differences in seasonal dependence. Namely, for both parameters, summer and autumn seasons have higher correlations with observed patterns. Regarding the advantages of the methods, delta addition (1) and delta correction (2) methods are the most satisfactory.

Results of comparison between observed and downscaled mean annual Tmax, Tmin in terms of statistical measures for validation period are given in Table B.4(a) and Table B.4(b).

Mean annual biases in validation were in the range of (+0.33)÷(+0.94)^{0}C and (+0.50)÷(+1.04)^{0}C for minimum and maximum temperature, respectively, with MAE about 1.5-2◦C and RMSE 2-2.5^{0}C. Different patterns of bias are observed in seasonal context. Both maximum and minimum temperature differences are similar across the seasons. The greatest positive deviations (3-4◦C) were found in winter for absolute errors and spring - for mean bias (Fig. A.5). The closest Simulations to observation have been found out in summer season. Annual and seasonal biases indicate that, in average, simulations for both parameters are overestimated regarding observed values with slightly higher deviations for maximum temperature, cool biases were found mostly in summer in the range up to 2^{0}C. All three metrics assessing the accuracy of the models have a strong seasonality among a majority of stations,

the relatively less effect they display among coastal stations while in both variables, the largest and most seasonally dependent bias magnitudes originate from a high-mountainous stations (Fig. A.6).

Comparison of downscaling methods with regard to model errors show an overall warm bias of the same magnitude similar for three (delta edition, delta correction, quantile mapping) methods deviations are higher for the last – regression-based approach. For MAE, and RMSE the less matching method is the delta correction, while three other methods have approximately same deviations in mean annual values.

Analysis of other statistical metrics used to test model on the prediction of mean values demonstrate the abilities of those statistical downscaling methods to reproduce mean minimum and maximum temperature (Fig. A.7). The differences between modeled and observed parameters are not significant, all within a range of ±0.8°C, depending on the metric. For instance, SD and SE_μ are strongly defended on site elevation and three among four downscaling methods (except delta correction) can reproduce this feature properly, whilst the best simulation of a median is performed by delta correction method.

After model evaluation by statistical metrics linear trend analysis has been fulfilled, the magnitude of annual and seasonal linear trends for maximum and minimum temperature for the investigated period (1986–2010) are presented in Table B.5.

Based on observation data, investigated stations show a positive trend with medium significance for both parameters in all seasons except winter, with the highest magnitude in autumn. In winter most trends are not significant, herewith minimum temperature has mostly cooling tendency. Due to this, annual trends are positive for both parameters, but with higher fidelity for minimum temperature. However, the magnitude of the trend is lower than the one for maximum temperature (+0.41°C decade^{-1} for minimums and +0.60°C decade^{-1} for maximums). In addition, the increase in minimum temperature is enhanced at the coastal zone and the western part of the country.

Finally, the effect of each downscaling method on trends in seasonal and annual average minimum and maximum temperatures have been investigated. Analysis of modeled data changing behavior shows that annual pattern of trends are more or less well captured by all GCMs downscaled using three of four methods. The exception is a delta addition method that revealed not a steady but negative annual trend for both parameters. Seasonal trends coincidence is relevant to annual. The exception is again the winter with the minimum cooling tendency repeated only by delta addition method.

Annual trends representing the tendency of changes via year-to-year variability is significantly reduced by the delta addition method. As in this case, the linear trend of observed temperatures for the testing period (1961-85) is repeated in corresponding downscaled parameters for the validation period and warming tendency is stronger in the validation period, than in the beginning for entire territory in average.

Investigation of model performance indicators (metrics) revealed no clear indication of the best downscaling method. First one (delta addition) more likely fit the observation, the other three methods show no fixed advantage. Statistical trends analysis revealed the weakness of the delta addition method. Comparison of linear trends magnitudes suggest that the most appropriate method for both parameters is delta correction as the best associated with observed trends pattern [32].

3. Projected changes for future climate scenarios

Future Tmin and Tmax time series were constructed for the period of 2021-2070 under RCP4.5 and RCP8.5 scenarios by RCMES. We used delta correction method to produce desired future scenarios with reference to the period of 1961-85, where relationship between large-scale predictors –GCMs output Tmin and Tmax and local scale variables (stations Tmin and Tmax) have been established and validated. In the following sections, temporal and spatial changes of mentioned two parameters, obtained from three downscaled GCM ensembles are described. Corresponding deltas between two future periods 2021-2045 and 1946-2017 in comparison with the 1986–2010 period are presented on charts and in tables. As well, future changes have been compared with the magnitude of past tendencies comparing the period of 1986–2010 to previous 25-year period (1961-1985).

3.1. Variation of seasonal air temperatures

Mean seasonal observed (1961-1985, 1986-2010) and projected (2021-2045, 2046-2070) minimum and maximum temperature in Georgia under the two scenarios are shown in the Fig. A.8. All

mean seasonal temperatures increase in the future 50 years under both scenarios.

Regarding seasonal pattern, for Tmin and Tmax the most significant increase in the past period occurring in summer, in the range of 0.6-0.7^{0}C, is predicted to be shifted in winter during the whole future period under both scenarios becoming the summer as the least experiencing warming season throughout the year. Although for Tmax at the end of the 2060s minimum increase in the range of 2^{0}C is anticipated in spring. The highest increase in Tmin and Tmax, up to 5^{0}C is expected in winter under RCP8.5 scenarios in 2046-2070.

Overall, past trends are sustained and will be enhanced in the future. The exception is Tmax behavior in autumn, when no significant decrease (-0.13^{0}C) is observed in the 2000s, will be reversed in future. According to simulation, autumn maximums will grow rapidly than in other seasons and will reach up to +3.96, and +4.58^{0}C to the end of the 2060s under the RCP4.5, and RCP8.5 scenarios, respectively, that are the highest after winter positive increments in the range of +4.26, and +5.19^{0}C. In the 2040s, the minimum increase under both scenarios for minimums is 0.14^{0}C occurring in summer and for maximums is 0.41^{0}C, occurring in spring, increasing to 1.5 and 2.5^{0}C to the end of 2060s.

Therefore, the temperature will show an obviously increasing tendency averaged over entire territory in the future. The patterns of increase are similar for minimum and maximum temperatures with slightly more considerable warming for maximums than for minimums.

3.2. Variation of annual mean air temperatures

Fig. A.9 shows the projections obtained for minimum/maximum temperature averaged over the 27 stations of Table B.2. Different colors correspond to distinct scenarios. The solid lines correspond to the ensemble means for the RCP4.5 and RCP8.5 scenarios. The Spread of models are shown as shaded areas for each scenario and models historical run for 1961-2010 with observation time-series plotted as a black solid line. As can be seen all GSM/RCP project are increasing temperatures. For both temperature variables, the MPI-ESM-MR (GFDL-CM3) systematically projects the weakest (strongest) increments, whereas the HadGEM2 provides moderate results. The mean increments for 2021-2045 and 2046-2070 are in between 1.5^{0}C and 4.5^{0}C (2^{0}C and 5^{0}C) for minimum (maximum) temperature, depending on the GCM and RCP.

Table B.6 shows the changes in temperature for Georgia in the 2000s, 2040s, and 2060s with respect to the reference period under the RCP4.5 and RCP8.5 scenarios obtained from the RCMES. Under the RCP4.5 scenario, the mean annual minimum (maximum) temperature will increase by 1.66 (1.91) and 2.62^{0}C (3.14) in the 2040s, and 2060s, respectively that are significantly higher than the past 2000s increments (0.32^{0}C) with regard to 1980s, for both targeted variables. As expected, the changes under RCP8.5 are greater than under RCP4.5 and mean annual minimum (maximum) temperature will increase by 1.82 (2.16) and 3.35^{0}C (4.01) in the 2040s, and 2060s, respectively. Therefore, it is clear that in Georgia temperature shows significant positive trends and these changes will be more intensive towards the end of this century.

It is also revealed that increase in Tmax is more prominent than in Tmin. The upward rate of Tmax is especially obvious under RCP8.5 for the second future period. Except this, the difference between two scenarios is also more considerable for Tmax and for annual values, it is in the range of 0.7-0.9^{0}C whilst for Tmin it is not more than 0.2-0.3^{0}C, depending on the period.

3.3 Spatial patterns of air temperature

In order to assess the spatial distribution of these results, deltas are calculated by subtracting the mean of the historical reference period (1986-2010) from the ensemble mean of the target scenario periods (2021-2045 and 2046-2070) - for all investigated stations over the country. Positive deltas are obtained throughout the whole country for both temperatures, finding the highest increments over the plain territory of east Georgia. Moreover, the projected warming signal is higher for minimum than for maximum temperature, extended also over the west Georgia central lowlands in the second future 25-years period. The smallest warming magnitudes are revealed in the Black Sea coastal zone and adjacent lowlands under both scenarios for the whole future period. Relatively moderate changes are expected in the high-mountainous area with the altitude higher 1000 and 1500 meter above sea level for minimum and maximum temperatures, respectively. Finally, the two RCPs considered lead to similar delta spatial patterns (although intensified for the RCP8.5) for the two target variables. It should

be noted that revealed spatial peculiarities of warming are in accordance with the past period, but with slightly greater magnitudes of upward trends for maximum temperature. Also, the most significant warming occurring currently in the furthest eastern part (Kakheti region) getting relatively less intensive in future with regard to the rest of the territory.

In the 2000s the spatial distribution of the increase in air temperature is similar for both variables experiencing greater warming in the east part of the country with the average magnitude not more than a half degree with regard 1980s records. Furthermore, the maximum warming is located over Kakheti region (East Georgia), reaching $+0.54^0$C.

For the 2040s, the experiencing warming is greater than in the 2000s and is mainly located over Qvemo Qartli region (East Georgia), where the annual minimum and maximum temperature will increase by amounts in the range 2.0–2.5^{0}C under both RCP4.5 and RCP8.5. The remaining parts experiencing slightly less warming (1.5–2.0^{0}C).

In the 2060s, the increase will be larger than 3^{0}C in most of the territory under RCP8.5 and up to 4.0-4.5^{0}C under RCP8.5. In addition, the maximums increase will be greater than minimums.

On the whole, most of the territory may experience an obviously increasing trend in the future 50-years period under both scenarios. However, a few areas, including some patches, such as coastal zone and mountainous regions, are expected to show not so steady trends. With the passage of the decades (the 2000s, 2040s, and 2060s), the increase will be greater, and the area of higher temperature will grow in size.

4. Conclusion

Validation of statistical downscaling methods show that all of the methods have some advantages and disadvantages on the temporal and spatial scale. The metrics we used for model performance evaluation varies from station to station, year to year, and season to season.

The results of calculations have shown that the mean Person's CCs between modeled and observed Tmax and Tmin for all three GCMs (GFDL, MPI, HadGEM2) using four candidate methods for each season, over all 27 stations, exceeded or equaled to 0.8 during the validation period (1986-2010). Also, Tmin has been modelled slightly better than Tmax for both parameters, summer and autumn seasons have slightly higher correlations with observed patterns and delta addition with delta correction method had the most satisfactory results.

Comparison of downscaling methods, with regard model errors, have shown an overall warm bias of the same magnitude similar for three (delta edition, delta correction, quantile mapping) methods and deviations have been higher for the last – regression-based approach. For MAE and RMSE the less matching method was the delta correction, while three other methods had approximately same deviations in mean annual values.

The magnitudes of annual and seasonal linear trends for Tmin and Tmax based on observation data in all seasons except winter (Tmin had mostly cooling tendency) were positive with medium significance (with the highest magnitude in autumn, with higher fidelity for Tmin) for the investigated period (1986–2010). However, the magnitude of the trend is lower for minimum compare to maximum temperature (+0.41°C decade−1 for minimums and +0.60°C decade−1 for maximums). In addition, the increase in minimum temperature is enhanced at the coastal zone and the western part of the country.

The effect of each downscaling method on the tendency of seasonal and annual average Tmin and Tmax has shown that annual pattern of trends more or less well captured by all downscaling methods with exception of delta addition method.

Investigation of model performance indicators (metrics) revealed no clear indication of the best downscaling method. Delta addition method more likely fit the observation, the other three methods show no fixed advantages. Statistical trends analysis revealed the weakness of the delta addition method. Comparison of linear trends magnitudes suggest that the most appropriate method for both parameter is delta correction as the best associated with observed trends pattern and future temperatures were downscaled using this method.

According to the simulations the mean annual minimum (maximum) temperature will increase by 1.66 (1.91) and 2.62^{0}C (3.14) in the 2040s, and 2060s under the RCP4.5 scenario, that are significantly higher than the past 2000s increments (0.32^{0}C) with regard to 1980s, for both targeted variables. As expected, the changes under RCP8.5 are greater than under RCP4.5 and mean annual minimum (maximum) temperature will increase by 1.82 (2.16) and 3.35^{0}C (4.01) in the 2040s, and 2060s, respectively.

Regarding the seasonal pattern, for Tmin and Tmax past trends are sustained and will enhance in the future. The most significant increase is predict-

ed to be in winter during the whole future period under both scenarios becoming the summer as the least experiencing warming season throughout the year. Although for Tmax at the end of 2060s minimum increase in the range of 2^0C anticipated in spring. The highest increase in Tmin and Tmax up to 5^0C is expected in winter under RCP8.5 scenarios in the period of 2046-2070.

It should be noted that this research contains several uncertainties (choice of GCM, RCP and downscaling methods) and more precise investigations of each type of uncertainties and calculation of probabilities are planned for the future.

Acknowledgement

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Appendices
Appendix A: Figures

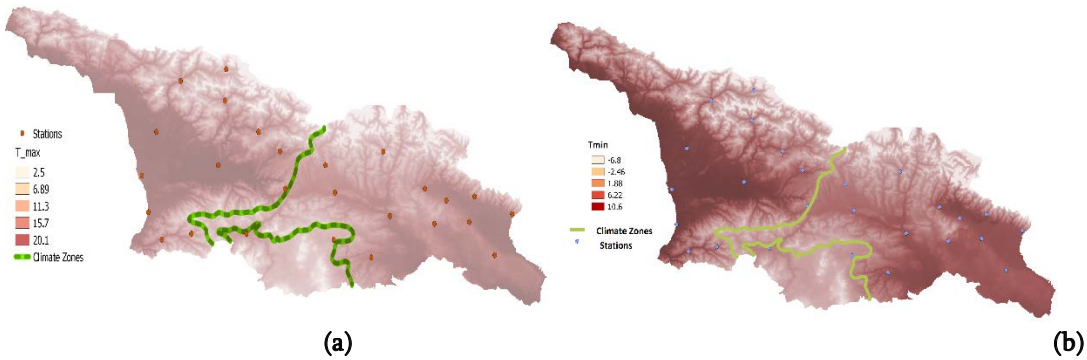

Fig. A.1 *Maps of annual mean maximal (a) and minimal (b) temperatures for 1961-85 period, interpolated from observation of 90 Georgian meteorological network's stations.*

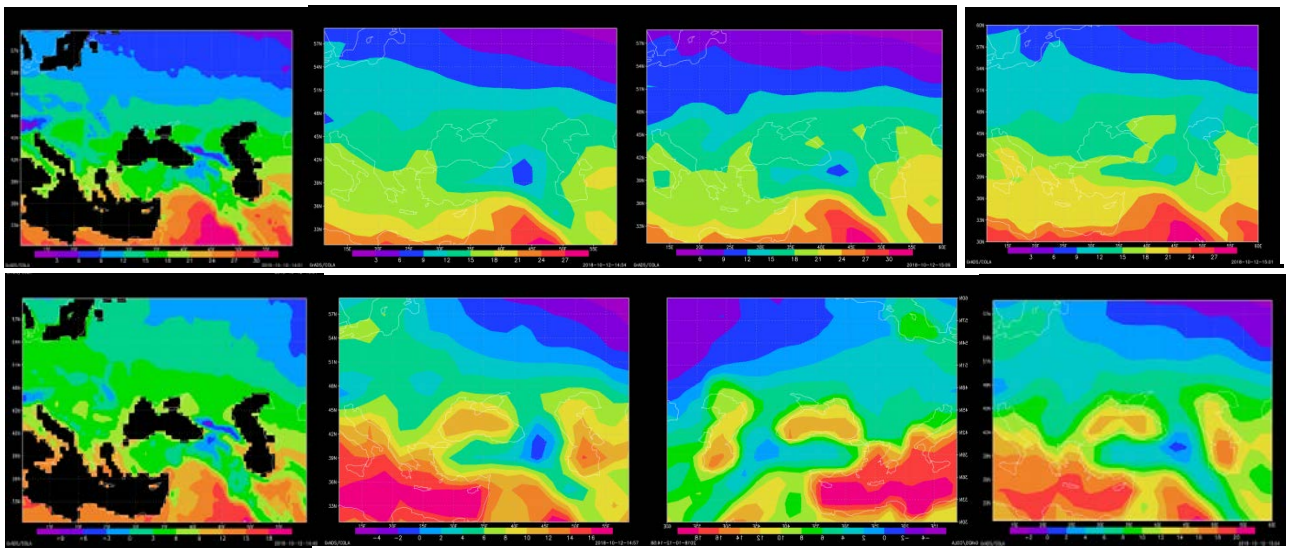

Fig. A.2. *Maps of observed and simulated Tmax and Tmin for 1961-85 period. The first plot on the upper panel is Tmax constructed from CRU data, the second – from the output of GFDL-CM3, III and IV – from HadGEM2-ES and MPI-ESM-MR, respectively. On the second panel are identical maps for Tmin.*

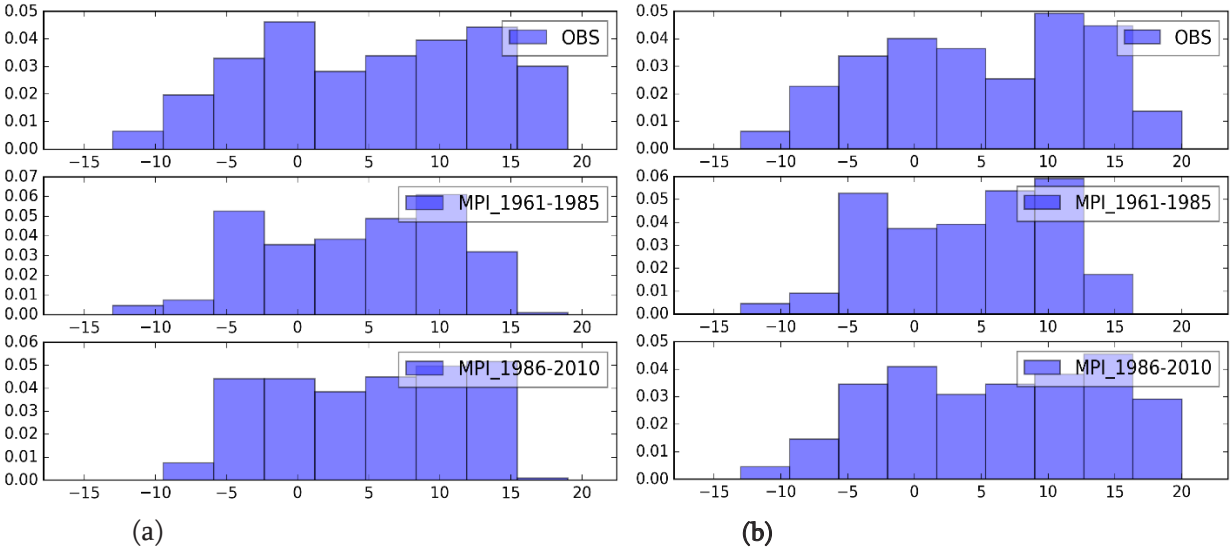

Fig. A.3 *(a) Original and (b) downscaled by delta addition method mean Tmin time series frequency distribution of observed and MPI simulated ones for two periods for Tbilisi.*

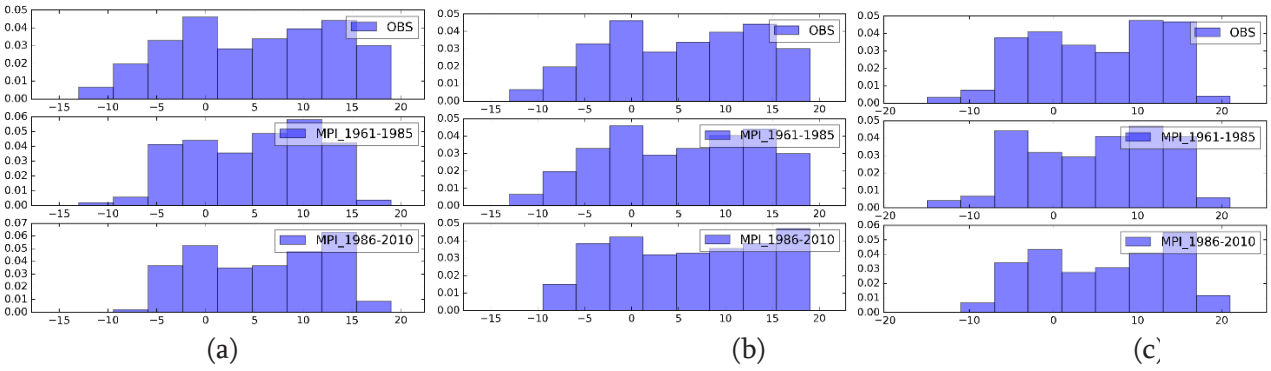

Fig. A.4. *Frequency distribution of mean Tmin time series for two periods for Tbilisi observed and MPI simulated downscaled by (a) Delta method (bias correction); (b) quartile mapping; (c) Statistical Asynchronous Regression (SAR) method.*

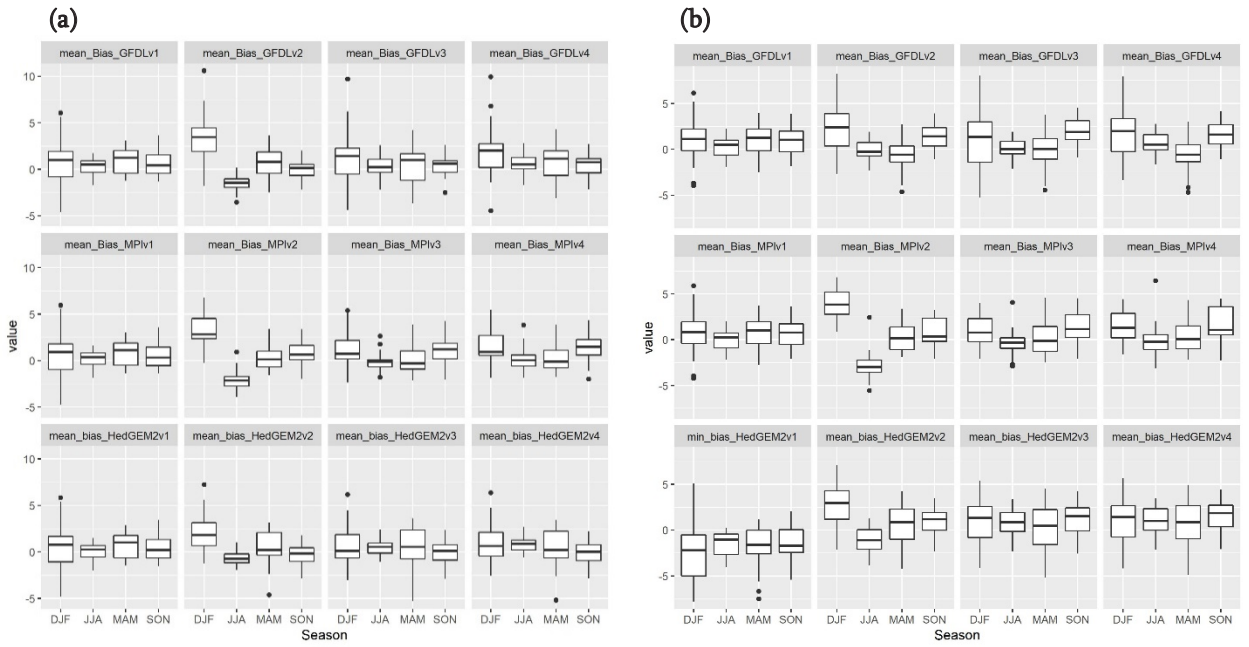

Fig. A.5. *Mean bias values by seasons between the observed and downscaled projections of mean monthly minimum (a) and maximum (b) temperatures at 27 stations in Georgia for validation period (1986-2010). Downscaling methods are shown as: 1 – Delta Addition, 2 – Delta Correction, 3 – Quantile Mapping, 4 – Asynchronous Linear Regression. Solid lines show medians, the boxes represent the range between first and third quartiles, and the whiskers indicate minimum and maximum values of all data.*

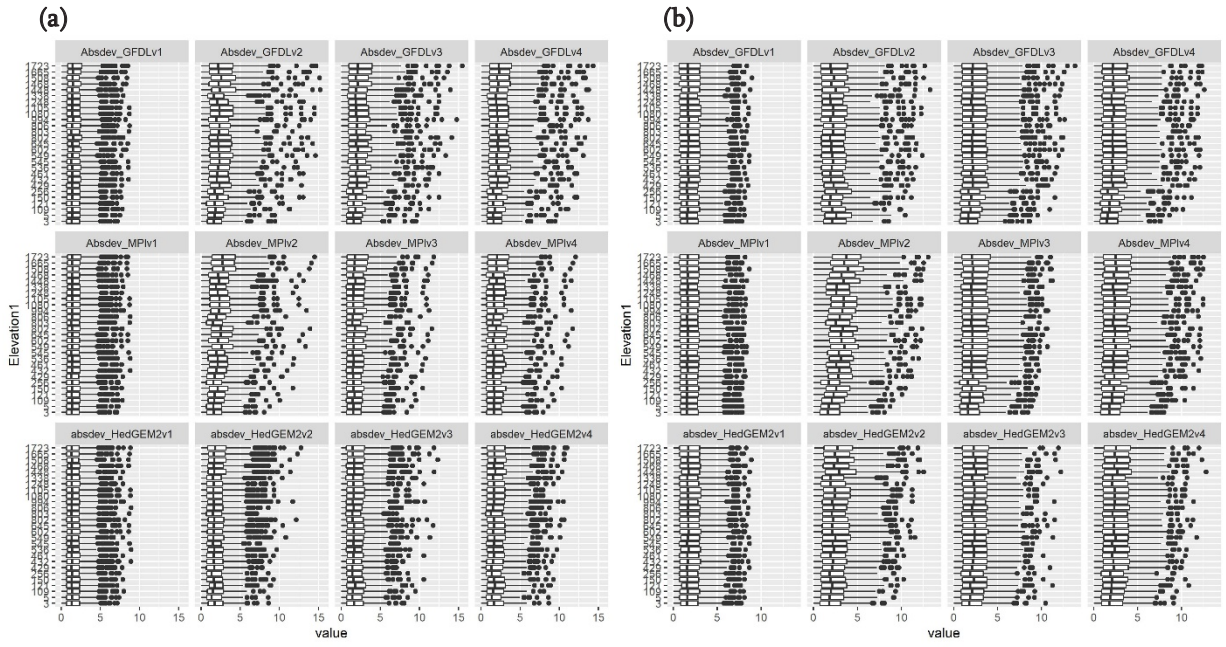

Fig. A.6. *Mean Absolute Errors (MAE) between the observed and downscaled projections of mean monthly minimum (a) and maximum (b) temperatures at 27 stations in Georgia for validation period (1986-2010). Values are plotted as a function of the station elevations. Downscaling methods are shown as: 1 – Delta Addition, 2 – Delta Correction, 3 – Quantile Mapping, 4 – Asynchronous Linear Regression. Solid lines show medians, the boxes represent the range between first and third quartiles, and the whiskers indicate minimum and maximum values of all data.*

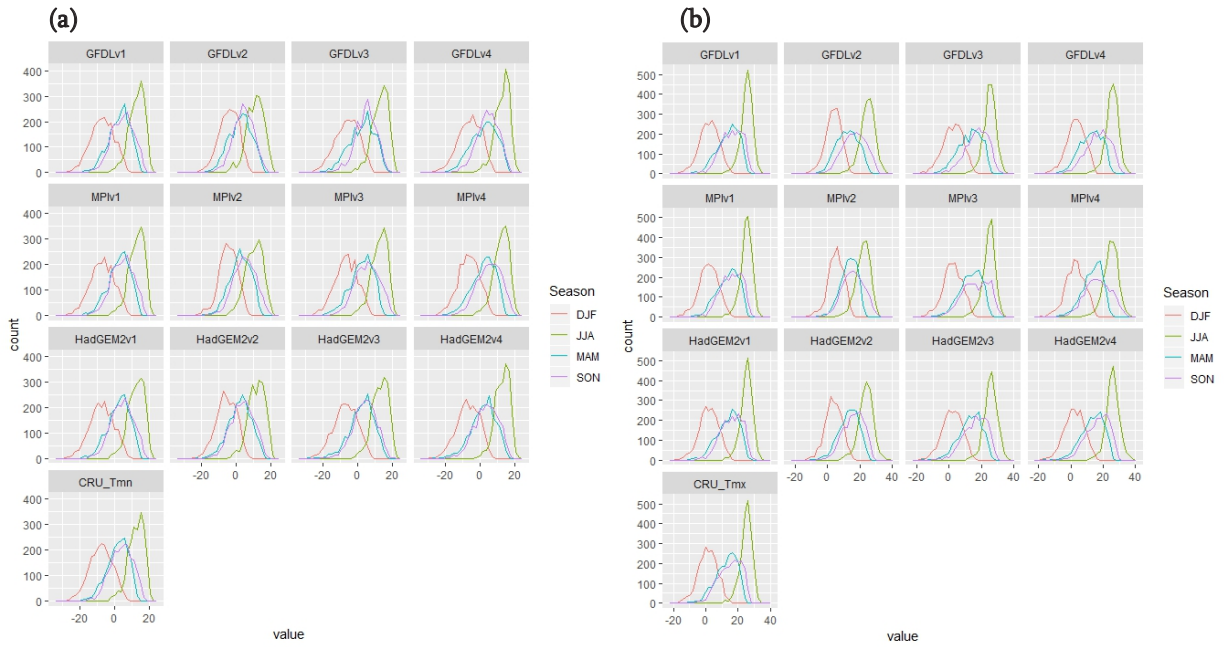

Fig. A.7. *Frequency polygons by seasons for the observed and downscaled projections of mean monthly minimum (a) and maximum (b) temperatures at 27 stations in Georgia for validation period (1986-2010). Downscaling methods are shown as: 1 – Delta Addition, 2 – Delta Correction, 3 – Quantile Mapping, 4 – Asynchronous Linear Regression.*

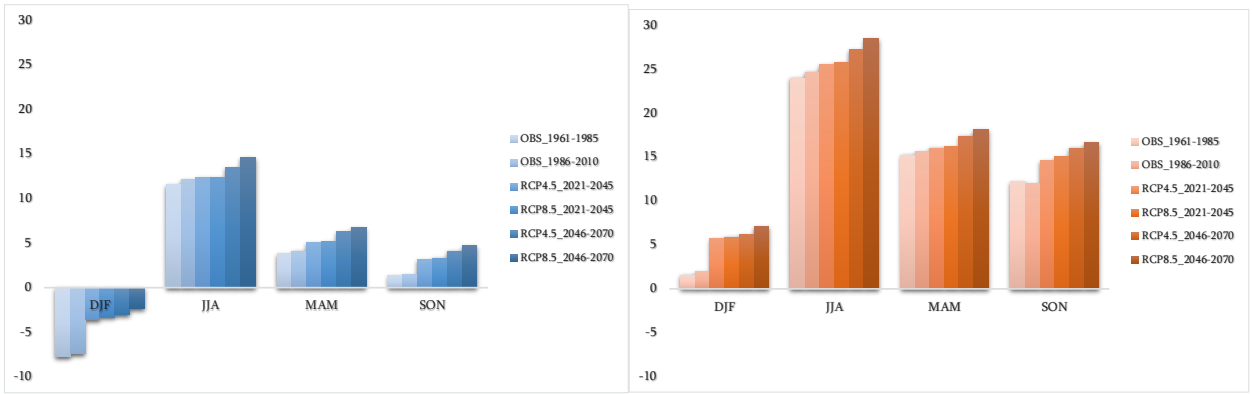

Fig. A.8. *Mean seasonal observed and projected minimum (a) and maximum (b) temperatures under RCP4.5 and RCP8.5 scenarios simulated by the subset of CMIP5 multi-model ensemble presented for four 25-years periods.*

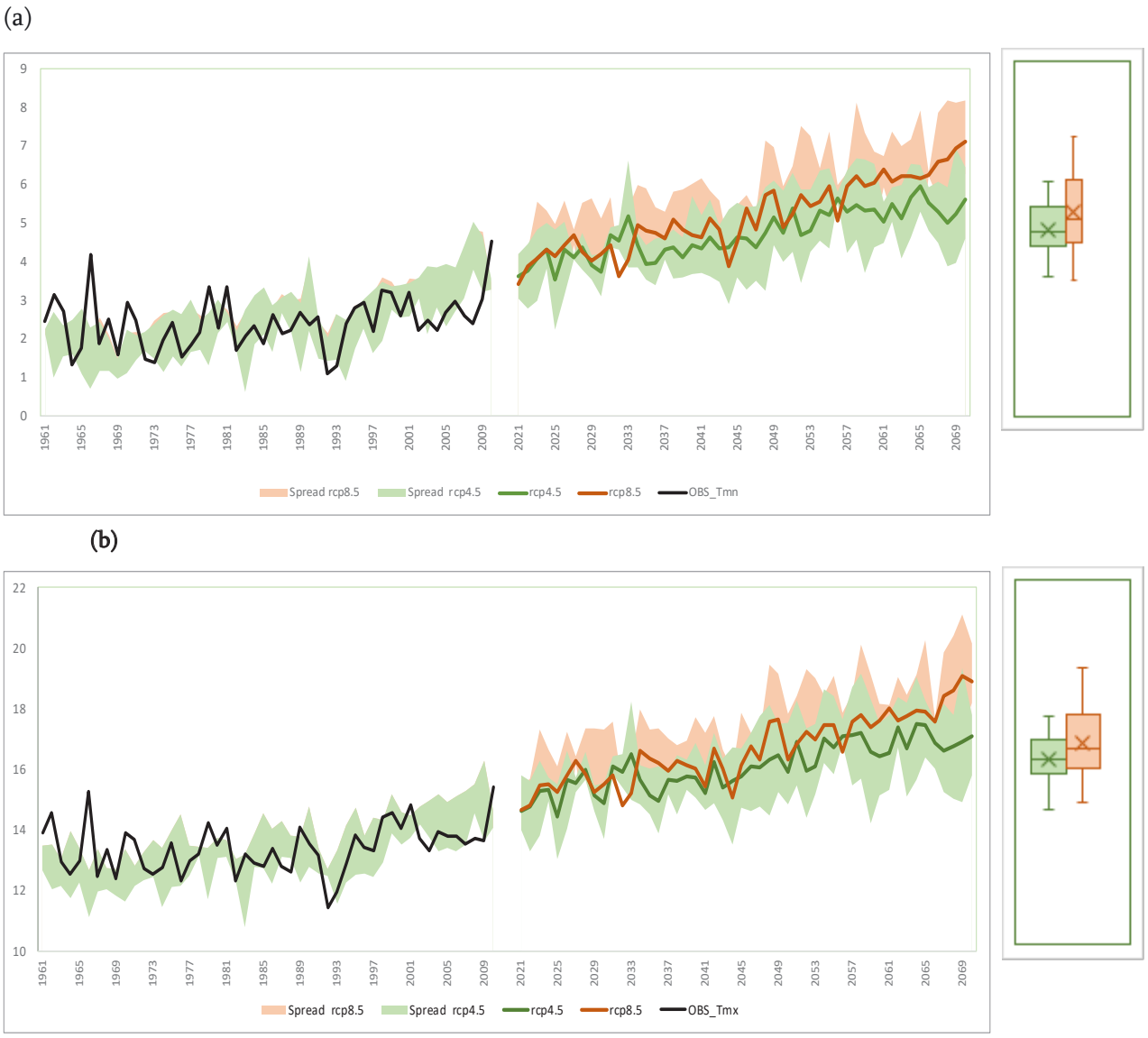

Fig. A. 9 *Time series of historical and projected change for the mean annual minimum (a) and maximum (b) temperatures, as simulated by the subset of CMIP5 multi-model ensemble averaged over 27 stations of Georgia. The shaded areas represent the spread of simulation results for individual models, while the heavy lines indicate the ensemble average. Results are based on statistical downscaling of 27 weather stations in Georgia. Change is computed relative to the 1961-2010 period. The spread amongst models, evident from the shaded area, is quantified by the box and whisker plots to the right of each panel. The boxes represent the range between first and third quartiles, and the whiskers indicate minimum and maximum values of all data for the 2021-2070 period for RCP4.5 and RCP8.5 scenarios separately.*

Appendix B. Tables

Table B.2. *Summary information for the selected stations in Georgia*

#	Station Name	Elevation (m)	Latitude (°N)	Longitude (°E)
1	Akhalqalaqi	1723	41.40	43.48
2	Akhaltsikhe	994	41.65	43.00
3	Ambrolauri	549	42.53	43.13
4	Bakuriani	1665	41.73	43.52
5	Bolnisi	536	41.45	44.57
6	Borjomi	802	41.83	43.38
7	Dedoplistskaro	803	41.47	46.10
8	Gori	602	42.00	44.12
9	Khashuri	645	42.03	43.82
10	Khulo	1338	41.65	42.30
11	Lagodekhi	429	41.82	46.30
12	Mestia	1448	43.07	42.75
13	Mta-Sabueti	1248	42.03	43.47
14	Pasanauri	1080	42.35	44.68
15	Poti	3	42.13	41.68
16	Qeda	256	41.60	41.92
17	Qobuleti	5	41.87	41.78
18	Qutaisi	109	42.25	42.62
19	Sachkhere	461	42.33	43.43
20	Sagarejo	806	41.75	45.32
21	Shovi	1508	42.70	43.68
22	Tbilisi	432	41.75	44.77
23	Telavi	545	41.93	45.52
24	Tianeti	1105	42.10	44.97
25	Tsalka	1468	41.60	44.10
26	Zestaphoni	150	42.12	43.02
27	Zugdidi	121	42.52	41.88

Table B.3. *Explained variances between candidate methods of mean minimum (a) and maximum (b) temperatures (predicted) over the Georgia territory. Values are Pearson's correlation coefficients (CC) averaged over 27 weather stations (Table 1). Downscaling methods are shown as: 1 – Delta Addition, 2 – Delta Correction, 3 – Quantile Mapping, 4 – Asynchronous Linear Regression*

(a)

GCM		GFDL				MPI				HadGEM2			
Method		1	2	3	4	1	2	3	4	1	2	3	4
Season	DJF	0.91	0.88	0.88	0.87	0.91	0.96	0.96	0.97	0.91	0.90	0.90	0.90
	MA												
	M	0.96	0.94	0.91	0.91	0.96	0.96	0.94	0.94	0.96	0.92	0.90	0.91
	JJA	0.98	0.96	0.96	0.96	0.98	0.96	0.97	0.95	0.97	0.96	0.95	0.95
	SON	0.96	0.97	0.96	0.96	0.96	0.97	0.95	0.95	0.96	0.97	0.96	0.96

(b)

GCM		GFDL				MPI				HadGEM2			
Method		1	2	3	4	1	2	3	4	1	2	3	4
Season	DJF	0.88	0.85	0.84	0.88	0.88	0.96	0.96	0.96	0.88	0.87	0.89	0.88
	MA												
	M	0.91	0.88	0.86	0.87	0.91	0.92	0.88	0.89	0.91	0.85	0.83	0.81
	JJA	0.93	0.88	0.92	0.90	0.93	0.86	0.88	0.82	0.92	0.91	0.87	0.86
	SON	0.91	0.93	0.91	0.91	0.92	0.92	0.90	0.88	0.91	0.92	0.89	0.89

Table B.4. *Statistical comparison of observed and downscaled mean monthly minimum (a) and maximum (b) temperatures during validation period (1986-2010). Downscaling methods are shown as: 1 – Delta Addition, 2 – Delta Correction, 3 – Quantile Mapping, 4 – Asynchronous Linear Regression*

(a)

Method	Model	μ	Med	SE_μ	SD	CV	MAD	Bias	MAE	RMSE
	CRU	2.58	3.20	0.17	8.74	3.39	8.40			
1	GFDL	3.22	4.00	0.17	8.59	2.67	8.18	0.65	1.33	1.73
	MPI	3.12	3.91	0.17	8.59	2.76	8.13	0.54	1.30	1.69
	HedGEM2	2.99	3.83	0.17	8.63	2.88	8.20	0.33	1.30	1.70
2	GFDL	3.22	3.52	0.14	7.31	2.27	7.43	0.65	2.00	2.72
	MPI	3.12	3.46	0.14	7.19	2.31	7.42	0.54	1.98	2.53
	HedGEM2	2.99	3.21	0.15	7.91	2.64	8.28	0.33	1.62	2.19
3	GFDL	3.23	3.83	0.16	8.49	2.63	8.43	0.66	1.60	2.20
	MPI	3.13	3.78	0.16	8.42	2.69	8.50	0.55	1.35	1.76
	HedGEM2	3.00	3.38	0.17	8.71	2.90	8.63	0.33	1.44	1.93
4	GFDL	3.52	4.05	0.16	8.37	2.38	8.55	0.94	1.68	2.32
	MPI	3.41	4.00	0.16	8.32	2.44	8.70	0.84	1.47	1.90
	HedGEM2	3.16	3.39	0.17	8.66	2.75	9.07	0.48	1.53	2.03

(b)

Method	Model	μ	Med	SE_μ	SD	CV	MAD	Bias	MAE	RMSE
	CRU	13.56	14.73	0.18	9.42	0.69	9.34			
1	GFDL	14.32	15.49	0.18	9.26	0.65	9.00	0.76	1.58	1.98
	MPI	14.06	15.22	0.18	9.27	0.66	9.09	0.50	1.50	1.89
	HedGEM2	14.33	15.54	0.18	9.27	0.65	9.03	0.77	1.58	1.98
2	GFDL	14.32	14.78	0.17	8.76	0.61	9.76	0.76	1.96	2.54
	MPI	14.06	14.64	0.14	7.32	0.52	7.53	0.50	2.44	3.02
	HedGEM2	14.33	14.90	0.16	8.27	0.58	8.45	0.77	2.03	2.55
3	GFDL	14.34	15.68	0.18	9.33	0.65	9.78	0.77	1.86	2.41
	MPI	14.07	15.14	0.17	9.09	0.65	9.63	0.51	1.55	1.96
	HedGEM2	14.34	15.35	0.18	9.55	0.67	9.86	0.78	1.86	2.26
4	GFDL	14.45	15.26	0.18	9.19	0.64	10.00	0.89	1.84	2.39
	MPI	14.38	15.35	0.17	9.02	0.63	9.35	0.81	1.71	2.19
	HedGEM2	14.60	15.66	0.18	9.54	0.65	9.65	1.04	1.96	2.38

Table B.5. *Statistical trends slope and significance of observed and downscaled mean monthly minimum (a) and maximum (b) temperatures during validation period (1986-2010). Downscaling methods are shown as: 1 – Delta Addition, 2 – Delta Correction, 3 – Quantile Mapping, 4 – Asynchronous Linear Regression*

(a)

	Model	GFDL				MPI				HadGEM2				CRU
	Method	1	2	3	4	1	2	3	4	1	2	3	4	
Slope	DJF	-0.008	0.019	0.027	0.024	-0.008	0.007	0.018	0.009	-0.008	0.086	0.098	0.099	-0.010
	MAM	0.003	0.084	0.107	0.104	0.003	0.057	0.078	0.072	0.003	0.088	0.109	0.101	0.043
	JJA	-0.030	0.058	0.072	0.072	-0.030	0.070	0.071	0.089	-0.030	0.061	0.080	0.070	0.040
	SON	-0.008	0.051	0.064	0.062	-0.008	0.100	0.119	0.127	-0.008	0.074	0.085	0.085	0.066
Rho	DJF	0.009	0.129	0.178	0.125	0.009	0.067	0.128	0.067	0.009	0.235	0.230	0.222	-0.080
	MAM	0.006	0.361	0.375	0.361	0.006	0.411	0.382	0.411	0.006	0.459	0.505	0.458	0.339
	JJA	-0.322	0.472	0.432	0.455	-0.322	0.535	0.536	0.536	-0.322	0.687	0.705	0.687	0.380
	SON	-0.035	0.400	0.428	0.409	-0.035	0.645	0.612	0.644	-0.035	0.558	0.544	0.555	0.603

(b)

Model		GFDL				MPI				HadGEM2				CRU
	Method	1	2	3	4	1	2	3	4	1	2	3	4	
Slope	DJF	-0.039	0.016	0.021	0.017	-0.039	0.005	0.006	0.006	-0.039	0.095	0.103	0.113	0.035
	MAM	-0.015	0.099	0.114	0.104	-0.015	0.051	0.074	0.066	-0.015	0.098	0.119	0.117	0.050
	JJA	-0.010	0.078	0.072	0.082	-0.010	0.084	0.080	0.110	-0.010	0.076	0.096	0.091	0.047
	SON	-0.016	0.078	0.079	0.082	-0.016	0.103	0.125	0.134	-0.016	0.057	0.070	0.068	0.076
Rho	DJF	-0.158	0.114	0.119	0.114	-0.158	0.055	0.064	0.055	-0.158	0.288	0.274	0.288	0.122
	MAM	-0.087	0.321	0.318	0.321	-0.087	0.228	0.208	0.223	-0.087	0.375	0.390	0.376	0.372
	JJA	-0.118	0.421	0.428	0.421	-0.118	0.424	0.450	0.424	-0.118	0.366	0.435	0.363	0.382
	SON	-0.138	0.402	0.400	0.397	-0.138	0.472	0.472	0.472	-0.138	0.363	0.298	0.363	0.589

Table B. 6. *Mean seasonal changes in observed and projected minimum (a) and maximum (b) temperatures under RCP4.5 and RCP8.5 scenarios simulated by the subset of CMIP5 multi-model ensemble between four 25-years periods. Differences are shown as: Δ, indexes indicate comparable periods, corresponding to: 1 - 1961–1985, 2 - 1986-2010, 3 – 2021-2045, 4 – 2046-2070*

	Season	Δ_{21}_OBS	Δ_{32}_RCP4.5	Δ_{32}_RCP8.5	Δ_{42}_RCP4.5	Δ_{42}_RCP8.5
Tmin, °C	DJF	0.32	3.82	4.12	4.36	5.09
	JJA	0.60	0.15	0.14	1.28	2.37
	MAM	0.27	1.01	1.12	2.15	2.62
	SON	0.08	1.65	1.90	2.67	3.30
	Year	0.32	1.66	1.82	2.62	3.35
Tmax, °C	DJF	0.40	3.73	3.99	4.29	5.19
	JJA	0.69	0.90	1.03	2.53	3.80
	MAM	0.34	0.41	0.56	1.80	2.46
	SON	-0.13	2.60	3.05	3.96	4.58
	Year	0.32	1.91	2.15	3.14	4.01

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Checklist of leaf beetles (Coleoptera: Chrysomelidae) from Sakartvelo (Georgia)

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A B S T R A C T

Leaf beetles (Coleoptera: Chrysomelidae) is one of the most numerous and most studied groups of insects all over the world. The paper represents renewed checklist of Chrysomelidae in Georgia. Our study revealed that 407 taxa belonging to 74 genera are currently known from Sakartvelo (Georgia). The provincial distributions are given based on available literature records. The species of which occurrences need confirmation are not included in the list but are given in the end separately. The paper is from the series representing summarizing data about different taxa.

Keywords: Leaf Beetles, Caucasus, Georgia, Chrysomelidae, Pests, Insects.

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Introduction

Leaf beetles (Coleoptera: Chrysomelidae) is one of the most numerous groups of insects with up to 45.000 species described [1,2]. They have an important role in ecosystems as they are ecologicaly connected with plants [3]. Very limited studies are available from Georgia (in Georgian: Sakartvelo) which is one of the world's biodiversity hotspots harboring a diverse fauna and flora [4]. First notes on the fauna of leaf beetles of Georgia were published in 1878 [5]. Later Zaitsev [6,7] provided some new data and Shengelia [8] published the first list of Chrysomelidae of Georgia including 22 species. Kobakhidze [9] indicated 10 species of chrysomelids for the Lagodekhi region. Since then, several authors contributed in the study of Chrysomelidae diversity of Georgia [10, 18] resulting in a total of 407 taxa recorded from Georgia. Subfamily classification subject to different opinions among researchers. Here, we adopt the classicial classification (excluding Bruchinae) and represent renewed checklist of Chrysomelidae distributed in Georgia.

We continue series of publishing renewed checklists of different taxa from Georgia, previously had been published checklists of bees [19] and scale insects [20].

Material and Methods

We analyzed all published and available literature about distributions of leaf beetles in Georgia. The species list and the mentioned localities are gathered from literature review on Georgian leaf beetles, no additional material or field work is included. Additionally, we preferred to list all the genera in alphabetical order, not per subfamily.

Gruev & Döberl [16], Özdikmen [21-26], and Löbl & Smetana [27] list some species as recorded from Georgia without showing any data regarding locality or collecting site, therefore we added these species with the locality information as "Georgia".

Results

Updated checklist

Genus – *Acolastus* Gerstaecker, 1855

1. *Acolastus fausti* (Weise, 1882)
   Georgian localities: Vashlovani (Lopatin, Seperteladze [15] as *Thelyterotarsus fausti*), SE Georgia (Lopatin [47] as *Acolastus georgicus*).

Genus - *Aeschrocnemis* Weise, 1888

2. *Aeschrocnemis caucasica* (Weise, 1886)
   Georgia [27], **Georgian localities:** Tbilisi [16], Borjomi, Martkopi, Sokhumi, Gagra [28].
3. *A. laterufa* (Pic, 1909)
   Georgia [27], **Georgian localities:** Mt. Kazbegi [16], Borjomi, Martkopi, Sokhumi [28].
4. *A. ossetica* (Heikertinger, 1922)
   Georgian localities: Samachablo (Shida kartli or South Ossetia), Kobi [16,28].
5. *A. pubipennis* (Reitter, 1892)
   Georgia [16, 27, 28]

Genus - *Agelastica* Dejean, 1836

6. *Agelastica alni* (Linnaeus, 1758)
   Georgian localities: Lagodekhi [9,18], Mtskhetisjvari, Skra [12], Colchis National Park [29], Abkhazia, Gagra [30], Batumi [48].

Genus - *Altica* Geoffroy, 1762

7. *Altica carduorum* Guérin-Méneville, 1858
   Georgia [16, 27].
8. *A. carinthiaca* Weise, 1888
   Georgian localities: Lagodekhi protected areas [18].
9. *A. hampei* (Allard, 1867)
   Georgian localities: Lagodekhi protected areas [18].
10. *A. helianthemi* Allard, 1859
    Georgia [16, 27].
11. *A. jarmilae* Král, 1979
    Georgia [27], Georgian localities: Adjara [16].
12. *A. oleracea* (Linnaeus, 1758)
    Georgia [16, 27], **Georgian localities:** Kojori, Tbilisi, Sokhumi [30], Lagodekhi protected areas [18].
13. *A. palustris* Weise, 1888
    Georgia [27], **Georgian localities:** Kodori Valley [16], Lagodekhi protected areas [18].
14. *A. quercetorum* Foudras, 1861
    Georgia [27], **Georgian localities:** Lagodekhi (Kobakhidze [9] as *Haltica saliceti* [18], Svaneti [16].
15. *A. tsharynensis* Ogloblin, 1921
    Georgia [16, 27].
16. *A. viridula* Weise, 1889
    Georgia [16, 27].

Genus - *Aphthona* Chevrolat in Dejean, 1836

17. *Aphthona abdominalis* (Duftschmid, 1825)
    Georgia [16, 27].
18. *A. beckeri* Jacobson, 1895
    Georgia [16, 27].

19. *A. euphorbiae* (Schrank, 1781)
Georgia [16, 27], **Georgian localities:** Khashuri, Bekami, Akhaldaba [31], Lagodekhi protected areas [18].
20. *A. flaviceps* Allard, 1859
Georgia [16, 27], **Georgian localities:** Pitsunda [31].
21. *A. gracilis* Faldermann, 1837
Georgia [16, 27], **Georgian localities:** Akhaldaba, Tbilisi, Borzhomi, Taugli [31].
22. *A. lutescens* (Gyllenhal, 1813)
Georgia [16, 27], **Georgian localities:** Pitzunda [31].
23. *A. nigriceps* (Redtenbacher, 1842)
Georgia [16, 27], **Georgian localities:** Tbilisi [31].
24. *A. nigriscutis* Foudras in Mulsant, 1860
Georgia [16, 27], **Georgian localities:** Akhaldaba/Kvishheti [31].
25. *A. nonstriata* Goeze, 1777
Georgia [16, 27], **Georgian localities:** Pitzunda [31], Colchis National Park [29].
26. *A. pygmaea* Kutschera, 1861
Georgia [27], **Georgian localities:** Akhaldaba [31], Tbilisi [16].
27. *A. reitteri* Allard, 1884
Georgia ([27], **Georgian localities:** Ertso surroundings, Lagodekhi [15,18].
28. *A. rugipennis* Ogloblin, 1927
Georgia [16, 27], **Georgian localities:** Vashlovani reserve [31].
29. *Aphthona semicyanea* Allard, 1859
Georgia [16, 27], **Georgian localities:** Kodzhory [31].
30. *A. testaceicornis* Weise, 1894
Georgia [27, 32], **Georgian localities:** Avadhara [31], Lagodekhi protected areas [18].
31. *A. violacea* Koch, 1803
Georgia [16, 27], **Georgian localities:** Akhaldaba, Gagra [31].

Genus - *Batophila* Foudras, 1860
32. *Batophila fallax* Weise, 1888
Georgian localities: Svaneti [16].
33. *B. olexai* Král, 1964
Georgia [16], **Georgian localities:** Mariamjvari, Babaneuri [30], Lagodekhi protected areas [18].

Genus - *Bedelia* Lefevre, 1875
34. *Bedelia insignis* Lefèvre, 1875
Georgian localities: Tbilisi (Seperteladze [11] as *Bedelia angustata*), Adigeni (Seperteladze [14] as *Bedelia angustata*)

Genus - *Bromius* Chevrolat 1836
35. *Bromius obscurus* (Linnaeus, 1758)
Georgian localities: Tana valey (Seperteladze [13] as *Adoxus*), Atskuri [14], Abkhazeti (Gulripshi, Machara valley) [30].

Genus – *Calomicrus* Stephens, 1831
36. *Calomicrus caucasicus* (Weise, 1879)
Georgian localities: Manglisi, Borjomi, Lomismta, Kobi, Teberda (Shengelia [8] as *Luperus*), Tana valley (Seperteladze [13] as *Luperus caucasicus*), Abastumani (Shengelia [8] as *Luperus*) [14].
37. *C. discolor* (Faldermann, 1837)

Georgian localities: Borjomi (Shengelia [8] as *Luperus*), Tbilisi [8], (Seperteladze [11] as *Luperus*) Atskuri, Abastumani [8,14].

38. *C. orientalis* (Faldermann, 1837)
Georgian localities: Atskuri [12], (Seperteladze [14] as *Luperus orientalis*).

Genus - *Cassida* Linnaeus, 1758

39. *Cassida bella* Faldermann, 1837
Georgian localities: Borjomi, Bakuriani, Lomismta, Tana lowland [6], Tana valley, Mtskhetisjvari [12], Aspindza, Atskuri [14].
40. *C. denticollis* Suffrian, 1844
Georgian localities: Bakuriani, Borjomi, Kvishkheti, Lagodekhi [6,18], Mtskheta, Tbilisi [6,11 misspelled as *genticollis*) Samgori (Seperteladze [11] as *genticollis*), Breti, Abisi [12], Aspindza [14].
41. *C. hablitziae* Motschulsky, 1838
Georgian localities: Borjomi, Tsemi, Bakuriani, Shuamta, Shulaveri [6],Tana valley [6,13] Ajara, Keda; Aphkhazeti, Mamzishkha [30].
42. *C. hemisphaerica* Herbst, 1799
Georgian localities: Tbilisi, Avchala (Seperteladze [11] as *haemisphaerica nigriventris*).
43. *Cassida inquinata* Brullé, 1832
Georgian localities: Lagodekhi [12,18], Colchis National Park [29].
44. *C. margaritacea* Schaller, 1783
Georgian localities: Borjomi, Bakuriani, Kvishkheti, Lagodekhi [6,18], Tbilisi, Mtskheta [6,11], Atskuri [6,14].
45. *C. murraea* Linnaeus, 1767
Georgian localities: Skra [13], Apkhazeti [30].
46. *C. nebulosa* Linnaeus, 1758
Georgian localities: Teliani, Lagodekhi, Asureti (Elisabedtali), Pasanauri, Khashuri, Borjomi, Agara [6],Tbilisi [11], Kartli [12], Logodekhi protected areas [18].
47. *C. nobilis* Linnaeus, 1758
Georgian localities: Teliani, Karaia, Borjomi [6], Khidistavi, Grakali, Skra surroundings, Noste, Kaspi surroundings [12], Kumisi [11].
48. *C. palaestina* Reiche, 1858
Georgian localities: Tbilisi, Kumisi, Mtskheta [11],Gori, Khashuri, Khidistavi, Skra [12], Logodekhi protected areas [18].
49. *C. pannonica* Suffrian, 1844
Georgian localities: Samgori [11].
50. *C. parvula* Boheman, 1854
Georgian localities: Eldari [6], Surroundins of lake Kumisi [12].
51. *C. prasina* Illiger, 1798
Georgian localities: Tbilisi [11].
52. *C. reitteri* Weise, 1892
Georgian localities: Kumisi [11].
53. *C. rubiginosa* Muller, 1776
Georgian localities: Bakuriani, Borjomi, Algeti, Mamutli, Likhi, Surami, Tbilisi, Karaia, Teliani, Surroundings of Khozapini (Kartsakhi)[6], Kojori [6,11], Atskuri [6,14].
54. *C. rufovirens* Suffrian, 1844
Georgia [27].
55. *C. sanguinolenta* Muller, 1776
Georgian localities: Borjomi, Bakuriani, Tbilisi, Mtskheta [6], Tana valley [6,13], Abastumani [6,14].
56. *C. saucia* Weise, 1889
Georgian localities: Akhalkalaki (Kartli) [13].

57. *C. stigmatica* Suffrian, 1844
Georgian localities: Tbilisi (11).
58. *C. subreticulata* Suffrian, 1844
Georgian localities: Lagodekhi [6,18], Tbilisi [6,11], Mtskhetisjvari (Seperteladze [13] as *subreticulata helvex*), Colchis National Park [29].
59. *C. transcaucasica* Borowiec et Swietojanska, 2001
Georgian localities: Borjomi [33].
60. *C. undecimnotata* Gebler, 1841
Georgia [27].
61. *C. vibex* Linnaeus, 1767
Georgian localities: Borjomi, Bakuriani, Kvishkheti, Likhi, Gomi [6], Tana valley [6,13].
62. *C. viridis* Linnaeus, 1758
Georgian localities: Borjomi, Bakuriani, Algeti lowland, Manglisi, Tana lowland [6], Lagodekhi [6,9,18], Kojori [11], Tana valley, SkraMtskhetisjvari, Chocheti, Metekhi [13], Abastumani [6,14], Achara (Adjara)[30].

Genus - *Chaetocnema* Stephens, 1831
63. *Chaetocnema breviuscula* (Faldermann, 1837)
Georgian localities: Ahaldaba, Rustavi, poima Kura river [35].
64. *Ch. concinna* Marsham, 1802
Georgia [27], **Georgian localities:** Lagodekhi [9,18].
65. *Ch. heptapotamica* Lyubishchev, 1963
Georgia [27], **Georgian localities:** Rustavi [34].
66. *Ch. hortensis* (Geoffroy, 1785)
Georgian localities: Apkhazeti [30], Colchis National Park [29].
67. *Ch. obesa* (Boieldieu, 1859)
Georgian localities: Surami [35].
68. *Ch. orientalis* (Bauduer, 1874)
Georgian localities: Poti, Tskhakaia [15], Colchis National Park [29].
69. *Ch. picipes* Stephens, 1831
Georgia [16, 27], **Georgian localities:** Mtkvari (Ahald. Kura River) [35].
70. *Ch. semicoerulea* (Koch, 1803)
Georgian localities: Abkhasia, Pitsunda, N. Gudauta, Pskhu, Bzyb river, Tbilisi, Ahaldaba, Ahaldaba-Hashuri [35].
71. *Ch. tbilisiensis* Konstantinov et al., 2011
Georgian localities: Tbilisi [35]. .
72. *Ch. tibialis* (Illiger, 1807)
Georgian localities: Surami, Rustavi, Mtkvari (Kura river) [35].

Genus - *Cheilotoma* Chevrolat, 1837
73. *Cheilotoma erythrostoma* Faldermann, 1837
Georgian localities: Tbilisi, Gardabani (Seperteladze [11] as *Chilotoma*), Igoeti (Seperteladze [13] misspelled as *Chilotoma*).

Genus - *Chrysochares* Morawitz, 1861
74. *Chrysochares constricticollis* Lopatin, 1963
Georgian localities: Tbilisi (Bot.Gard), Rustavi [15].

Genus - *Chrysolina* Motschulsky, 1860

75. *Chrysolina adzharica* Lopatin, 1988
Georgian localities: Adjara, Jojo, Chakvistavi, Chkhutuneti [30].
76. *Ch. analis* Linnaeus, 1767
Georgian localities: Akhaltsikhe [14].
77. *Ch. armeniaca* (Faldermann, 1837)
Georgia [42], **Georgian localities:** Dmanisi [15], Gagra [30].
78. *Ch. apsilaena* (Silfverberg,1977)
Georgia [27].
79. *Ch. caspica* (Weise, 1892)
Georgian localities: Lebarde (Seperteladze [12] as *Chrysomela*), Gagra, Achandara [40], Logodekhi protected areas [18].
80. *Ch. cerealis cerealis* (Linnaeus, 1767)
Georgia [25], **Georgian localities:** Gurshevi [10].
81. *Ch. cerealis rufolineata* (Motschulsky, 1860)
Georgia [27].
82. *Ch. chalcites* (Germar, 1824)
Georgia [27], Georgian localities: Tbilisi, Samgori (Seperteladze [11] as *Chrysomela*), Akhaltsikhe, Khertvisi, Atskuri [14].
83. *C. circumducta* (Ménétriés, 1848)
Georgia [46].
84. *Ch. coerulans coerulans* (Scriba, 1791)
Georgia [27, 40].
85. *Ch. coerulans splendorifera* Motschulsky, 1860
Georgia [27].
86. *Ch. cuprina* (Duftschmid, 1825)
Georgia [27, 46].
87. *Ch. differens* (Franz, 1952)
Georgia [27], Georgian localities: Borjomi, Khino, Svaneti, Gori [30].
88. *Ch. fastuosa* (Scopoli, 1763)
Georgia [27], Georgian localities: Tbilisi (Seperteladze [11] as *Chysomela*), Brili, Chocheti, Metekhi, Mtskhetisjvari [13], Akhalkalaki [14], Abkhazeti [30].
89. *Ch. geminata* (Paykull, 1799)
Georgia [27], Georgian localities: Tbilisi (Seperteladze [11] as *Chrysomela*), Tana valley (Seperteladze [13] as *Chrysomela*).
90. *Ch. graminis* (Linnaeus, 1758)
Georgian localities: Kojori (Seperteladze [12] as *Chrysomela***)**
91. *Ch. grata* (Faldermann, 1837)
Georgia [41].
92. *Ch. gypsophilae* (Küster, 1845)
Georgia [27], Georgian localities: Utsera [10], Aspindza, Surroundings of Rustavi [14], Tbilisi (Seperteladze [11] as *Chrysomela*), [30].
93. *Ch. haemoptera* (Linnaeus, 1758)
Georgia [27].
94. *Ch. halysa* Bechyne, 1950
Georgia [42], **Georgian localities:** Borjomi [40].
95. *Ch. herbacea* (Duftschmid, 1825)
Georgia [27], Georgian localities: Tbilisi, Kojori (Seperteladze [11] as *Chrysomela menthastri*), Skra surroundings, Metekhi, Mejvriskhevi (Seperteladze [13] as *Chrysomela menthastri*), Akhaltsikhe, Adigeni, Samshvilde, Akhalkalaki, Surroundings of lake Paravani [14], Akhali atoni, Akhali Gagra [30].

96. *Ch. hyperici daghestanica* (Reitter, 1913)
Geogia [27], Georgian localities: Tbilisi, Ninotsminda (Seperteladze [11, 14] as *Chrysomela hyperici*).
97. *Ch. imperfecta bakuensis* Bechyné, 1952
Georgia [27, 42], **Georgian localities:** Tbilisi [30].
98. *Ch. limbata* (Fabricius, 1775)
Georgia [27], Georgian localities: River Tetnashera valley [10], Aspindza, surroundings of Rustavi, Ninotsminda [14], Lagodekhi, Tbilisi [30], Logodekhi protected areas [18].
99. *Ch. marginata* (Linnaeus, 1758)
Georgian localities: Samgori, Ialguja, Surroundings of lake Kumisi, Kojori, Tbilisi (Seperteladze [11] as *Chrysomela*), Adigeni, Akhaltsikhe, Vardzia, Akhalkalaki, Ninotsminda [14], Bakuriani, Ozurgeti, Tbilisi [30].
100. *Ch. olivieri azurea* Bechyné, 1946
Georgia [27].
101. *Ch. orientalis intercalaria* Bechyné, 1950
Georgia [27].
102. *Ch. polita ogloblini* Ter-Minassian, 1950
Georgia [27], **Georgian localities:** Tbilisi [11,30]. Tana valley, Skra, Mtskhetisjvari, Mejvriskhevi [12], Tbilisi, Bakuriani, Western Geoegia [30].
103. *Ch. porphyrea* (Faldermann, 1837)
Georgia [27], Georgian localities: Atskuri, Zekari pass [14], Abkhazia [30].
104. *Ch. pseudolurida* (Roubal, 1917)
Georgian localities: Surroundings of Vaziani, Surroundings of Kumisi, Kojori, Tbilisi (Seperteladze [11] as *Chrysomela lurida*), Adigeni, Ota, Akhalkalaki, Ninotsminda (Seperteladze [14] as *Chrysolina lurida*).
105. *Ch. reitteri* (Weise, 1884)
Georgia [27], **Georgian localities:** Mestia [30].
106. *Ch. rosti* (Weise, 1892)
Georgian localities: Abkhazia, Tbilisi [30].
107. *Ch. sahlbergi* (Menetries, 1832)
Georgian localities: Kojori, Near Tbilisi (Seperteladze [11] as *Chrysomela*), Gudauta district [30].
108. *Ch. salviae* (Germar, 1824)
Georgian localities: Surroundings of Variani, Tbilisi (Seperteladze [11] as *Chrysomela*), Igoeti (Seperteladze [13] as *Chrysomela*), Akhaltsikhe, Atskuri [14].
109. *Ch. songarica* Gebler, 1843
Georgia [27], **Georgian localities:** Ialguja, Pitareti, Tandzia [15] as *Ch. hyrcana*).
110. *Ch. staphylaea* (Linnaeus, 1758)
Georgian localities: Borjomi [30]
111. *Ch. sturmi* (Westhoff, 1882)
Georgian localities: Kurzu, Akhmeta (Seperteladze [12] as *Crysomela violacea* Mull). New Gagra, Bzipi gorge, Borjomi [30].
112. *Ch. tesari* (Roubal, 1936)
Georgia [42], **Georgian localities:** Surroundings of Lake Ertso (As *Chrysomela tesari*, in Seperteladze [12], Surroundings of Lake Ertso, Tskratskaro, Tianeti [15] as *Ch. kulzeri*.

Genus - *Chrysomela* Linnaeus, 1758

113. *Chrysomela collaris* Linnaeus, 1758
Georgian localities: Atskuri (Seperteladze [14] as *collare*)
114. *Ch. populi* Linnaeus, 1758
Georgian localities: Surroundings of Rustavi, Mtskheta, Tbilisi, Sartichala (Seperteladze [11] as *Melasoma populi*), Tana valley, Metekhi, Gori, Ateni, Kareli, Igoeti, Muxrani, Gorisjvari (Seperteladze [13] as *Melasoma popili*), Akhaltsikhe, Abastumani [14].

115. Ch. vigintipunctata Scopoli, 1763
Georgian localities: Mtskheta (Seperteladze [11] as *Melasoma populi*).

Genus - *Clytra* Laicharting, 1781
116. Clytra atraphaxidis (Pallas, 1773)
Georgian localities: Tbilisi, Near Tbilisi [11].
117. C. laeviuscula (Ratzeburg, 1837)
Georgian localities: Tbilisi [11],Gori, Tkviavi, Brili, Skra, Mtskhetisjvari, Mejvriskhevi [13], Aspindza, Surroundings of Rustavi, Vardzia, Surroundings of lake Paravani [14].
118. C. nigrocincta Lacordaire, 1848
Georgian localities: Tbilisi [11].
119. C. novempunctata Olivier, 1808
Georgian localities: Tbilisi [11], Khakhabo [30].
120. C. quadripunctata (Linnaeus, 1758)
Georgian localities: Tbilisi (Krtsanisi) [11], Grakli, Khidistavi, Mejvriskhevi [13], Akhaltsikhe, Vardzia, Aspindza, Khertvisi [14].
121. C. valeriana (Ménétriés, 1832)
Georgian localities: Tbilisi [11], Igoeti, Brili, Breti, Ali, Mtskhetisjvari, Skra surroundings, Skra [13], Abastumani (Seperteladze [14] as *valerianae*).
Genus – *Colaphellus* Weise, 1916
122. Colaphellus sophiae hoefti Menetries, 1832
Georgian localities: Ialguja, Samgori, Surroundings of Kumisi, Tbilisi (Seperteladze [11] as *Colaphellus hofti*), Atskuri (Seperteladze [14] as *Colaphellus hofti*).

Genus - *Coptocephala* Chevrolat, 1836
123. Coptocephala chalybaea (Germar, 1824)
Georgian localities: Digomi, Vashlovani, Lisi lake surroundings [12].
124. C. destinoi Fairmaire, 1884
Georgia [27].
125. C. rubicunda rossica (Medvedev, 1977)
Georgia [27].
126. C. scopolina **(**Linnaeus, 1767)
Georgian localities: Kesleti, Chishkhali, Shovi, Buba, Gurshevi [10], Akhalkalaki surroundings [13].
127. C. unifasciata (Scopoli, 1763)
Georgian localities: Tbilisi, Samgori [11],)Mereti, Tkviavi, Zerti, Mejvriskhevi, Kheltubani, Noste, Igoeti, Kaspi surroundings, Kavtiskhevi, Tsinarekhi, Chocheti, Metekhi, Skra [13], Atskuri [14].

Genus - *Crepidodera* Chevrolat in Dejean, 1836
128. Crepidodera aurata (Marsham, 1802)
Georgia [16, 27].
129. C. aurea (Geoffroy, 1785)
Georgia [16, 27].
130. C. fulvicornis (Fabricius, 1792)
Georgia [16, 27].
131. C. lamina (Bedel, 1901)
Georgia [16, 27].
132. C. plutus (Latreille, 1804)
Georgia [16, 27].

Genus - *Crioceris* Müller, 1764

133. *Crioceris asparagi* (Linnaeus, 1758)
Georgian localities: Gori [13], Adigeni, Atskuri [14].
134. *C. bicruciata* (Sahlberg, 1823)
Georgian localities: Surroundings of lake Paravani (Seperteladze [14] misspelled as *bircuciata*), Borjomi [30].
135. *C. duodecimpunctata* (Linnaeus, 1758)
Georgian localities: Gori, Skra, Mtskhetis jvari [13], Atskuri [14].
136. *C. quatuordecimpunctata* (Scopoli, 1763)
Georgian localities: Skra [13], Adigeni [14].

Genus - *Cryptocephalus* Geoffroy, 1762
137. *Cryptocephalus androgyne* Marseul, 1875
Georgian localities: Mtskheta [Seperteladze [11] as *coerulescens*).
138. *C. anticus* Suffrian, 1848
Georgian localities: Plavi, Brili (Seperteladze [13] as *octacosmus*)
139. *C. apicalis* Gebler, 1830
Georgian localities: River Tana valley [13].
140. *C. bicolor* Eschscholz, 1818
Georgian localities: Teliani, Lagodekhi (Seperteladze [12] as *concinnus*), [18], Atskuri (Seperteladze [12,14] as *concinnus*)
141. *C. bilineatus* (Linnaeus, 1767)
Georgia [27].
142. *C. bipunctatus* (Linnaeus, 1758)
Georgian localities: Tbilisi [11], Shavshvebi, Skra, Gorijvari, Mejvriskhevi [13], Atskuri [14].
143. *C. blandulus* Harold, 1872
Georgian localities: Tbilisi [11].
144. *C. chrysopus* Gmelin, 1790
Georgian localities: Mtskheta [11], Atskuri [14].
145. *C. concolor* Suffrian, 1847
Georgian localities: Tbilisi, Ialguji, Sadakhlo, Kojori, Vazianni surroundings [11],River Tana Valley, Khrtsisi, Igoeti, Brili, Gomi (misspelled as Gromi), Tkviavi, Karaleti, Khashuri surroundings, Savshvebi, Mtskhetisjvari, Skra surroundings, Rene, Skra, Kavtiskhevi [13], Abastumani, Adigeni, Aspindza, Surroundings of Rustavi, Akhaltsikhe, Akhalkalaki, Zekari pass, Atskuri [14].
146. *C. connexus* Olivier, 1807
Georgian localities: Samgori [11], Mereti, Noste, Igoeti, Metekhi [13], Atskuri, Zekari pass [14].
147. *C. cribratus* Suffrian, 1847
Georgian localities: Tbilisi, Mtskheta [11], River Tana Valley [13], Sapara, Adigeni [14], Samegrelo [30].
148. *C. cristula* Dufour, 1843
Georgian localities: Kesleti, Gvandra, Ipari, Shovi, Buba, Dolomistsveri, Glola, Gebi, Chiora, Saglolo, Tsana, Gentsvishi, Khutia [10], Kitsnisi, Tkviavi, Mereti, Mtskhetisjvari, Mejvriskhevi, Zerti, Kheltubani, Gorisjvari [13], Abastumani, Vardzia, Atskuri [14].
149. *C. curda* Jakobson, 1897
Georgia [27].
150. *C. duplicatus* Suffrian, 1847
Georgia [27].
151. *C. elegantulus* Gravenhorst, 1807
Georgian localities: Tbilisi, Avchala [11], Abastumani, Vardzia, Akhaltsikhe, Zekari pass [14], near Alazani and Agrichai joint [30].
152. *C. ergenensis* Morawitz, 1863
Georgian localities: Ialguji (Seperteladze [11] as *C. ergenensis georgicus*).

153. C. exiguus Schneider, 1792
Georgian localities: Tbilisi [11]
154. C. flavipes (Fabricius, 1781)
Georgian localities: Georgia, Tbilisi, Betania, Tskheta, Sadakhlo [11], Igoeti, Brili, Mejvriskhevi, Zerti, Rene, Skra surroundings [13], Atskuri, Akhaltsikhe [14].
155. C. flexuosus Krynicki, 1834
Georgian localities: Ialguja [11].
156. C. frenatus Laicharting, 1781
Georgian localities: Orchard of acclimatisation [11].
157. C. fulvus (Goeze, 1777)
Georgian localities: Tbilisi [11].
158. C. gamma Herrich-Schäffer, 1835
Georgian localities: Ialguja [11], Skra surroundings [13].
159. C. imperialis Laicharting, 1781
Georgian localities: Mtskheta [12], Atskuri [12,14].
160. C. janthinus Germar, 1824
Georgian localities: Rene, Karaleti, Kaspi surroundings, Metekhi, Mtkhetis Jvari [13].
161. C. labiatus Linnaeus, 1760
Georgian localities: Tbilisi [11]
162. C. laetus Fabricius, 1792
Georgia [27,36].
163. C. lederi Weise, 1889
Georgian localities: Atskuri, Surroundings of lake Ertso [12].
164. C. moraei (Linnaeus, 1758)
Georgian localities: Kitsnisi, Mereti, Mtskhetis Jvari, Zerti, Gomi (misspelled as Gromi), Mejvriskhevi, Skra, Shavshvebi, Gorisjvari, Noste, Chocheti [13], Atskuri, (Seperteladze [14] misspelled as *moraci*), Colchis National Park [29].
165. C. ocellatus Drapiez, 1819
Georgian localities: Tbilisi, Mtskheta [11],Tana valley, Skra [13], Atskuri, Akhaltsikhe [14], Colchis National Park [29].
166. C. octomaculatus Rossi, 1790
Georgian localities: Mejvriskhevi [13], Akhaltsikhe [14], Gudauri [30].
167. C. octopunctatus (Scopoli, 1763)
Georgian localities: Georgia, Akhaltsikhe [12], Akhaltsikhe [14], Gudauri [30].
168. C. parvulus Müller, 1776
Georgian localities: Chiatura, Sokhumi, Kojori, Teliani [12].
169. C. phaleratus (Tappes, 1871)
Georgia [27, 53].
170. C. populi Suffrian, 1848
Georgian localities: Tkviavi [13], Adigeni [14].
171. C. praticola Weise, 1889
Georgia [27,36].
172. C. prusias Suffrian, 1853
Georgian localities: Borjomi, Mtskheta [12], Atskuri [12,14].
173. C. pusillus Fabricius, 1777
Georgian localities: Tkviavi, Mtskhetisjvari, Gorisjvari [13].
174. C. pygmaeus vittula Suffrian, 1848
Georgia [27].
175. C. quadriguttatus Richter, 1820
Georgia [36], **Georgian localities:** Akhalkalaki [14].

176. C. quadripustulatus Gyllenhal, 1813
Georgian localities: Tbilisi, Mtskheta [11].
177. C. rubi Ménétriés, 1832
Georgia [27].
178. C. schaefferi Schrank, 1789
Georgian localities: Tbilisi [11], Igoeti [13], Atskuri, Akhaltsikhe [14].
179. C. sericeus (Linnaeus, 1758)
Georgian localities: Georgia, Kojori, Tabakhmela, Tbilisi (Botanical Garden), Vaziani [11], Mejvriskhevi, Abisi, Mtskhetis Jvari, Khashuri surroundings, Skra surroundings, Ali, Gomi, Zerti, Igoeti, Tsinarekhi, Akhalkalaki surroundings [13], Aspindza, Surroundings of Rustavi, Akhalkalaki, Atskuri [14].
180. C. sexpunctatus (Linnaeus, 1758)
Georgian localities: Tbilisi, Mtskheta [11].
181. C. surdus Rapilly, 1980
Georgia [27].
182. C. tamaricis Solsky, 1867
Georgian localities: Vashlovani [15].
183. C. transcaucasicus Jakobson, 1898
Georgia [36], **Georgian localities:** Abastumani [12,14].
184. C. trimaculatus Rossi, 1790
Georgia [27].
185. C. turcicus Suffrian, 1847
Georgian localities: Avchala [12].
186. C. violaceus Laicharting, 1781
Georgian localities: Tbilisi, Avchala [11].
187. C. zaitzevi Lopatin, 1977
Georgia [27].

Genus - *Dibolia* Latreille, 1829
188. Dibolia carpathica Weise, 1893
Georgian localities: Tbilisi ([16, 27, 44].
189. D. cryptocephala Koch, 1803
Georgian localities: Tbilisi [44].
190. D. phoenicia Allard, 1866
Georgia [16, 27].
191. D. rugulosa Redtenbacher, 1849
Georgia [16, 27].
192. D. schillingii Letzner 1847
Georgian localities: Tbilisi [44].
193. D. weisei Mohr, 1981
Georgian localities: Mt. Mesket [27].

Genus - *Diorhabda* Weise, 1883
194. Diorhabda carinata Faldermann, 1837
Georgia [27]. Georgian localities: Eldari, Lagodekhi, Owtshaly, Mtskheta, Tbilisi [49].
195. D. elongata (Brullé, 1832)
Georgian localities: Tbilisi [11]. Hovewer, according to Tracy & Robbins [49] the presence of *D. elongata* in Georgia needs further confirmation. Reports of *D. elongata* from Georgia are considered to be *D. carinata*.

Genus - *Donacia* Fabricius, 1775

196. Donacia antiqua Kunze, 1818
Georgia [27].
197. D. aquatica (Linnaeus, 1758)
Georgian localities: Bakuriani, Baraleti, Tba [7],Surroundings of lake Baraleti [14].
198. D. bicolora Zschach, 1788
Georgian localities: Batumi, Natanebi, Poti, Gagra, Near lake Lisi [7],Tbilisi [11], Surroundings of Paravani lake [14], Colchis National Park [29], Dzibakhevi [30].
199. D. cinerea Herbst, 1784
Georgian localities: Poti, Surroundings of Jandari lake (as Karayaz), Lagodekhi [7,9,18], Tbilisi [7,11], Colchis National Park [29].
200. D. dentata Hoppe, 1795
Georgian localities: Tsebelda [7].
201. D. gracilicornis Jacobson, 1899
Georgian localities: Pitsunda, Poti, Batumi, Surroundings of Tbilisi [7,11], Colchis National Park [29] Poti, Abkhazeti, Surroundings of Kutaisi [30].
202. D. impressa (Paykull, 1799)
Georgian localities: Gori [7,13], Adigeni [14].
203. D. jacobsoni Semenov & Reichardt, 1927
Georgian localities: Surroundings of Madatapa and Tabatskuri [7], Surroundings of lake Madatapa [14].
204. D. koenigi Jacobson, 1899
Georgian localities: Surroundings of Zugdidi [7].
205. D. marginata Hoppe, 1795
Georgian localities: Surroundings of Poti [7], Colchis National Park [29], Batumi [30].
206. D. mistshenkoi Jakobson, 1910
Georgian localities: Tba, Gomna, Sakochavi, Surroundings of lake Tabatskuri [7].
207. D. simplex Fabricius, 1775
Georgia [27].
208. D. thalassina Germar, 1811
Georgian localities: Surroundings of lakes Sagamo [7], Madatapa, Tabatskuri [7,14], Ninotsminda [14].
209. D. versicolorea (Brahm, 1790)
Georgian localities: Bakuriani, Teberda, Borjomi [7], Adigeni [14].
210. D. vulgaris Zschach, 1775
Georgian localities: Poti, Karaiaz [7],Tbilisi [7,11,30], Gori [7,13], Colchis National Park [29], Gudauta-Utkhara [30].

Genus - *Entomoscelis* Chevrolat, 1836
211. Entomoscelis adonidis (Pallas, 1771)
Georgian localities: Surroundings of Vaziani [11], Skra surroundings [13], Sapara, Adigeni, Orchoshani, Akhaltsikhe [14].
212. E. pilula Lopatin, 1967
Georgian localities: Tbilisi, Lagodekhi [50].
213. E. sacra (Linnaeus, 1758)
Georgian localities: Tbilisi, Surroundings of Vaziani [11].
214. E. suturalis Weise, 1882
Georgian localities: Orchard of acclimatization [11], Tbilisi [30].

Genus - *Epitrix* Foudras, 1860
215. Epitrix atropae Foudras, 1860
Georgian localities: Lagodekhi protected areas [18].

216. E. caucasica Heikertinger, 1950
Georgia [27], **Georgian localities:** Tbilisi [15].
217. E. hirtipennis (Melsheimer, 1847)
Georgia [37], Georgian localities: Lagodekhi protected areas [18].
218. E. intermedia Foudras, 1861
Georgian localities: Lagodekhi protected areas [18].
219. E. pubescens (Koch, 1803)
Georgia [27], **Georgian localities:** Lagodekhi protected areas [18].
Comment: Some individuals have been misidentified as *E. setosella* in Aslan et al. [18], after reexamination by Dr Andrey Bienkovski, it was confirmed that individuals belong to *E. pubescens*.

Genus – *Euluperus* Weise, 1886
220. Euluperus xanthopus (Duftschmid, 1825)
Georgian localities: Borjomi, Svaneti [8], Tbilisi, Tskneti [11].

Genus – *Exosoma* Jacobi, 1903
221. Exosoma collare (Hummel, 1825)
Georgian localities: Atskuri (Seperteladze [12] as *Melasoma collare*), Sapara [14].

Genus - *Galeruca* Geoffroy, 1762
222. Galeruca circassica Reitter, 1889
Georgian localities: Sokhumi, Teberda [8], Tbilisi [11].
223. G. daurica (Joannis, 1865)
Georgian localities: Tbilisi [11].
224. G. armeniaca Weise, 1886
Georgian localities: Veli, Tskhinvali [8], Surroundings of Vaziani, Ialguja, Gardabani, Surroundings of lake Kumisi (Seperteladze [11] as *G. interrupta circumdata*), Tbilisi (Shengelia [8], Seperteladze [11] as *G. interrupta circumdata*), Brili, Abisi (Seperteladze [13] as *G. interrupta circumdata*), Gori, Skra surroundings [8], (Seperteladze [13] as *G. interrupta circumdata*), Khidistavi, Grakli [8], (Seperteladze [13] as *G. interrupta armeniaca*), Akhaltsikhe, Khertvisi, Surroundings of lake Paravani [14], Ninotsminda [8,14], Tskneti nr. Tbilisi, Prov. Kakheti [51].
225. G. pomonae (Scopoli, 1763)
Georgian localities: Borjomi, Manglisi, Teliani, Kazbegi, Kala [8], Surroundings of Vaziani, Kojori, Tbilisi, Betania [11], Mukhrani [8,13], Atskuri, Akhaltsikhe, Ninotsminda [14].
226. G. spectabilis (Faldermann, 1837)
Georgian localities: Kiketi, Manglisi, Sagarejo, Telavi, Borjomi, Mukhrovani, Tskhinvali, Java, Pasanauri [8], Tbilisi, Kojori, Mtskheta [8,11], Avchala (Seperteladze [11] as *orientalis*), Gori, Khashuri, Skra [13], Adigeni [14], Prov. Kakheti, Tbilisi, Shida Kartli, Gori [51].
227. G. tanaceti (Linnaeus, 1758)
Georgian localities: Kiketi, Sagarejo, Teliani, Lagodekhi, Bakuriani, Borjomi, Tskhinvali, Chaladidi, Gvandra, Kodori, Teberda, Klukhori, Sokhumi, Kala, Lentekhi, Latpari [8],Tbilisi, Kojori, Gardabani [8,11], Igoeti [13], Akhaltsikhe [14], Abastumani, Akhalkalaki [8,14], Lagodekhi protected areas [18].

Genus - *Galerucella* Crotch, 1873
228. Galerucella calmariensis (Linnaeus, 1767)
Georgian localities: Tbilisi [8,11], Skra, Mtskhetisjvari [13].
229. G. lineola (Fabricius, 1781)
Georgian localities: Borjomi [8], Samgori [11], Zerti, Mejvriskhevi, Mtskhetisjvari, Akhalkalaki (Kartli), Skra [13], Shroma Valley (Orlova-Bienkovskaja [30] as from Antsal-or Valley).
230. G. pusilla (Duftschmidt, 1825)

Georgian localities: Georgia, Bakuriani (Lopatin, Seperteladze [15] as *Altica*).

231. G. tenella Linnaeus, 1760

Georgian localities: Poti, Surroundings of lake Paliastomi [8], Atskuri [14], Colchis National Park [29].

Genus – *Gastrophysa* Chevrolat, 1836

232. Gastrophysa polygoni (Linnaeus, 1758)

Georgian localities: Lagodekhi [9,18], Tbilisi, Betania, Samgori, Surroundings of lake Kumisi (Seperteladze [11] as *Gastroidea*), Tana valley, Zerti, Kaspi surroundings, Mejvriskhevi, Kavtiskhevi, Mtskhetisjvari [13], Sapara, Ninotsminda, surroundings of lake Paravani [14].

233. G. viridula (De Geer, 1775)

Georgian localities: Mtskheta (Seperteladze [11] as *Gastroidea*), Tana valley [13], Abastumani, Adigeni, Akhalkalaki, Ninotsminda, Surroundings of lake Paravani, Akhaltsikhe [14].

Genus - *Gonioctena* Chevrolat, 1836

234. Gonioctena decemnotata (Marsham, 1802)

Georgian localities: Tsana (Seperteladze [10] as *Phytodecta rufipes*), Atskuri (Seperteladze [14] as *Phytodecta rufipes*).

235. G. linnaeana (Schrank, 1781)

Georgian localities: Ketrisi, Zagari pass (Seperteladze [10] as *Phytodecta linnaeus*)Tbilisi, Mtskheta (Seperteladze [11] as *Phytodecta*), Atskuri [14].

236. G. viminalis (Linnaeus, 1758)

Georgian localities: Akhalkalaki [14].

Genus - *Hispa* Linnaeus, 1767

237. Hispa atra Linnaeus, 1767

Georgian localities: Borjomi, Asureti (Elisabedtali), Akhtala [6], Tbilisi, Mtskheta [6], Seperteladze [11] as *Hispella*), Skra (Seperteladze [13] as *Hispella*).

Genus – *Hypocassida* Weise, 1893

238. Hypocassida subferruginea (Schrank, 1776)

Georgian localities: Telavi, Teliani, Lagodekhi, Borjomi, Mekvena, [6], Tbilisi [6], Seperteladze [11] as *sybferruginea*, Ialguja (Seperteladze [11] as *sybferruginea*), Mejvriskhevi, Karaleti, Gomi, Khidistavi, Skra [13], Adigeni, Aspindza, [14], Akhaltsikhe [6, 14], Colchis National Park [29].

Genus- *Ischyronota* Weise, 1891

239. Ischyronota desertorum (Gebler, 1833)

Georgian localities: Tbilisi (Zaitsev [6] misspelled as *Jschyronota*), [11].

Genus - *Labidostomis* Chevrolat, 1836

240. Labidostomis arnoldii Medvedev, 1962

Georgia [27].

241. L. asiatica Faldermann, 1837

Georgian localities: Tbilisi [11], Atskuri [14].

242. L. axillaris (Lacordaire, 1848)

Georgia [27].

243. L. brevipennis Faldermann, 1837

Georgia [27].

244. L. decipiens Faldermann, 1837

Georgia [27].

245. L. humeralis (Schneider, 1792)

Georgian localities: Tbilisi [11]

246. L. longimana (Linnaeus, 1760)

Georgian localities: Tskneti, Kojori [11],Karaleti, Khashuri surroundings, Abisi, Plavi, Tsagvi, Sakviralo, Rene, Brili, Mejvriskhevi, Skra [13], Sapara, Aspindza, Adigeni, Akhaltsikhe, Vardzia, Orchoshani [14].

247. L. lucida (Germar, 1824)

Georgian localities: Tbilisi [11], Atskuri [14].

248. L. oertzeni Weise, 1889

Georgia [27].

249. L. pallidipennis (Gebler, 1830)

Georgian localities: Mtskhetisjvari, Kavtiskhevi [13], Akhalkalaki [14].

250. L. peregrina Weise, 1900

Georgia [27].

251. L. propinqua Faldermann, 1837

Georgian localities: Sadakhlo, Surroundings of Kojori, Near Tbilisi, Mtskheta [11], Akhaltsikhe, Adigeni, Vardzia, Akhalkalaki, Zekari pass [14].

Genus – *Lema* Fabricius, 1798

252. Lema cyanella (Linnaeus, 1758)

Georgian localities: Skra, Kaspi, Kavtiskhevi [13], Akhaltsikhe [14].

Genus - *Leptinotarsa* Chevrolat, 1836

253. Leptinotarsa decemlineata Say, 1824

Georgia [27].

Genus - *Lilioceris* Reitter, 1913

254. Lilioceris faldermanni (Guérin-Meneville, 1844)

Georgian localities: Atskuri, Kvishkheti [12, 14], Kojori, Mcvane Kontskhi (Achara), Bakuriani, Borjomi, Tkibuli [30].

255. L. lilii (Scopoli, 1763)

Georgia [27].

256. L. merdigera (Linnaeus, 1758)

Georgian localities: Tbilisi [11], Aspindza [14],Meore Kesalo [30].

Genus - *Lochmaea* Weise, 1883

257. Lochmaea caprea (Linnaeus, 1758)

Georgian localities: Tskhinvali [8], Tana valley, Skra, Tkviavi, Zerti, Mejvriskhevi, Ertatsminda, Shavshvebi, Mtskhetisjvari (Seperteladze [13] misspelled as *Lochmaca caprea*), Gori [8], Seperteladze [13] misspelled as *Lochmaca caprea*, Surroundings of lake Paravani, Zekari pass (Seperteladze [14] as *Lochmaea capreae*), Swanetien, Kvabiskhevi, prov. Samtschke-Javakhewtii [51].

258. L. crataegi (Forster, 1771)

Georgian localities: Tbilisi, Surroundings of Tbilisi (Seperteladze [11] as *Luperus*), Tkviavi, Shavshvebi, Gorisjvari, Skra, Mejvriskhevi [13].

259. L. machulkai Roubal, 1926

Georgia [27]. **Georgian localities:** Tbilisi [52].

Genus - *Longitarsus* Latreille, 1829

260. Longitarsus absynthii (Kutschera, 1862)

Georgian localities: Khutia (Seperteladze [10] as *Longitarsus aeruginosus*)

261. L. aeneicollis (Faldermann, 1837)

Georgian localities: Tbilisi [16], Lagodekhi protected areas [18].

262. L. albineus (Foudras, 1860)
Georgian localities: Tbilisi [30]
263. L. alfierii furthi Gruev, 1982
Georgia [16, 27].
264. L. anchusae (Paykull, 1799)
Georgia [27].
265. L. ballotae (Marsham, 1802)
Georgia [16, 27].
266. L. dlabolai Král, 1964
Georgia [16, 27].
267. L. exsoletus (Linnaeus, 1758)
Georgia [16, 27], **Georgian localities:** Tsana, Gentsvishi [10].
268. L. fulgens (Foudras, 1860)
Georgia [16, 27], **Georgian localities:** Zagari pass [10].
269. L. fuscoaeneus Redtenbacher, 1849
Georgia [16, 27].
270. L. georgianus (Allard, 1866)
Georgia [27].
271. L. kutscherae (Rye, 1872)
Georgia [16, 27].
272. L. lederi Weise, 1889
Georgia [27]
273. L. ledouxi Doguet, 1979
Georgia [27], **Georgian localities:** Apkhazeti [30].
274. L. lewisii (Baly, 1874)
Georgia [16, 27].
275. L. linnaei (Duftschmid, 1825)
Georgia [27], **Georgian localities:** Kvareli [30]
276. L. luridus (Scopoli, 1763)
Georgia [16, 27].
277. L. lycopi (Foudras, 1860)
Georgia [16, 27], **Georgian localities:** Logodekhi protected areas [18].
278. L. melanocephalus (De Geer, 1775)
Georgia [16, 27].
279. L. nanus (Foudras, 1860)
Georgian localities: Lagodekhi protected areas [18].
280. L. niger (Koch, 1803)
Georgia [27], **Georgian localities:** Tbilisi [30].
281. L. noricus Leonardi, 1976
Georgian localities: Georgia [27].
282. L. obliteratoides Gruev, 1973
Georgia [16, 27].
283. L. obliteratus (Rosenhauer, 1847)
Georgia [16, 27].
284. L. pellucidus (Foudras, 1860)
Georgian localities: Lagodekhi protected areas [18].
285. L. picicollis Weise, 1900
Georgia [16, 27].
286. L. pinguis Weise, 1888
Georgia [27], **Georgian localities:** Bakuriani [16].

287. L. pratensis (Panzer, 1794)
Georgia [16,27].
288. L. pubescens Weise, 1890
Georgia [27], **Georgian localities:** Abkhazia (North-Western Georgia) [16].
289. L. pulmonariae Weise, 1893
Georgia [16], **Georgian localities:** Lagodekhi protected areas [18].
290. L. ratshensis Iablokov-Khnzorian, 1962
Georgia [16, 27].
291. L. rectilineatus (Foudras, 1860)
Georgia [16, 27].
292. L. salviae Gruev, 1975
Georgia [16, 27].
293. L. scutellaris (Mulsant et Rey, 1874)
Georgia [16, 27].
294. L. strigicollis Wollaston, 1864
Georgia [16, 27].
295. L. succineus (Foudras, 1860)
Georgian localities: Lagodekhi protected areas [18].
296. L. symphyti Heikertinger, 1912
Georgia [16, 27].
297. L. trepidus Warchałowski, 1973
Georgia [16, 27].
298. L. violentus Weise, 1893
Georgia [16, 27].

Genus – *Luperus* Geoffroy, 1762
299. Luperus armeniacus Kiesenwetter, 1878
Georgian localities: Borjomi, Gori, Meskheti, Kartli [8], Tbilisi [11], Gori, Skra surroundings, Rene, Mtskhetisjvari [13], Abastumani [14].
300. L. cyanipennis Kuster, 1848
Georgian localities: Tbilisi [11].
301. L. flavipes (Linnaeus, 1767)
Georgian localities: Tbilisi [11].
302. L. longicornis (Fabricius, 1758)
Georgian localities: Borjomi, Manglisi [8], Tbilisi [11], Gori [13].
303. L. luperus (Sulzer, 1776)
Georgian localities: Sanislo, Samtredia (Seperteladze [12] as *L. lyperus*)
304. L. viridipennis Germar, 1824
Georgian localities: Tskneti, Kojori, Surroundings of lake Kumisi [11], Atskuri [14].
305. L. xanthopoda (Schrank, 1781)
Georgian localities: Tbilisi [11].

Genus - *Macrocoma* Chapuis, 1874
306. Macrocoma rubripes (Schaufuss, 1862)
Georgian localities: Lagodekhi protected areas [18].

Genus – *Medythia* Jacoby, 1887
307. Medythia nigrobilineata Motschulsky, 1861
Georgian localities: Sagvichio, Kolkheti National Park [48].

Genus - *Mniophila* Stephens, 1831

308. Mniophila bosnica Apfelbeck, 1914

Georgia [27].

309. M. caucasica Nadein, 2009

Georgia: Manglisi [38].

310. M. muscorum (Koch, 1803)

Georgia [16], **Georgian localities:** Lagodekhi protected areas [18].

311. M. transcaucasica Nadein, 2009

Georgia [38].

Genus - *Neocrepidodera* Heikertinger, 1911

312. Neocrepidodera crassicornis (Faldermann, 1837)

Georgian localities: Glola, Khutia, Gentsvishi (Seperteladze [10] as *Crepidodera crassicornis*).

313. N. ferruginea (Scopoli, 1763)

Georgia [16, 27].

314. N. motschulskii (Konstantinov, 1991)

Georgia [16, 27].

Genus – *Neophaedon Jakobson, 1901*

315. Neophaedon pyritosus (Rossi, 1792)

Georgian localities: Tbilisi, Krtsanisi, Dmanisi, Abastumani [12], Abastumani [14].

Genus - *Nymphius* Weise, 1900

316. Nymphius stylifer (Weise, 1899)

Georgian localities: Borjomi (Shengelia [8] as *Luperus*), Atskuri [8], (Seperteladze [14] as *Luperus stylifer*).

Genus – *Ochrosis* Foudras, 1860

317. Ochrosis ventralis (Illiger, 1807)

Georgian localities: Between Anaklia and Tikori [48].

Genus - *Orestia* Chevrolat, 1836

318. Orestia caucasica Reitter, 1880

Georgian localities: Georgia [27], Borjomi, Abastumani, Apkhazerti (Gumista reserve) [30].

Genus –*Orsodacne* Latreille, 1802

319. Orsodacne humeralis Latreille, 1804

Georgian localities: Tbilisi (Seperteladze [11] as *O. lineola*).

Genus - *Oulema* Des Gozis, 1886

320. Oulema erichsonii (Suffrian, 1841)

Georgian localities: Rene, Mtskhetisjvari, Noste (Seperteladze [13] as *Lema erichsonii*).

321. O. melanopus (Linnaeus, 1758)

Georgian localities: Tbilisi (Seperteladze [11] as *Lema melanopus*); Gori, Grakli, Khidistavi, mejvriskhevi (Seperteladze [13] as *Lema melanopus*); Adigeni, Orchoshani, Vardzia, Paravani, Akhaltsikhe (Seperteladze [14] *Lema melanopus*); Sokhumi [39].

322. O. obscura (Stephens, 1831)

Georgian localities: Akhaltsikhe, Omalo, Bakuriani (Seperteladze [12] as *Lema gallaeciana*), Akhaltsikhe (Seperteladze [14] as *Lema lichenis*).

323. O. tristis (Herbst, 1786)

Georgian localities: Skra, Igoeti (Seperteladze [13] as *Lema tristis*).

Genus – *Pachnephorus* Chevrolat, 1836

324. Pachnephorus pilosus (Rossi, 1790)

Georgian localities: Kartli nursery gardens [13]

325. P. syriacus Reitter, 1886

Georgian localities: Telavi [12].

326. P. villosus (Duftschmid, 1825)

Georgian localities: Tbilisi [11].

327. P. tessellatus (Duftschmid, 1825)

Georgian localities: Tbilisi [11]

Genus - *Pachybrachis* Chevrolat, 1836

328. Pachybrachis albicans Weise, 1882

Georgia [27].

329. P. fimbriolatus Suffrian, 1848

Georgian localities: Samgori [11], Igoeti, Brili, Mtskhetisjvari, Sakviralo, Gorisjvari, Skra surroundings [13], Akhaltsikhe, Orchoshani [14].

330. P. laetificus Marseul, 1875

Georgian localities: Tbilisi (Seperteladze [11] misspelled as *lactificus*).

331. P. mendax Suffrian, 1860

Georgian localities: Surroundings of Vaziani, Kojori, Gardabani (Seperteladze [11] as *Pachybrachis pcobus*, which is misspelling of *Pachybrachis probus*).

332. P. scriptidorsum Marseul, 1875

Georgian localities: Grakali, Khidistavi, Tkviavi, Breti, Plavi, Mejvriskhevi, Zerti, Gomi, Skra, Shavshvebi, Gorisjvari [13], Aspindza, Surroundings of Rustavi, Surroundings of lake Paravani, Akhaltsikhe [14].

333. P. sinuatus Mulsant & Rey, 1859

Georgian localities: Tana velley [12].

334. P. tessellatus Olivier, 1791

Georgian localities: Atskuri [14], Alazani valley [30].

Genus – *Phaedon* Latreille, 1829

335. Phaedon armoraciae (Linnaeus, 1758)

Georgian localities: Mejvriskhevi, Rene, Rekha, Samtredia [12].

336. P. cochleariae (Fabricius, 1792)

Georgian localities: Lagodekhi [9], Lagodekhi protected areas [18].

337. P. laevigatus (Duftschmid, 1825)

Georgian localities: Telavi [12].

Genus - *Phratora* Chevrolat, 1836

338. Phratora vitellinae (Linnaeus, 1758)

Georgian localities: Aspindza, Vardzia [14], Apkhazeti [30].

339. P. vulgatissima (Linnaeus, 1758)

Georgia [27].

Genus - *Phyllobrotica* Chevrolat, 1837

340. Phyllobrotica elegans Kraatz, 1866

Georgian localities: Batumi, Borjomi [8],Tana valley, Skra [13], Vardzia, Zekari pass [14].

341. P. quadrimaculata (Linnaeus, 1758)

Georgian localities: Teberda [8].

Genus - *Phyllotreta* Chevrolat, 1836

342. Phyllotreta astrachanica Lopatin, 1977
Georgia [16, 27], **Georgian localities:** Lagodekhi protected areas [18].

343. Ph. atra (Fabricius, 1775)
Georgia [27], **Georgian localities: Tbilisi** [16].

344. Ph. cruciferae (Goeze, 1777)
Georgia [16, 27].

345. Ph. diademata Foudras, 1860
Georgia [16, 27].

346. Ph. erysimi Weise, 1900
Georgian localities: Lagodekhi protected areas [18].

347. Ph. flexuosa (Illiger, 1794)
Georgian localities: Ketrisi, Ushguli, Koruldashi (Seperteladze [10] misspelled as *Ph. flexiosa*).

348. Ph. nemorum (Linnaeus, 1758)
Georgia [16, 27], **Georgian localities:** Lagodekhi [9,18].

349. Ph. nigripes (Fabricius, 1775)
Georgian localities: Lagodekhi protected areas [18].

350. Ph. ochripes (Curtis, 1837)
Georgian localities: Lagodekhi [9], Lagodekhi protected areas [18].

351. Ph. procera (Redtenbacher, 1849)
Georgia [16, 27].

352. Ph. pseudoexclamationis Konstantinov, 1992
Georgia [16, 27].

353. Ph. sisymbrii Weise, 1888
Georgia [27], **Georgian localities:** Vashlovani [15].

354. Ph. striolata (Illiger, 1803
Georgian localities: Lagodekhi (Kobakhidze [9] as *vittata*), [18], Ketrisi (Seperteladze [10] as *Phyllotreta vittata*)

355. Ph. vittula (Redtenbacher, 1849)
Georgian localities: Lagodekhi protected areas [18].

Genus – *Pilemostoma* Desbrochers, 1891

356. Pilemostoma fastuosum (Schaller, 1783)
Georgian localities: Manglisi, Tsalka, Sochi, Tuapse [6].

Genus - *Plagiodera* Chevrolat, 1836

357. Plagiodera versicolora (Laicharting, 1781)
Georgian localities: Tbilisi [11],Gori, Mejvriskhevi, Shavshvebi, Skra [13], Aspindza [14].

Genus - *Plateumaris* Thomson, 1859

358. Plateumaris braccata (Scopoli, 1772)
Georgia [27].

359. P. discolor (Panzer, 1795)
Georgian localities: Lake Paravani surroundings [12,14].

360. P. sericea (Linnaeus, 1760)
Georgian localities: Bakuriani, Tba, Madatapa, Tetritskaro, Borjomi, Batumi [7], Surroundings of lakes Paravani and Madatapa [14].

Genus - *Podagrica* Chevrolat, 1837

361. Podagrica malvae (Illiger, 1807)
Georgia [16, 27].
362. P. menetriesi (Faldermann, 1837)
Georgian localities: Colchis National Park [29].

Genus - *Prasocuris* Latreille, 1802
363. Prasocuris glabra (Herbst, 1783)
Georgia [27].
364. P. junci (Brahm, 1790)
Georgia [27], **Georgian localities:** Tbilisi [11].

Genus - *Psylliodes* Latreille, 1829
365. Psylliodes arista Iablokoff-Khnozorian, 1962
Georgia [16, 27], **Georgian localities:** Akaldaba, Kvishheti [42].
366. Ps. attenuata (Koch, 1803)
Georgian localities: Georgia [42].
367. Ps. chalcomera (Illiger, 1807)
Georgian localities: Kodzhory, Manglis, Martkopi [42].
368. Ps. chrysocephala (Linnaeus, 1758)
Georgian localities: Tbilisi, Kutais, Adzharia, Batumskiy Distr., Kahaberi [42].
369. Ps. circumdata (Redtenbacher, 1842)
Georgia [16; 27], **Georgian localities:** Tiflis, Lagodekhi, Zakataly [42].
370. Ps. concolor Nadein, 2006
Georgian localities: Manglis, Martkobi [42].
371. Ps. cuprea (Koch, 1803)
Georgia [16, 27],**Georgian localities:** Tiflis, Adzharia, Batumskii Distr., Kakhaberi [42], Lagodekhi protected areas [18].
372. Ps. deplanata Medvedev, 1962
Georgia [27, 42].
373. Ps. hyoscyami (Linnaeus, 1758)
Georgian localities: Borjomi or Tbilisi [42].
374. Ps. instabilis Foudras, 1860
Georgia [16, 27, 42], **Georgian localities:** Shovi [10].
375. Ps. isaditis Heikertinger, 1913
Georgian localities: Lagodekhi protected areas [18].
376. Ps. longicollis Weise, 1900
Georgia [27], **Georgian localities:** Racha, Glola, Dolomisis, Bakuriani: Lake Tabatskuri [42].
377. Ps. luteola (Müller, 1776)
Georgian localities: Martkopi [42].
378. Ps. marcida (Illiger, 1807)
Georgia [16, 27, 42].
379. Ps. napi (Fabricius, 1792)
Georgia [42].
380. Ps. rubroaenea Heikertinger, 1916
Georgia [27].
381. Ps. testaceoconcolor Heikertinger, 1926
Georgian localities: Borshom [42].
382. Ps. thlaspis Foudras, 1860
Georgian localities: Atskhuri (former Akhaltsikhe Distr.), Tbilisi, Adjara (Batumskiy Distr.), Kahaberi [42].

383. Ps. tricolor Weise, 1888
Georgia [16, 27, 42].
384. Ps. valida Weise, 1889
Georgia [27, 30, 42], **Georgian localities:** Gentsvishi [10].
385. Ps. wrasei Leonardi & Arnold, 1995
Georgia [16, 27, 42].

Genus - *Pyrrhalta* Joannis, 1865
386. Pyrrhalta viburni (Paykull, 1799)
Georgian localities: Surroundings of Signagi (Shengelia [8] as *Galerucella viburni*), Kojori (Shengelia [8] as *Galerucella viburni*; Seperteladze [11] as *Galerucella viburni*).

Genus- *Radymna* Reitter, 1913
387. Radymna fischeri (Faldermann, 1837)
Georgian localities: Mtskheta, Martkopi [8], Borjomi (Shengelia [8] as *Diorhabda fissheri*), Tbilisi (Shengelia [8] as *Diorhabda fissheri*; 11). Gori [13], Georgia [45], Prov. Kakheti [51].
388. R. persica (Faldermann, 1837)
Georgia [45], **Georgian localities:** Akhalkalaki (Kartli) [13], Atskuri [14].

Genus – *Sermylassa* Reitter, 1913
389. Sermylassa halensis Linnaeus, 1767
Georgian localities: Betania [11], Mejvriskhevi, Noste [13].

Genus - *Smaragdina* Chevrolat, 1836
390. Smaragdina affinis (Illiger, 1794)
Georgian localities: Tbilisi, Mtskheta [11], as *Gynandrophthalma affinis*)
391. S. aurita aurita (Linnaeus, 1767)
Georgian localities: Samgori (Seperteladze [11] as *Gynadrophthalma*), Rv. Tana valley Skra, Skra surroundings, Mtskhetisjvari [13], Atskuri [14].
392. S. aurita auritoides (Achard, 1923)
Georgia [27].
393. S. biornata (Lefevre, 1872)
Georgia [27], **Georgian localities:** Tbilisi (Seperteladze [11] as *Gynandrophthalma biornata*).
394. S. chloris caucasica Medvedev, 1971
Georgia [27], **Georgian localities:** Gentsvishi, Avadkhara [12].
395. S. hypocrita (Lacordaire, 1848)
Georgia [27].
396. S. limbata (Steven, 1806)
Georgia [27], **Georgian localities:** Tbilisi, Kojori (Seperteladze [11] as *Gynandrophthalma limbata*).
397. S. salicina (Scopoli, 1763)
Georgia [27], **Georgian localities:** Skra surroundings (as *S. cyancea* (misspeling *cyanea*) in Seperteladze [13].
398. S. unipunctata (Olivier, 1808)
Georgia [27], **Georgian localities:** Beshumi [15].
399. S. xanthaspis (Germar, 1824)
Georgia [27], **Georgian localities:** Zerti [13].

Genus – *Stylosomus* Suffrian, 1848
400. Stylosomus flavus caucasicus Müller, 1948
Georgia [27], **Georgian localities:** Tbilisi [11].

401. S. tamaricis (Herrich-Schäffer, 1836)
Georgian localities: Tbilisi, Orchard of acclimatization [11].

Genus - *Timarcha* Latreille, 1829
402. Timarcha hummelii (Faldermann, 1837)
Georgian localities: Kojori [11], Mtskhetisjvari, Skra [13], Akhaltsikhe, Akhalkalaki, Abastumani [14], Batumi [30].
403. T. tenebricosa (Fabricius, 1775)
Georgia [27, 43].

Genus - *Tituboea* Lacordaire, 1848
404. Tituboea macropus (Illiger, 1800)
Georgia [27], **Georgian localities:** Rustavi Surroundings [11], Skra surroundings, Skra, Rene (Seperteladze [13] as *Antipa maccopus*,), Vardzia, Paravani (Seperteladze [14] as *Antipa macropus*).

Genus - *Xanthogaleruca* Laboissiere, 1934
405. Xanthogaleruca luteola (Müller, 1766)
Georgian localities: Tskneti, Kojori, Chaladidi, Surami (Shengelia [8] as *Galerucella*), Tbilisi (Shengelia [8] as *Galerucella*; Seperteladze [11] as *Galerucella*), Mukhrani, Skra, Gorisjvari (Seperteladze [13] as *Galerucella*), Atskuri (Seperteladze [14] as *Galerucella*), Colchis National Park [29] Ajameti reserve (Orlova_Bienkovskaja [30] as *Galerucella*).

Genus - *Zeugophora* Kunze, 1818
406. Zeugophora scutellaris Suffrian, 1840
Georgian localities: Tbilisi [11].

Genus - *Zygogramma* Chevrolat, 1836
407. Zygogramma suturalis (Fabricius, 1775)
Georgia [27, 37], **Georgian localities:** Orchards for acclimatization [11].

Doubtful records which we did not include in the list

1. *Aeschrocnemis graeca* Allard, 1884
Comment: Georgia is mentioned by Nadein [28]. However, we were not able to confirm this information.
2. *Apthona guanella* Redtb.
Georgian localities: Glola [10].
Comment: We were not able to confirm this old record.
3. *Chrysolina aeruginosa* (Faldermann, 1835)
Georgian localities: Tbilisi (Seperteladze[11] as *Chrysomela*).
Comment: This species is probably misspelled and was not possible to check and confirm.
4. *Coptocephala rubicunda rubicunda* (Laicharting, 1781)
Comment: Borowski [54] mentions Georgia in distribution area of this species without any material examined or related literature.
5. *Cryptocephalus (Cryptocephalus) hypochoeridis praticola* Weise, 1889
Comment: Borowski [55] mentions Georgia in distribution area of this species without any material examined or related literature.
6. *Gynandrophtalma psudogyanea* Ach.
Georgian localities: Mara [10].
Comment: We were not able to find the mentioned species.
7. *Labidostomis pachysoma* Medvedev, 1965

Comment: Borowski [54] mentions Georgia in distribution area of this species without any material examined or related literature.

8. Malegia colchica Reitter, 1912

Comment: Borowski [54] mentions Georgia in distribution area of this species without any material examined or related literature.

9. Mantura rustica (Linnaeus, 1767)

Comment: Georgia is mentioned by Özdikmen [26]. However, we were not able to know where he took this information from.

Conclusion and Discussion

This study represents the first attempt to present a comprehensive checklist of Chrysomelidae of Georgia, summarizing the species diversity and distribution data. Totally, 407 species belonging to 74 genera are listed from Sakartvelo (Georgia). The paper is from the series representing revised data about different taxa [19, 20]. Georgia has a rich fauna due to its geographic location; we expact that future investigations in poorly collected localities and forthcoming surveys throughout the country will most likely contribute this number even with new records or species.

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Some issues according to the "Great book of Gurjistan's Vilayet of 1574 year"

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A B S T R A C T

The paper deals with the historical past of Southwest Georgia, which led to the overthrow of the Ottoman-occupied Georgian provinces and the establishment of an Ottoman socio-political system in the country. As it is known, from the first half of the XVI century the Ottomans invaded Southwest Georgia and created Ottoman sanjaks. Over the centuries, both the territory of Georgia and the names of the toponyms have been changed. The population was being displaced and their national and confessional structure or economic life was changed. Our study of the „Great Book of Gurjistan's Vilayet of 1574" is studied in detail in terms of administrative-territorial arrangement, and it deals with the distribution of agriculture, particularly the distribution of cereal crops, and the number of taxes by livas and Nahies. From the statistical point of view, the villages, ruined villages, grazing lands / dominion grazing lands, chiptliq, summer pastures, fortress, church, district and vineyard of the XVI century Gurjistan's Vilayet livas and Nahies. Taxes on the major agricultural crops (wheat, barley, rye, millet, lucerne / hay, pea, chick-pea, lentils, flax) are being verified in Gurjistan's Vilayet livas and Nahies.

Keywords: Liva, Nahie, Village, Ruined village, Seed-land, Cereal crops.

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Introduction

One the most important source of study is the „Great Book of Gurjistan's Vilayet of 1574" [1], a 16th-century document drawn up by the Turks for the occupied Georgian territories: „And Ottomans became reinforced by their own rule"[2].

In XVI century mentioned district turned out to be between two aggressors. As noted, „From the West, it was followed by the Ottomans, and from the South and South-east it was surrounded by Iran Khan. Weak neighbor was watched by both enemies to be swallowedThe book depicts a period when Southwest Georgia was part of the Ottoman Empire and the source of Ottoman state's livelihood was robbery of conquered or its own people"[3].

In the Great book of 1574 Ottomans described occupied Georgian provinces by that time and called them „Gurjistan's Vilayet", after what both long and short logs of population were created. One of these documents is „Great Book of Gurjistan Vilayet" by S. Jikia, which is preceded by Kanun-Name of Gurjistan's Vilayet [4]. This Kanun-Name is published by N. Shengelia [5].

„The Great Book of Gurjistan's Vilayet of 1574" includes very important materials regarding discussion of social-economic condition and culture, also historical geography and other issues of Southwest Georgia of XVI century.

Gurjistan's Vilayet was located mainly in the upper basin of the river Mtkvari and covered territories of both modern and historical Georgia. Only small part of Vilayet covered some parts of riv. Oltistskali and rivers of its right basin – Bardusistskali, Banistskali. Administratively, it was included in the livas of Oltisi and Phanaki. The total area of Vilayet was 15204 km^2. Most part of this territory (8681 km^2) nowadays is outside of modern Georgia [6].

Methods and initial data

In the Book of 1574 many unique references are reserved for the better representation of this region. For establishment of a political organization for Ottoman ownership violation of Georgian land ownership and transforming it into Ottoman style was needed [1].

Research book is done in traditional form for Ottoman Books. After village household titles in Nahies tax type and their quantity was listed. Capacity of each part, village and district was calculated. Ottomans were particularly cruel towards Christians. Christian population was obligated to pay such additional taxes, which weren't paid by Muslims. For example, Georgian population had to pay tax „Ispenci" in amount of 25 Akhchis.

In the list of taxes we also find taxes on: wheat, barley, rye, shire, oil, vineyard, vegetable and fruit, lucerne and hay, hive, pigs, sheep, honey and deshtiban, mill, dye-houses, etc.

We explored „The Great Book of Gurjistan's Vilayet of 1574" in terms of administrative-territorial arrangement, after what we found out quantity of villages by levies, villages distribution by nahies and levies, distribution of villages and ruined villages by nahies and levies, sowing lands percentage by levies, cultural distribution of grains and taxes amount by levies and nahies.

Main results

Research had been carried out in several steps:

- Creating database of „The Great Book of Gurjistan's Vilayet of 1574".
- Listing the geographic objects (Classification of livas, Nahies, villages, ruined villages, seed lands, etc. Covered by Gurjistan's vilayet).
- Determining distribution and quantity of taxes of basic acricultural corps (wheat, barley, rye, millet, lucerne / hay, pea, chick-pea, lentil, flax) by Nahies and livas.
- Exploring and observing of these issues revealed that Gurjistan's Vilayet consisted of four livas in XVI century: Artanuji, Great Artaani, Tortumi and Oltisi. Artanuji Liva covered Artanuji, Ishkhani, Taoskari and Khacheni; Great Artaani Liva covered - Mzvare, Mishe ‖ Tkiani, Phanaki, Phanaskerti, Kiamkhisi and Chrdili; Tortumi Liva - Tortumi, Kudrusuri, Phertegreki, Judrukhuri and Hudurjuri ‖ Huldrajuri; Oltisi Liva covered - Anzavi, Bardizi, Gobi ‖ Kavi, Masarsori, Mzvare and Chrdili Nahies.

Table. *Gurjistan's Vilayet (1574 year.) administrative-territorial arrangement*

Livas	Nahies	Villages	Ruined village	Seed-land	Grazing land ‖ Dominion grazing land	Chiptliqi	Pasture	Fortress	Church	District	Vineyard
Artanuji	Artanuji	56	7	3	3					1	3
	Ishkhani	7									
	Taoskari	26									
	Khacheni	6		1							
	Total	**95**	**7**	**4**	**3**					**1**	**3**

Great Artaani	Mzvare	58	11	11				1	1		
	Mishe ‖ Tkiani	70	33	10							
	Phanaki	34	6	40							
	Phanaskerti	36	4	25	1						
	Kiamkhisi	13	3	14							
	Chrdili	34	3	6							
	Total	**245**	**60**	**106**	**1**			**1**	**1**		
Tortumi	Tortumi	1		3							
	Kudrusuri	1									
	Phertegreki	22		32		1					
	Judrukhuri	2		1				1			
	Hudurjuri‖	1									
	Total	**27**		**36**		**1**		**1**			
Oltisi	Anzavi	17	3	10				1			
	Bardizi	18	22	17							
	Gobi ‖ Kavi	16	13	10				1			
	Masarsori	8	5	4							
	Mzvare	23	4	13	1						
	Chrdili	19	8	14			2				
	Total	101	55	68	1		2	2			
Total		468	122	214	5	1	2	4	1	1	3

According to „The Great Book of Gurjistan's Vilayet of 1574 year" quantitavely most villages were confirmed in Great Artaani Liva (245 village), next in Oltisi and Artanuji livas (101, 95 villages), least – in Tortumi Liva (27 village) (Table, Fig. 1).

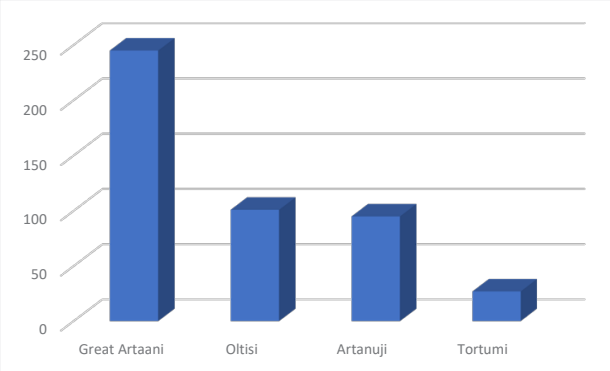

Fig 1. *Villages quantity by livas*

By the quantity of villages of Great Artaani Liva Mishe ǁ Tkiani Nahie was on the first place (up to 70 %), next was Mzvare Nahie (up to 60 %), almost similar situation was in Phanaskerti (up to 40 %), in Phanaki and Chrdili Nahies (up to 40-40 %), the least quantity of villages was confirmed in Kiamkhisi Nahie (10 %). In Artanuji Liva villages by spreading more than 50 % was held by Artanuji Nahie, next Taoskari Nahie (more than 20 %), while there was slightest difference was between Ishkhani and Khacheni Nahies (more than 5-5 %). In Oltisi Liva Mzvare Nahie was on the first place (20 %), more than 10 % of villages were found in Chrdili, Bardizi, Anzavi and Gobi ǁ Kavi Nahies, also more than 5 % in Masarsori Nahie. In Tortumi Liva we have most of indicators in Phertegreki Nahie (20 %), almost same situation was found in Judrukhuri, Tortumi, Kudrusuri and Hudurjuri ǁ Huldrajuri Nahies (1 %) (Table, Fig. 2).

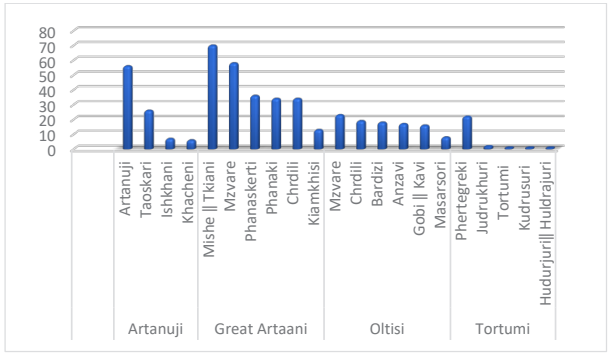

Fig 2. *Distribution of villages by Nahies and livas*

One of the objectives of our study was comparison of villages and ruined villages by their distribution and showing overall image by Nahies and livas. We have already discussed villages above. At this time we will focuse on the ruined villages. We have most indicators in Miche Nahie if Great Artaani Liva, where quantity of ruined villages was up to 30 %; next in Bardizi Nahie of Oltisi Liva (20 %). In the Gobi ǁ Kavi Nahies of this Liva quantity of ruined village was more than 10 %. Ruined villages were not found in Taoskari, Ichkhani and Khacheni Nahies of Artanuji Liva and Tortumi Liva (Table, Fig. 3).

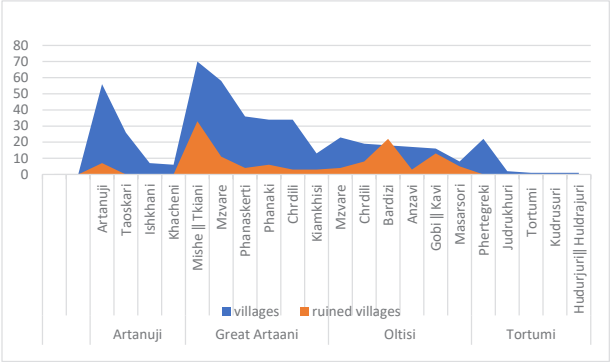

Fig 3. *Distribution of villages and ruined villages by Nahies and livas*

According to „Great Book of Gurjistan's Vilayet of 1574 year", most part of seed-lands are confirmed in Great Artaani Liva (49 %), next in Oltisi (32 %), seed-lands of Tortumi Liva was holding 17 %, and Artanuji Liva - 2 %. (Fig.4).

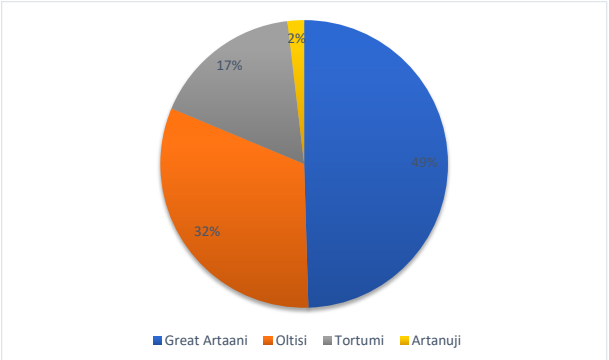

Fig 4. *Percentage distribution of seed-lands by livas*

According to „Great Book" of study the The major agricultural crops in Gurjistan Vilayet were: wheat, barley, rye, millet, lucerne / hay, pea, chickpea, lentil, flax. The highest rate of taxes is evidenced in Mzvare Nahie of Great Artaani Liva (rye - 225000 Akhcha), Miche ǁ Tkiani Nahie (wheat - 150 000 Akhcha), Mzvare Nahie (barley – up to

100 000 Akhcha); the least – in Mzvare Nahie on pea and chick-pea. The greatest indicator in Artanuji Liva was found in Artanuji Nahie (wheat - up to 100 000 - Akhcha), the least for lucerne and hay. In Tortumi Liva most taxes were evidenced in Judrukhuri Nahie (rye - more than 50 000 - Akhcha), the least – for lucerne / hay, chick-pea, flax. The greatest indicator in Oltisi Liva was found in Mzvare Nahie (wheat - more than 50 000 - Akhcha), the least – for lucerne / hay, chick-pea. (Fig. 5).

Conclusion

As some observations of Great book of Gurjistan's Vilayet of 1574 year have shown, Gurjistan's Vilayet covered total of 468 villages, also 122 ruined villages (villages empty from population). Also named seed-land – 214, grazing land / dominion grazing land – 5, chiptliqi – 1, pasture – 2, fortress – 4, church – 1, District – 1, vineyard – 3.

By quantity of villages Great Artaani Liva was on the first place, on the last place – Tortumi Liva. Most of seed-lands were evidenced in Great Artaani Liva. By the taxes for cereal crops the greatest indicator was seen in Mzvare Nahie of Great Artaani Liva.

It looks like that the vine was quite widespread in Gurjistan's Vilayet. From more than 1000 villages vineyard was named in 3 top tens, which my indicate small distribution of the vine at the first glance. Vineyards were very scattered on the whole territories of Vilayet. But vineyards were found in strongly dispersed Nahies (Artanuji, Great Artaani, Totroma, Oltisi) and several villages. This scattering is considered to be authentic proof that viticulture must be promoted and separate facts preserved by 1574 year should be considered, as relics of the once existing field [7].

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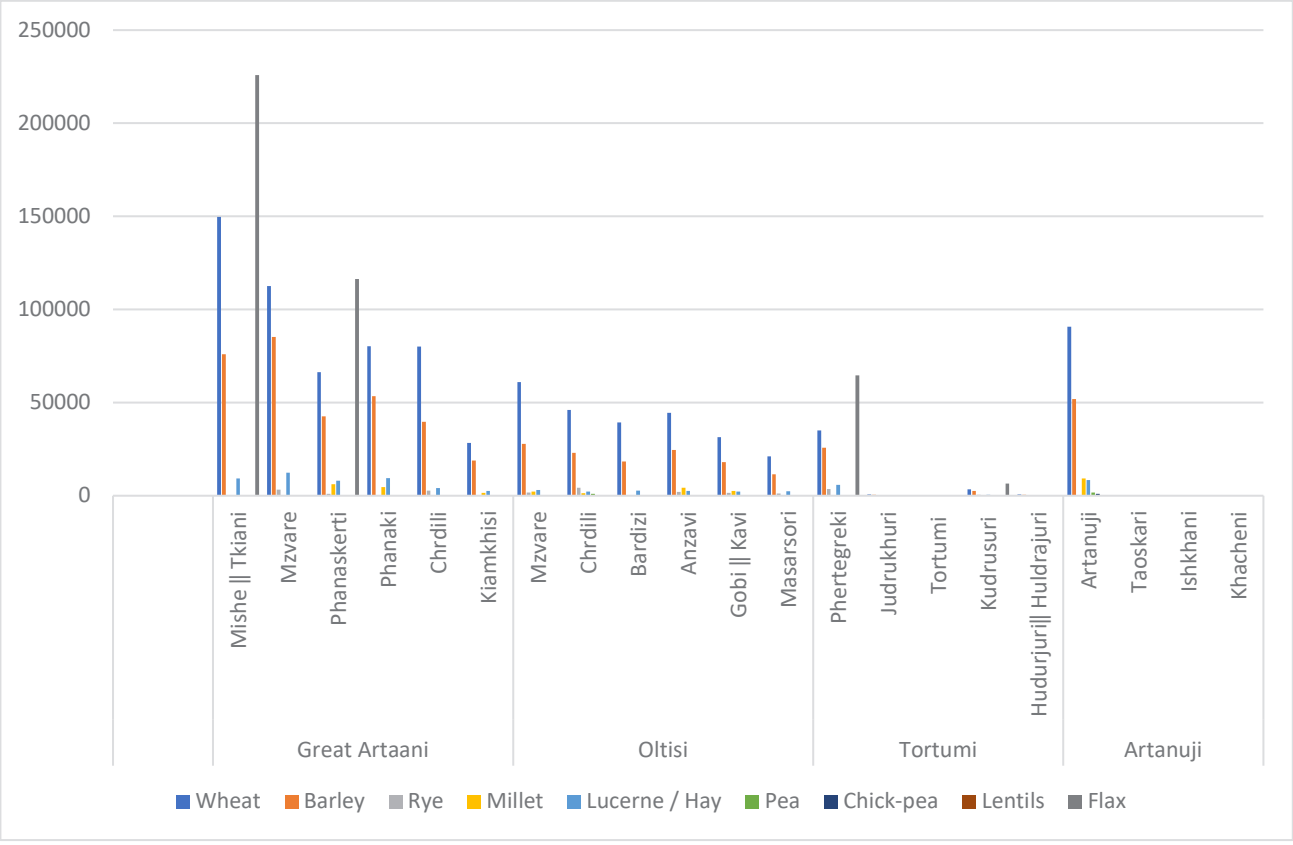

Fig 4. *Distribution of cereal crops and taxes quantity by livas and Nahies*

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Influence of Ca on the assimilation of Cr and Zn by the chromium resistant bacterium *ARTHROBACTER GLOBIFORMIS* 151B

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ABSTRACT

The process of assimilation of Cr(VI) and Zn by chromium-resistant bacteria (Arthrobacter globiformis 151B) and the influence of high-concentration **Ca** ions on this process have been studied in the article. The bacteria are known for their property to assimilate intensively the hexavalent chromium [Cr(VI)] ions from the environment, to convert them into trivalent form [Cr(III)] and to accumulate it in cell. Thanks to these properties, it is possible to use them for detoxification of the environment polluted by highly toxic Cr(VI). The strain of bacteria under investigation was isolated from basalt samples, taken from the places highly contaminated by Cr(VI) in Kazreti. The solutions of the studied elements (Cr and Zn) and of **Ca** were introduced simultaneously into the nutrient medium. We studied the influence of different concentrations of **Ca** ions during different period of time of bacteria cultivation (17h, 24h, 48h, 96h, 144h) on the process of assimilation of Cr and Zn by bacteria. Ca concentration in nutrient medium made up 100 mcg/ml, 400 mcg/ml and 1600 mcg/ml.For determination of the content of Cr and Zn in the cell, after the cultivation of bacteria the precipitation of cells by centrifuge and the preparation of the obtained bacterial pellet for the analysis were carried out. The content of metals was measured by atom-absorption spectrometry.

Keywords: Bacteria (*Arthrobacter globiformis* 151B), Biomass, Metals, Concentration, Cultivation, Detoxification.

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Introduction

Metals at the excess concentrations have toxic and carcinogenic properties. It is very important to develop the technologies by means of which it is possible to remove the toxic metals from the environment. Among the most prospective methods of remediation of polluted environment are the biological technologies based on the use of different microorganisms [1, 2].

The pollution of the environment by the materials containing Cr(VI) is an urgent problem for many countries [3]. Chromium can be extremely toxic or nontoxic depending on its concentration and valence state [4]. In nature usually it is met in trivalent [Cr(III)] and hexavalent forms which have different transport properties. Cr(VI)-contained materials are well water-soluble and toxic compounds, while Cr(III)-contained materials are less water-soluble and relatively harmless. The genotoxic and carcinogenic action of Cr(VI)-contained material is caused by their ability to penetrate rapidly into cell, as well as by activation of this ability as a result of the intercellular reduction process [5].

Detoxification of Cr(VI), that appeared in the environment, can be made by its conversion into trivalent form, and as it is known, trivalent chromium precipitates, mainly, in the form of $Cr(OH)_3$ or makes

a complex with surrounding ligands [6]. The recent researches proved that Many of the well-studied bacterial spaces, Are not metal resistant/tolerant. They loss their viability in co-existence of high concentration of heavy metals. Thus, it is reasonable to isolate the bacteria under investigation directly from soil, mineral strata and water contaminated by metals [7-11]. At present, the testing of technologies based on endogenic microorganisms is carried out intensively in many countries [12-14], providing that recently the application of biotechnologies is of high priority in the process of environment reduction in many countries [15]. The efficiency of biotransformation depends on the mechanism of bacteria-metal interaction, thus, for bacteria of any specific species it is necessary to study preliminarily this mechanism in detail.

The natural vital medium of bacteria we are interested in, contains, alongside with the elements under investigation (Cr and Zn) as well the elements (macroelements) that are widely spread in the nature (Na, K, Si, Ca). These elements have an influence on the growth – evolution of bacteria, including the process of assimilation of elements Cr and Zn by bacteria and the biochemical process proceeding in bacteria.

It is interesting to study the influence of Caon the process of assimilation and distribution of Cr, and Zn in bacteria. Ca ions are important activators of enzymes inside the cell.

Calcium is the key intracellular metabolic regulator. Ion Ca^{2+} functions as the most important intracellular factor (secondary mediator) controlling the processes of control of cell functions.Calcium is also important for the functioning of cell membranes.

The experimental material, obtained as a result of the proposed investigation, makes it possible to draw a certain conclusion about the biochemical processes, taking place in bacteria and about the mechanisms, by which the assimilation of metals and the conversion of their compounds are made.

Objectives and Methods

For the object of investigation we chose the bacteria of *Arthrobcterglobiformis* 151B. As is known, the genus *Arthrobacter* is aerobic, gram-positive bacteria, living in the soil. *Arthrobacter* belong to the class *Actinobacteria*, order – *Actinomycetales*. Among the reductive bacteria, the interest to the bacteria of this genus is great as, according to the existing data [16, 17] they have a high potential of remediation of chromium-contaminated environment. The Georgian investigators studied the distribution of Cr(VI)–resistant microorganisms in basalt rocks, taken from ecologically the most contaminated regions of Georgia (Kazreti, Zestaphony) [18]. The object of investigation is bacterial strains isolated from Kazreti basalts.

For studying the influence of **Ca** on the process of assimilation of Cr(VI) and Zn by Arthrobcterglobiformis 151B, we cultivated bacteria in 500 ml Erlenmaier flasks in 100 ml TSB liquid medium. We additionally introduced Ca solution in the form of $CaCl_2$ into some samples (flasks), thus, the concentration of Ca, added in the nutrient medium, was100 mcg/ml, 400 mcg/ml and 1600 mcg/ml.

In five samples, we additionally introduced a solution of Cr (VI), the final concentration of which in the nutrient medium was 40 μg/ml.

The nutrient medium also (itself) contained elements of the following concentrations: **Na-3.5mg/ml, K-0.6mg/ml, Ca-25μg/ml,Cr - 7 μg/ml, Zn - 1 μg/ml.**Thus, in these 5 samples, the total concentration of Cr in the nutrient medium was 47 μg/ml. The cultivation of bacteria proceeded during 17h, 24h, 48h, 96h and 144h. After cultivation we carried out the precipitation by centrifuge (3000 rpm, 10 min., 0^0C), we poured out supernatants and the remained bacterial pellet washed in sterile distillated water. We dried the obtained biomasses by low-temperature lyophilizer and weighted them (the whole masses). From the total quantity of bacterial pellet we took the amount necessary for analyses, weighted it (~30 mg) and put it into test tubes. In order to convert the samples into a liquid state, we added the concentrated nitric acid (1 ml) into the test tubes, heated it and after a complete ashing dissolved it by bidistillate to a certain volume. The analysis of the obtained samples on the content of metals was made by atom-absorption spectrometer (Analyst 800, acetylene–air flame). We studied the process of assimilation of Cr(VI) and Zn by bacteria and the influence of Ca ions of this process.

Results and Discussion

The results of measurement are given in Fig. 1, 2 and 3.

The content of Cr in bacteria, after 144 hours of cultivation is the same for all concentrations of Ca, added to the nutrient medium.

The content of Cr in bacteria does not undergo significant changes during the entire period of bacteria cultivation, when 0 mg/ml and 1.6 mg/ml Ca are added to the nutrient medium.

Adding 0.4 mg/ml Ca to the nutrient medium increases the penetration of Cr in bacteria within 17 hours of cultivation.

After 17 hours of cultivation, Cr is gradually removed from bacteria. After 144 hours, the Cr content becomes equal when the Ca content in the nutrient medium was 0%/ml, 0.1 mg/ml and 1.6 mg/ml. When the Ca content in food is 0.1 mg/ml, there is a tendency for the Cr content in bacteria to increase at the beginning of cultivation.

The addition of Ca in the nutrient medium causes an increase in the zinc content of the bacteria during the entire cultivation period. For various concentrations of Ca added in the nutrient medium, the highest Zn content in bacteria is observed under 17-hour cultivation with the addition of up to 0.4 mg / ml Ca in the nutrient medium. For this Ca concentration in the food environment, in the next period of cultivation, the concentration of Zn in bacteria gradually decreases. When the concentration of Ca in the medium is 1.6 mg/ml (maximum), we have the maximum concentration of Zn in bacteria after 24 hours of cultivation. During the period after cultivation, the concentration of Zn in bacteria gradually decreases. After 144 hours of cultivation, Zn concentrations are equal in those bacteria that grow in the nutrient medium with Ca. When we did not add Ca in the medium, the concentration of Zn in bacteria is 2 times less.

The addition of Ca in the nutrient medium leads to a sharp decrease in the bacterial mass. The exception is when the Ca concentration in the nutrient medium is 1.6 mg/ml.

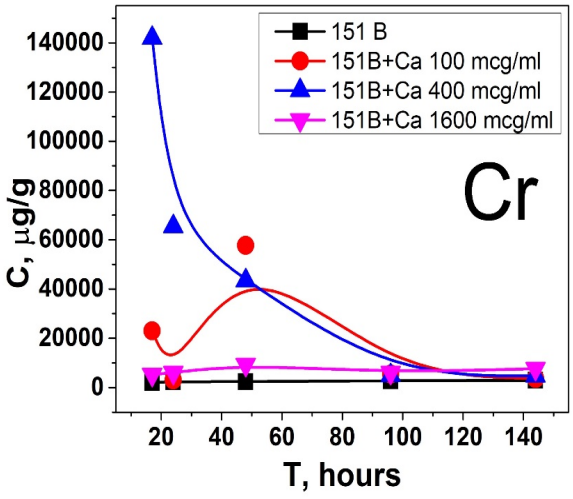

Fig 1. *The effect of Ca on the process of uptake Cr by bacteria (Arthrobacter globiformis 151B). T(hours)- The growth time of bacteria. The Ca concentration in the nutrient medium is 100 mcg/ml, 400 mcg/ml and 1600 mcg/ml.*

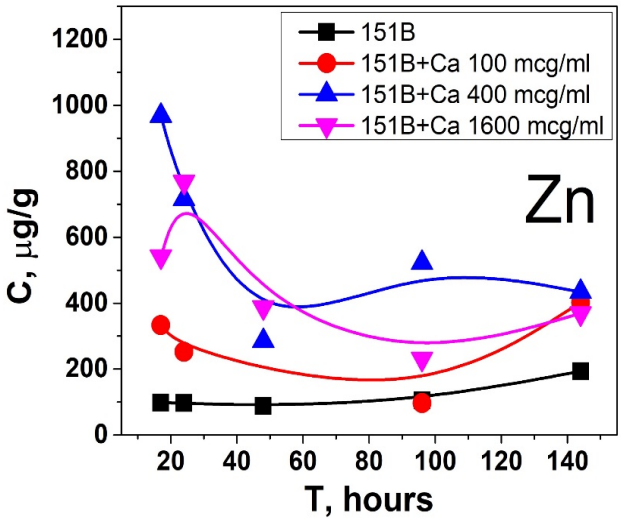

Fig 2. *The effect of Ca on the process of uptake Zn by bacteria (Arthrobacter globiformis 151B). T(hours)- The growth time of bacteria. The Ca concentration in the nutrient medium is 100 mcg/ml, 400 mcg/ml and 1600 mcg/ml*

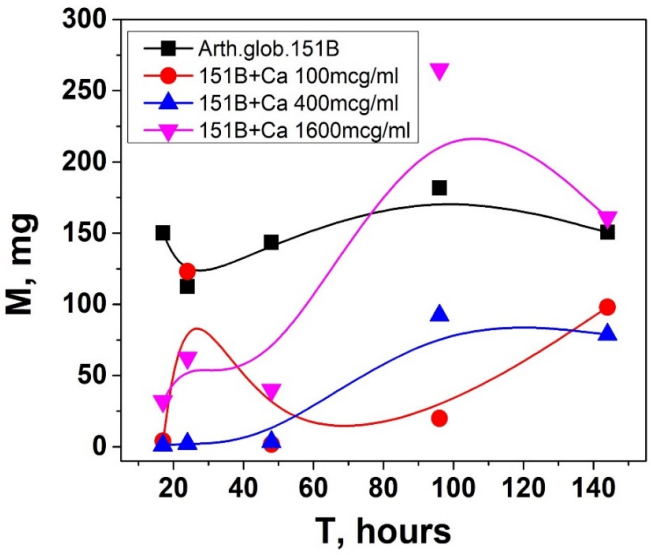

Fig 3. *The Ca concentration in the nutrient medium is 100 mcg/ml, 400 mcg/ml and 1600 mcg/ml.*

Conclusion

The addition of Ca in the nutrient medium increases the content of Cr in bacteria in the initial stage of cultivation, when the concentration of Ca in the nutrient medium is 100 and 400 µg/g. After cultivation, the Cr content in bacteria is almost the same for different concentrations of Ca in the environment.

The addition of Ca promotes the penetration of Zn into bacteria at various concentrations of Ca in the environment. At various concentrations of Ca

in the environment, the content of Zn in bacteria is higher during the entire cultivation period.

The addition of Ca in the nutrient medium slows the growth of bacteria, at various concentrations of Ca. An exception is the case when 1.6 mg/ml Ca is added to the nutrient medium. The influence of Ca is pronounced at the initial stage of the cultivation of bacteria. In the next cultivation period, the bacterial biomass increases and approaches the biomass value when bacteria are cultured without addition of Ca.

Acknoeledgements

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Challenges of modern World and the Georgian agricultural anti-crisis plan

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A B S T R A C T

The paper discusses the problems that will help governments' first priorities in tackling the COVID-19 pandemic have been to overcome the health emergency and to implement rapid economic rescue measures, the latter mostly aimed at providing essential liquidity and protecting livelihoods in the face of abrupt losses of income. As the health crisis gradually abates in some countries, attention is now turning to preparing stimulus measures for triggering economic recovery. The relative importance of the other dimensions will likely vary across different country contexts, according to their development priorities, infrastructure needs and social circumstances, in particular for developing countries. The food sector is fundamentally important for the conservation and sustainable use of natural capital, and ultimately dependent on it. Secure food supply is essential for well-being and economic stability – indeed even to sustain life – meaning that the availability and affordability of food are likely to be key government priorities coming out of the crisis. The agriculture sector faces growing threats including from climate change and infectious diseases of plants and livestock. In some countries, initiatives have been voiced to protect national producers, such as introducing minimal quotas for local products on shelves of supermarkets (Bulgaria and Croatia); Some countries have banned the import of food and live animals from the countries and regions significantly affected by the virus (Croatia); in Bosnia and Herzegovina, small farmers are offered sowing packages for the development of local production. Taxes will be returned to people living above 600 meters above sea level, the government will help them with the purchase of agricultural equipment, support the production and irrigation infrastructure, develop the livestock business and strengthen the processing industries for domestic use. Additional funds will be spent on the cultivation of industrial crops and the development of organic farms. Also, attention will be paid to the cultivation of previously abandoned croplands. The article also discusses let to address the challenges of the pandemic and support agriculture, the Government of Georgia has promptly developed an adequate plan. Because the plan is very complex, it will help to reduce the impact of the pandemic on the country's economy and all directions of agriculture. Most of the problems in the agrofood sector are directly related to the efficiency of the land market and land profitability. Launching a land market will help to enlarge the area of agricultural land, spread intensive agro technology, and increase the banks' interest in the sector. The way the authorities provide information on external markets of agrofood production and international standards must be streamlined, which will help to improve sales opportunities and the issuing of bank loans for the processing sector in order to meet the demand of processing enterprises working with raw materials supplied by farmers. All of this will significantly accelerate rehabilitation of the processing industry, which could play an intermediate role between the financial institutions and the farmers.

Keywords: Agricultural sectors, Agrofood, Climate changes, Food sector, Economy principles, Land.

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The rational use of land is important in many countries [1-17].

For the economic recovery from the COVID-19 crisis to be durable and resilient, a return to 'business as usual' and environmentally destructive investment patterns and activities must be avoided. Unchecked, global environmental emergencies such as climate change and biodiversity loss could cause social and economic damages far larger than those caused by COVID-19. To avoid this, economic recovery packages should be designed to "build back better". This means doing more than getting economies and livelihoods quickly back on their feet. Recovery policies also need to trigger investment and behavioural changes that will reduce the likelihood of future shocks and increase society's resilience to

them when they do occur. Central to this approach is a focus on well-being and inclusiveness. Other key dimensions for assessing whether recovery packages can "build back better" include alignment with long-term emission reduction goals, factoring in resilience to climate impacts, slowing biodiversity loss and increasing circularity of supply chains. In practice, well-designed recovery policies can cover several of these dimensions at once, such as catalysing the shift towards accessibility-based mobility systems, and investing in low-carbon and decentralised electricity systems.

Governments' first priorities in tackling the COVID-19 pandemic have been to overcome the health emergency and to implement rapid economic rescue measures, the latter mostly aimed at providing essential liquidity and protecting livelihoods in the face of abrupt losses of income. As the health crisis gradually abates in some countries, attention is now turning to preparing stimulus measures for triggering economic recovery.

Rrecovery measures can be assessed across a number of key dimensions. Common to all these dimensions is the need for urgent decisions taken today to incorporate a longer-term perspective. A central dimension of building back better is the need for a people-centred recovery that focuses on well-being, improves inclusiveness and reduces inequality.

The relative importance of the other dimensions will likely vary across different country contexts, according to their development priorities, infrastructure needs and social circumstances, in particular for developing countries. These dimensions include:

- **Aligning recovery measures with long-term objectives for reducing GHG emissions.** Avoiding the worst impacts of climate change is key to future resilience and stability. A careful assessment of the influence of stimulus packages on future GHG emissions trajectories is crucial, including in the context of moving towards net-zero emissions. This relates both to near-term emissions of economic activities receiving liquidity support, as well as long-term structural implications of potential lock-in through infrastructure investment decisions facilitated by recovery packages. The long-lived nature of infrastructure investments likely to be made through stimulus packages means that decisions made now will have implications for decades to come, and could determine whether the world can achieve its goals of averting the worst impacts of climate change.
- **Strengthening resilience to the impacts of climate change.** Resilience to climate change is one specific aspect of improving the overall resilience of economies and societies. In particular, infrastructure networks will face increasing pressures from the impacts of climate change, but also play an important role in building society's resilience to those impacts. Infrastructure investment is likely to be a key component of recovery measures in many countries – in part because of job creation potential – and it is important to ensure that infrastructure investments are climate resilient and do not increase exposure and vulnerability.
- **Integrating more ambitious policies to halt and reverse biodiversity loss and restore ecosystem services, including through nature-based solutions.** Biodiversity and ecosystem services are fundamental to economic activities and human health; deforestation and other land use change have been linked to the spread of diseases. Investment in natural infrastructure such as reforestation and wetland restoration are not only a cost effective and sustainable way to improving resilience to climate impacts, but offer employment opportunities similar to man-made infrastructure investments. Investments targeted through stimulus packages need to better assess and value biodiversity and ecosystem services, and integrate these values into decision-making.
- **Fostering innovation that builds on enduring behaviour changes**. Continued technological and process innovation will be critical to achieving climate and other sustainability goals.
- **Improving resilience of supply chains, including through increased adherence to circular economy principles:** the COVID-19 pandemic and containment measures have raised new questions about the systemic resilience of complex global production methods and value chains, triggering renewed interest in more diversified and more localised production and shorter supply chains in certain sectors.

The food sector is fundamentally important for the conservation and sustainable use of natural capital, and ultimately dependent on it. Secure food supply is essential for well-being and economic stability – indeed even to sustain life – meaning that the availability and affordability of food are likely

to be key government priorities coming out of the crisis. The agriculture sector faces growing threats including from climate change and infectious diseases of plants and livestock. It is also a major driver of environmental degradation. Land-use change, including for agriculture, is responsible for a large part of deforestation. Furthermore, excessive fertilizer use has important implications for freshwater ecosystems due to nutrient run-off. Increased ecosystem pressures due to agriculture could also have implications for potential creation of new human diseases. Agricultural expansion into zones close to wilderness areas increases pressures on biodiversity, and agricultural intensification, for example with denser livestock populations, can increase the chance of zoonotic transfer of viruses across species.

Agriculture already receives substantial government support globally. In addition to securing jobs and preventing near-term supply disruption, recovery measures should aim to reshape policies in the sector to promote environmental sustainability and resilience, and innovation for improved productivity.

The global COVID-19 pandemic is still spreading rapidly and poses a threat to mankind, also it has a high negative influence on food demand and supply chains. The risk of the food crisis is growing, especially for poor and vulnerable countries. Border closure, quarantines, closed markets, and, in general, suspensions in trade particularly seriously impact the countries severely affected by the virus and the countries without food security. To prevent this, governments have to take certain immediate actions to minimize the risk of food insecurity in several countries around the world.

Due to the closure of hotels, restaurants, cafes (HoReCa), schools, various institutions, the cancellation of festivals and events in developed countries because of Coronavirus, demand on food has declined sharply, and in some places, farmers have no choice but to destroy their produce; the closure of the borders has completely halted the movement of the seasonal workforce, leaving the EU and the US farms face to face against the dramatic shortage in workers; Due to the prevailing situation less money flows into this sector, farmers in some countries are faced with a shortage of money; and the developing countries are now at risk of acute food shortages.

What are the different countries doing to help farmers?

The US government has mobilized tens of billions of dollars for various programs that cover the agricultural sector and provide direct financial assistance, loans, exemption from taxation of the payment for bona fide leave of absence (due to Covid-19), simplified granting of H-2A and H-2B visas to the agricultural sector and other measures. Also the USA government will buy 3 billion dollars' worth food from farmers.

The **Canadian** government's response to the crisis caused by the Coronavirus epidemic is as follows: they are providing financial aid to individuals, businesses and industries, by direct distribution of money and access to credit, which includes providing financial assistance to farmers: interest payments of 6 -12 months and access to an additional credit lines. 5 billion Canadian dollars have been allocated for this purpose.

The **Australian** Government has classified agriculture and food systems as essential services that are largely exempt from lockdown restrictions. Besides, it has simplified the procedures for extending work visas to seasonal workers. Australia is one of the safest countries in the world in terms of food self-sufficiency, and the share of imported food accounts for only 16% (processed fruit and vegetables, chocolate, coffee, pasta, and rice).

South Africa, which is a net exporter of food, will provide financial support to small farmers directly affected by the virus. The government has allocated an equivalent of approximately USD 62 million, which includes assistance to sectors such as the development of poultry, through the purchase of incubators, food, and medication, the supply of livestock with feed and medication, as well as assistance to farmers in the vegetable sector through the purchase of seedlings, fertilizers, and pesticides for them in order to improve soil fertility. However, only those farmers will be provided with the support who have been farming for a minimum of the past 12 months and **are registered on farmer register or will be registered to receive support**. The package does not include support in infrastructure, mechanization, or debt repayment, and serves only to mitigate the impact caused by COVID-19.

As it was mentioned the main challenge for Europe is the shortage of the workforce and the ways out of the crisis for the different European countries are stimulation of the employees that lost their jobs and have a call for the agricultural faculty students to work at the local farms (for example in France and Germany); farms and enterprises have suspended unnecessary visits and inspections, they also charter airplanes (The Great Britain) to bring in agricultural workers, because, for example, last year 98% of

fruit in the UK were picked by foreign nationals; by creating various online platforms, they try to eliminate the workers' shortage in agriculture (Italy); they are softening regulations to attract workforce and employ migrants (Spain); they extend visas for seasonal workers (Poland); farmers are assisted in partial repayment of loans to help ensure liquidity for companies and preserve money flow (Latvia, 45.5 million euros).

In some countries, initiatives have been voiced to protect national producers, such as introducing minimal quotas for local products on shelves of supermarkets (Bulgaria and Croatia); Some countries have banned the import of food and live animals from the countries and regions significantly affected by the virus (Croatia); in Bosnia and Herzegovina, small farmers are offered sowing packages for the development of local production. Taxes will be returned to people living above 600 meters above sea level, the government will help them with the purchase of agricultural equipment, support the production and irrigation infrastructure, develop the livestock business and strengthen the processing industries for domestic use. Additional funds will be spent on the cultivation of industrial crops and the development of organic farms. Also, attention will be paid to the cultivation of previously abandoned croplands **(Republika Srpska (Bosnia and Herzegovina)).**

As for the **European Union, t**he European Commission has developed a 100 billion euro solidarity instrument to help companies in the agro-food sector keep jobs. The money will be transferred to the Member States in the form of loans, and they themselves will determine the most necessary and needed activities.

The Government of Georgia announced the "State Program for Subsidizing Wheat Import" a few days ago for such a scenario, for which GEL 5.2 million were allocated. Earlier, in March, the government began subsidizing prices for 9 types of food products.

The anti-crisis plan of the Government of Georgia: rural and agriculture support

We can boldly say that the interest of the representatives of the business community in the agricultural sector is growing. In 2019, according to the data declared by enterprises, food, beverages and tobacco worth GEL 4.2 billion were produced, which is 20% more than in 2018 and 114% higher than the corresponding figure for 2012.

According to preliminary data for 2019 (a total figure for 4 quarters), the turnover of the business sector in rural, forestry and fish farms amounted to GEL 478 million, which is 273 million GEL (133%) more than in 2012.

According to the preliminary data of 2019 (the sum of 4 quarters), the Business Sector Production Output in Agriculture, forestry and fishery amounted to GEL 486 million, which has exceeded the index of 2012 by GEL 252 million (108%). In 2012-2019, the Average Absolute Growth of this rate was GEL 36 million, while the Average Annual Growth rate was 11%.

To address the challenges of the pandemic and support agriculture, the Government of Georgia has promptly developed an adequate plan. Because the

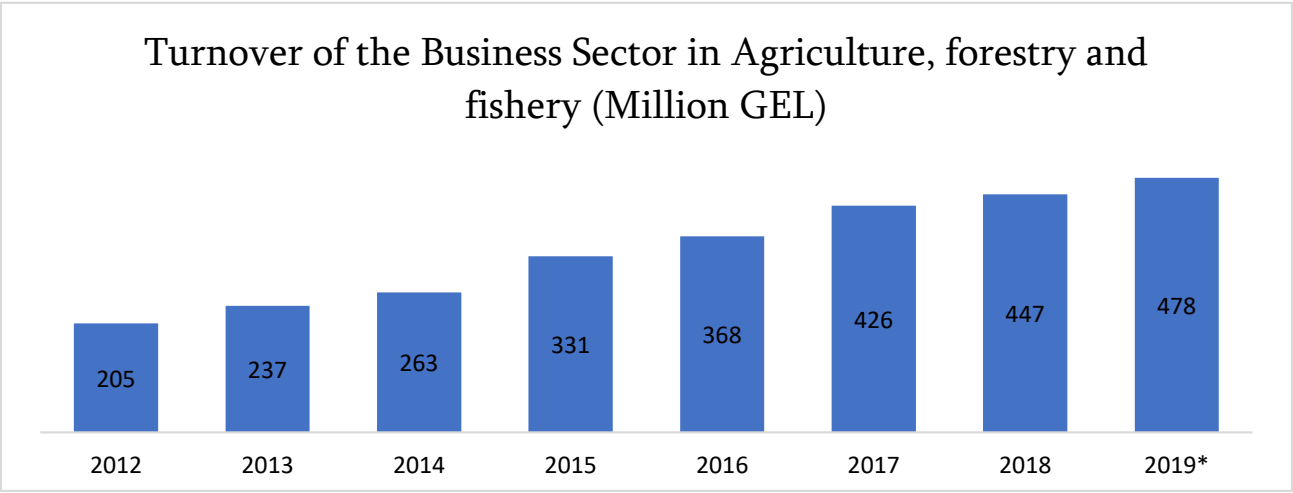

Fig . *Turnover of the business sector in Agriculture, forestrt and fishery (million gel)*

* Preliminary data. Source: Geostat.

plan is very complex, it will help to reduce the impact of the pandemic on the country's economy and all directions of agriculture.

In response to the pandemic, an anti-crisis plan was developed - an unprecedented program of assistance to farmers, that provides financial and technical support for all links in the agricultural value chain. The Government aims to minimize the damage caused by the global crisis in the country.

For above-mentioned reasons, the GoG formed the portfolio of support that amounted GEL 300 million (including the loan portfolio issued by the banking sector that amounted GEL 50 million. The details are described below) to ensure that every citizen involved in agriculture can receive assistance from the state during the crisis posed by the pandemic, in particular:

- GEL 37 million is mobilized. Thus, the farmers can buy fertilizers, plant protection and maintenance products, seed and planting materials, as well as cover the cost of ploughing.
- A new state program "Stimulation of Agricultural Landowners" is launched, which considers subsidising the cost of agricultural goods and ploughing services. To receive the subsidy, individuals and legal entities shall own agricultural land registered in the public register. The amount of the subsidy is determined by GEL 200 for 1 ha (200 points accrued on the agro-card). In the framework of the project, the subsidy for land plot no more than 10 ha is a maximum of GEL 2000. The program will have about 200,000 beneficiary farmers, and the program budget is GEL 37 million.
- To encourage the growth of agricultural production, individuals and legal entities owning 0.25 to 100 hectares of agricultural land registered at the National Agency of Public Registry can buy diesel fuel at a lower price as part of a new state project. The fuel limit was set at 150 litres per hectare. The beneficiaries of the program will be 200,000 farmers who will save GEL 40 million.
- GEL 8 million will be completely written off to farmers, which were accumulated in 2012-2019 due to non-payment of amelioration service fees. farmers will be exempted from the amelioration service fee in this year, the state will pay GEL 75 per hectare - a total of GEL5 million.
- The percentage of co-financing increases in the component of fixed assets of "preferential agro-credit". the Government will finance 11% for 48 months, instead of the existing 8% per annum. The percentage of co-financing for leasing is also increasing, instead of the current 9%, it will be 12%. In the component of fixed assets and all its sub-components, the upper limit of the interest rate imposed on banks increases, instead of 15%, it will be 18%. In total loans disbursed to farmers under the program will amount to GEL 25,000,000. The total budget for co-financing of annual interest rate amounts to GEL 4,000,000 for 2 years.
- A secondary security component has been set up for loans issued for working capital for livestock and Hazelnut production. Within the component, the secondary security collateral of not more than 50% of the total amount of each new loan will be issued and secured by the state within the next 18 months following the issuance of the loan or its first tranche.
- The financing of food industry starts. the amount of the loan is determined from GEL 1 500 001 to GEL 5 000 000. the government will co-finance the loan with an interest rate of 10% per annum for 24 months. Grape processing, bread and bakery production, pasta production will be added to the targeted credits. A sub-component of agro-leasing for the food industry will be added as well, where state co-financing will be 12% for 24 months. Under the frame of the program, the estimated total amount of loans for farmers will amount to GEL 20 million. Through a secondary security component GEL 0.5 million will be covered.
- To facilitate primary production, the "Agricultural Support Program" will be renewed, which foresees to co-finance the purchase of agricultural machinery and also main tools for the installation of an irrigation system for annual crops, an arrangement of new or enlargement/modernization of existing greenhouses. The total amount of state co-financing per beneficiary amounts to 50%, although it shouldn't exceed GEL 50,000. The total budget for co-financing of the program amounts to GEL 10 million. The program is expected to financing 200 tractors, 80,000 sq/m greenhouses and the irrigation system will be arranged on 400 ha.
- Support for agricultural cooperatives is becoming one of the top priorities. The program has been launched to finance agricultural cooperatives and help them to pur-

chase the farm equipment to produce products in accordance with market demand. The program will also support cooperatives in introducing international standards for food safety management and branding of products.

- To support the development of the rural market and agriculture, the systematic registration of land plots will be accelerated in 2020-2022. 1.2 million land plots will be registered in different regions of Georgia.

Based on the results of the analysis for finding the effective ways for a rapid overcoming of the crisis in the agricultural segment, it is necessary and essential to use differentiated organizational and economic mechanisms of market and state regulations. Also developing and stimulation of the existing potential.

Most of the problems in the agrofood sector are directly related to the efficiency of the land market and land profitability. Launching a land market will help to enlarge the area of agricultural land, spread intensive agro technology, and increase the banks' interest in the sector. The way the authorities provide information on external markets of agrofood production and international standards must be streamlined, which will help to improve sales opportunities and the issuing of bank loans for the processing sector in order to meet the demand of processing enterprises working with raw materials supplied by farmers. All of this will significantly accelerate rehabilitation of the processing industry, which could play an intermediate role between the financial institutions and the farmers.

Hereby it is clear that finding the solutions on the given tasks require a long-term perspective and large investments. Agriculture as an industry sector is, of course, less attractive for investors, since only communications and energy are highly profitable for them. Agriculture should be rendered state support in a way that makes every peasant (farmer) want to join this sphere. For example, such countries as Belgium, Norway, Austria, Canada, the U.S., and others directly finance agriculture from the budget in many cases, and this financing is quite significant. The European Union granted 60 million Euros in 2008 alone to support agriculture. Besides, it is important to implement several kinds of reforms such as – the acknowledgment of the modern management criteria, providing adequate continuous education, constant training, consulting for the farmers and employees in the agricultural sphere.

The intentions of the society towards sustainable land management is very important [18]. It is crucial to increase the activity of the insurance system in the Agricultural sector, especially when the state provides co-financing in almost all directions of Agriculture.

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Response pattern of local, inbred and hybrid monsoon rice varieties to elevated nitrogen levels

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ABSTRACT

The experiment was conducted at the Bangladesh Agricultural University during July to December 2017 to investigate the response of local, inbred and hybrid rice varieties to elevated nitrogen fertilizer application. The experiment comprised two factors such as factor A: nitrogen levels viz., control (without N fertilizer), 40, 80, 120, 160 and 180 kg N ha^{-1}; factor B: rice varieties viz., Latma (local), BRRI dhan49 (inbred) and Agrodhan-12 (hybrid). Experiment was laid out in a Split-plot design with three replications where nitrogen levels were assigned to main plots and varieties were to sub-plots. Nitrogen levels, varieties and their interactions significantly influenced the yield contributing characters and yield of rice. Agrodhan-12 fertilized with 120 kg N ha^{-1} produced the highest grain yield which was statistically similar to BRRI dhan49 interacted with 80 kg N ha^{-1}. The lowest yield was obtained from Latma without N fertilizer. The treatment 40 kg N ha^{-1} resulted the highest nitrogen use efficiency. In terms of yield and economic performances, 120 kg N ha^{-1} performed best. Based on these results it may conclude that 120 kg N ha^{-1} is the optimum dose for hybrid Agrodhan-12, whereas 80 kg N ha^{-1} for local Latma or inbred BRRI dhan49.

Keywords: Aman rice, Nitrogen levels, Yield performance, N use efficiency, Grain yield, Split-plot.

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Introduction

Rice is one of the most important food crops feeding more than 50% of the world's populations [1], and about 90% of the world rice is grown in Asia [2]. The top ten rice producing countries in the world today are India, China, Indonesia, Bangladesh, Thailand, Vietnam, Burma, the Philippines, Cambodia and Pakistan [3]. These countries also consume about 90% of the world's rice. According to the Food and Agricultural Policy Research Institute, the world's demand for milled rice can be expected to rise to 496 million tons in 2020, from 439 million tons in 2010. This demand for rice is expected to increase until 2035.

Nitrogenous fertilizer is one of the major inputs of rice production [4]. The doubling of crop production over the past four decades has been associated with a 7-fold increase in the use of nitrogenous fertilizers worldwide [5]. Besides, the excessive fertilization and unique conditions of paddy fields promote nitrogen losses to the environment, which results in low nitrogen utilization rate and unstable grain production. Farmers of the developing countries have the tendency to apply a higher amount of nitrogenous fertilizer than the optimum to get desirable yield of rice [6], but over application of nitrogenous fertilizer may actually decrease grain yield by increasing susceptibility to lodging, and disease and insect pest infestation [7, 8]. Hence, before making nitrogen fertilizer recommendations for a particular rice variety, one should identify the optimum dose, nitrogen use efficiency and economics to get maximum out returns from minimum input.

Now-a-days, different inbred and hybrid rice varieties are gaining popularities in the Asian countries due to their higher yield potentiality than local varieties (Islam et al., 2017). However, local culti-

vars have advantages of withstanding environmental stress, and pests and diseases [9]. Hybrid varieties, on the other hand possess a more vigorous and extensive root system and rapid growth rate during vegetative period. Uphoff et al. [10] stated that high yielding or hybrid rice varieties yielded more than 15 t ha^{-1}, while traditional/local varieties produced 6-12 t ha^{-1} under well managed condition. Iqbal et al. [4] revealed that inbred and hybrid rice varieties are highly responsive to different levels of nitrogen.

Variety-wise fertilizer recommendation is one of the important options to increase rice yield. So it is very essential to know nitrogen response behaviour of inbred and hybrids compared to the local rice varieties. However, the response of different local and inbred rice varieties in comparison with hybrid varieties to elevated levels of nitrogen especially under Bangladesh condition is not well flourished and widely known to the researchers. In this back drop, this study was undertaken to investigate into the differences in response to elevated doses of nitrogenous fertilizer among local, inbred and hybrid rice varieties and to identify the best economic dose(s) for local, inbred or hybrid rice varieties.

Materials and Methods

Experimental Site

The experiment was conducted at the Agronomy Field Laboratory, Bangladesh Agricultural University (latitude 24.75° N, longitude 90.50° E and elevation from sea level l8 m) during June-December, 2017. The experimental area was a fairly leveled well drained medium high land belonging to the Sonatola series of non–calcareous dark grey floodplain soil under the Old Brahmaputra Floodplain agro-ecological zone [11]. The experimental soil was silt loam having bulk density of 1.35 g cc^{-1} and pH 5.70. The soil contained 0.09% total nitrogen, 1.02% organic matter, 5.68 ppm available phosphorus, and 49.12 ppm exchangeable potassium and 8.28 ppm available sulphur. The experimental site was characterized by high temperature, high humidity and heavy rainfall with occasional gusty wind in April-September and scanty rainfall associated with moderately low temperature during October-March. During the growing season (July– December, 2017), monthly average maximum, minimum temperature, relative humidity and average of monthly total rainfall were 32.3°C, 24.4°C, 84.6% and 229.5 mm, respectively.

Experimental Treatments and Design

The experiment comprised six levels of nitrogen application *viz.* 0, 40, 80, 120, 160 and 180 kg N ha^{-1} and three rice varieties *viz.* Latma (local), BRRI dhan49 (high yielding inbred) and Agrodhan-12 (hybrid). The experiment was laid out in a Split-plot design with three replications where nitrogen levels were assigned to main plots and varieties were in sub-plots. The size of unit plot was 4.0 × 2.5 m (10 m^2) where block to block and plot to plot distances were 1m and 0.5 m, respectively.

Crop Husbandry and Data Recording

Twenty-five days old seedlings were transplanted at 25 cm× 15 cm spacing with three seedlings $hill^{-1}$. The fertilizers TSP, MoP, Gypsum, and Zinc sulphate were applied @ 130-120-70-10 kg ha^{-1}, respectively. All the fertilizers were applied as basal dose except urea which was applied as top dressing in 3 equal installments at 15 days after transplanting (DAT), tillering and panicle initiation stages as per the treatment specification. Weeding was done manually twice at 30 and 45 DAT. Intercultural operations *e.g.* gap filling, irrigation and drainage were done as per requirement. As there were no remarkable infestation of disease and insect, hence no plant protection measure was taken. At maturity (when 90% of the seeds became golden yellow in color), three square meter area from each plot was marked from the central portion and cut manually from the ground level to take grain and straw yields. Agrodhan-12, Latma and BRRI dhan49 variety were harvested at 13, 18 and 20 November, 2017, respectively. The grains were cleaned and dried to a moisture content of 14%. Straws were sun dried properly. Final grain and straw yields $plot^{-1}$ were recorded and converted to t ha^{-1}. Prior to harvesting, five hills were randomly selected from each plot for recording data on different yield contributing characters. Nitrogen use efficiency, grain yield merit and monetary advantage were calculated as follows:

$$\text{Nitrogen use efficiency} = \frac{\text{Total grain yield}}{\text{Amount of applied nitrogen}} \quad \text{.....(i)}$$

$$\text{Grain yield merit (\%)} = \frac{\text{Grain yield of N applied plot} - \text{grain yield of control plot}}{\text{Grain yield of coltrol plot}} \times 100 \ldots\ldots\ldots\ldots\ldots (ii)$$

Monetary advantage = Total grain yield (t ha^{-1}) × Unit price of the grain ……………………(iii)

Statistical Analysis

The recorded data related to yield contributing characters and yield were compiled and tabulated in proper form for statistical analyses. Analysis of variance was done at 5% probability level with the help of MSTAT–C computer package program. The mean differences among the treatments were evaluated with DMRT test. The relationship between grain yield and fertilizer dose were fitted by the following quadratic model using 'R' statistical programme:

$$Y = a + bX + cX^2 \ldots\ldots\ldots\ldots\ldots\ldots (iv)$$

Where, Y = seed yield (t ha^{-1}), X = the dose of the nitrogen applied (kg ha^{-1}), a, b and c are the parameters of the model.

Results and Discussion

Yield Contributing Characters

All the yield contributing characters differed significantly due to nitrogen levels, but only number of effective tillers hill^{-1} and 1000-grain weight differed significantly among the varieties (Table 1). Whereas, their interactions had significant effect on all the yield contributing characters (Table 1). The highest number of effective tillers hill^{-1} (18.15), grains panicle^{-1} (213.80), 1000-grain weight (26.27 g) and longest panicle (19.72 cm) were observed in 120 kg N ha^{-1}, which was statistically identical to 80 kg N ha^{-1} (Table 1). The lowest number of effective tillers hill^{-1} (12.14), grains panicle^{-1} (170.87), 1000-grain weight (22.59 g) and shortest panicle (15.58 cm) were found from the control (Table 1). The hybrid variety Agrodhan-12 produced the highest number of effective tillers hill^{-1} (16.98) and 1000-grain weight (24.98 g), and both the values were statistically similar with BRRI dhan49 (Table 1). Local variety Latma produced the lowest number of effective tillers hill^{-1} (15.36) and 1000-grain weight (22.84 g).

In case of interaction, the highest number of effective tillers hill^{-1} (21.02), grains panicle^{-1} (244.15), 1000-grain weight (30.12 g) and longest panicle (25.25 cm) were found in Agrodhan-12 applied with 120 kg N ha^{-1}, which was statistically similar to BRRI dhan49 interacted with 80 kg N ha^{-1} application (Table 2). The lowest number of effective tillers hill^{-1} (8.02), grains panicle^{-1} (156.25), 1000-grain weight (22.22 g) and shortest panicle (15.05 cm) were found in the local variety Latma without N application. The variations among the varieties regarding these yield contributing characters are mainly related to their genetic makeup [12].

The number of effective tillers hill^{-1} at higher rates of nitrogen could be attributed to increased photosynthate production and its translocation for panicle formation at the reproductive stage [12, 13] also found that number of effective tillers hill^{-1} was significantly influenced by the higher dose of nitrogen. There was a significant increase in number of grains panicle^{-1} with increase in each successive level of N up to 80 kg N ha^{-1} for inbred and local variety, and 120 kg N ha^{-1} for hybrid variety. Further increase in the rate of nitrogen fertilizer from the above-mentioned levels reduced the number of grains (Table 2). Similar type of results were also reported by [14, 9, 12].

The results also showed that hybrid variety Agrodhan-12 needs higher dose of nitrogen (120 kg N ha^{-1}) to produce highest 1000-grain weight compared to inbred BRRI dhan49 (80 kg N ha^{-1}). Due to application of higher nitrogen, plant may get the higher sink in its grain. More nitrogen may increase the dry matter partitioning in grain and then converted into seed protein content and higher seed protein increased the 1000-grain weight. This result contradicts with the findings of [15] who found no significant differences in 1000-grain weight due to application of different levels of nitrogen. Mingotte et al. [16] and Boldieri et al. [17] also reported that 1000-grain mass differences was due to cultivars, and had no influence of the nitrogen application. However, 1000-grain weight differences among different varieties were also reported by [18, 19].

Table 1. *Effect of N-levels and variety on yield contributing characters and harvest index of monsoon rice*

	No. of effective tillers hill^{-1}	Panicle length (cm)	No. of grains panicle^{-1}	Weight of 1000-grain (g)	Harvest index (%)
Nitrogen Levels (kg ha^{-1})					
0	12.14e	15.58c	170.87d	22.59d	45.14
40	16.80c	16.91b	186.91a	23.47cd	44.79
80	17.66ab	19.52a	209.95ab	25.71ab	45.62
120	18.15a	19.72a	213.80a	26.27a	46.75
160	17.10bc	16.41bc	201.73b	24.72bc	46.96
180	15.67d	15.99bc	182.83c	24.51bc	43.88
CV (%)	3.62	5.53	5.25	5.14	6.10
Level of sig.	**	**	**	**	NS
Varieties					
Latma	15.36b	16.50	187.94	22.84b	45.13
BRRI dhan49	16.42a	17.67	196.88	24.82ab	45.74
Agrodhan-12	16.98a	17.90	198.23	24.98a	45.70
CV (%)	6.73	10.36	9.83	9.13	2.31
Level of sig.	**	NS	NS	*	NS

Values with common letter (s) within a column do not differ significantly at 5% level of probability analysed by LSD.
*, ** indicate significant at 5% and 1% level of probability, respectively, NS= Non-significant

Table 2. *Interaction effect of N-levels and variety on yield contributing characters and harvest index of monsoon rice*

Interaction [N-levels (kg ha^{-1}) × Variety]		No. of effective tillers hill^{-1}	Panicle length (cm)	Grains panicle^{-1}	Weight of 1000-grain (g)	Harvest index (%)
0	Latma	8.02e	15.05b	156.25d	22.22b	42.77d
	BRRI dhan49	13.22de	15.85b	175.12cd	22.56b	45.04bc
	Agrodhan-12	15.19cd	16.02b	181.24b-d	23.01b	46.14bc
40	Latma	16.55bc	16.85b	178.52b-d	23.56b	44.57cd
	BRRI dhan49	15.98cd	17.01b	184.02b-d	22.98b	44.47b-d
	Agrodhan-12	17.88b	16.88b	190.12bc	23.88b	45.33b-d
80	Latma	16.52bc	16.81b	201.23bc	24.45b	44.26cd
	BRRI dhan49	20.92ab	24.75a	238.52a	29.02a	47.29ab
	Agrodhan-12	15.56cd	17.02b	198.21bc	23.67	45.44bc
120	Latma	16.65bc	17.12b	200.01bc	24.18b	44.91cd
	BRRI dhan49	16.78bc	16.80b	201.12bc	24.52b	47.68ab
	Agrodhan-12	21.02a	25.25a	244.15a	30.12a	48.27a
160	Latma	17.58b	15.55b	205.52b	24.08b	47.65ab
	BRRI dhan49	16.52bc	16.56b	197.25bc	24.89b	45.78bc
	Agrodhan-12	17.20b	17.13b	198.55bc	25.21b	46.84b
180	Latma	16.88bc	16.59b	186.15bc	24.56b	44.67cd
	BRRI dhan49	15.12c	16.12b	185.25bc	24.98b	44.19cd
	Agrodhan-12	15.02c	15.11b	177.11cd	24.01b	44.12cd
CV (%)		6.73	10.36	9.83	9.13	2.31
Level of sig.		**	**	*	*	**

Values with common letter (s) within a column do not differ significantly at 5% level of probability analysed by LSD.
*, ** indicate significant at 5% and 1% level of probability, respectively, NS= Non-significant.

Grain and Straw Yield

Nitrogen level, variety and their interactions significantly influenced the grain and straw yields of rice (Figure 1). The figure showed that there was an increasing trend found with the increased N levels up to 120 kg N ha^{-1} and thereafter decreased (Fig. 1). The highest grain (8.26 t ha^{-1}) and straw (9.40 t ha^{-1}) yield were found from the application of 120 kg N ha^{-1}, whereas the lowest grain (4.27 t ha^{-1}) and straw (5.19 t ha^{-1}) yield were found from control *i.e.* 0 kg N ha^{-1}. Hybrid variety Agrodhan-12 produced the highest grain (6.83 t ha^{-1}) and straw (8.07 t ha^{-1}) yield followed by inbred BRRI dhan49, whereas the lowest grain (5.96 t ha^{-1}) and straw (7.25 t ha^{-1}) yield were obtained from the local variety Latma (Fig. 2).

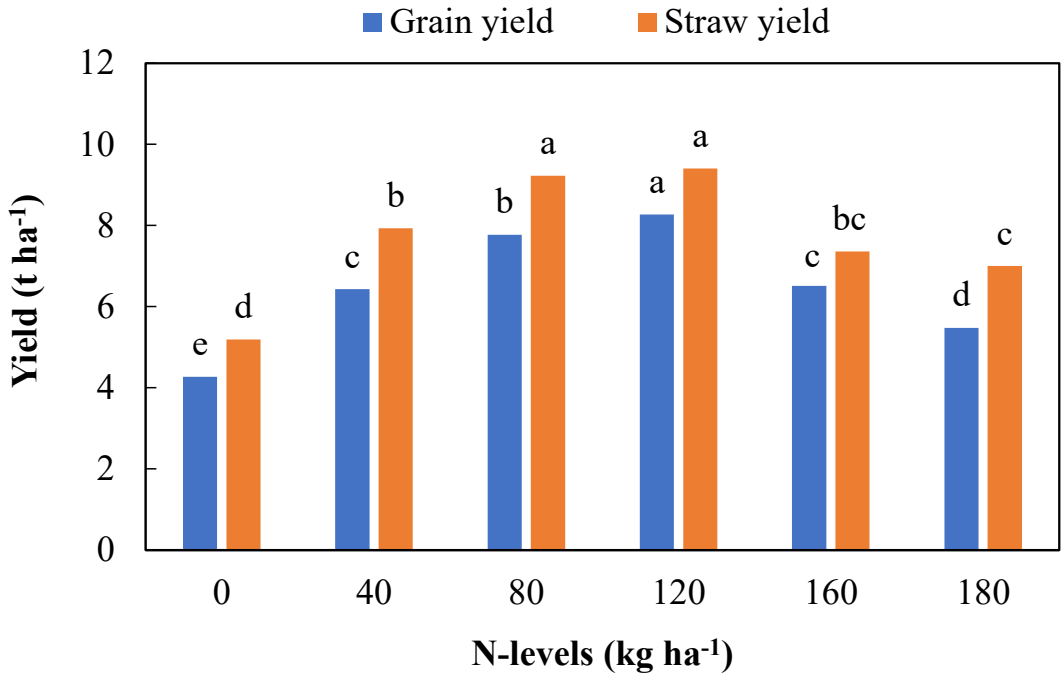

Fig 1. *Effect of N-level on grain and straw yield of monsoon rice*

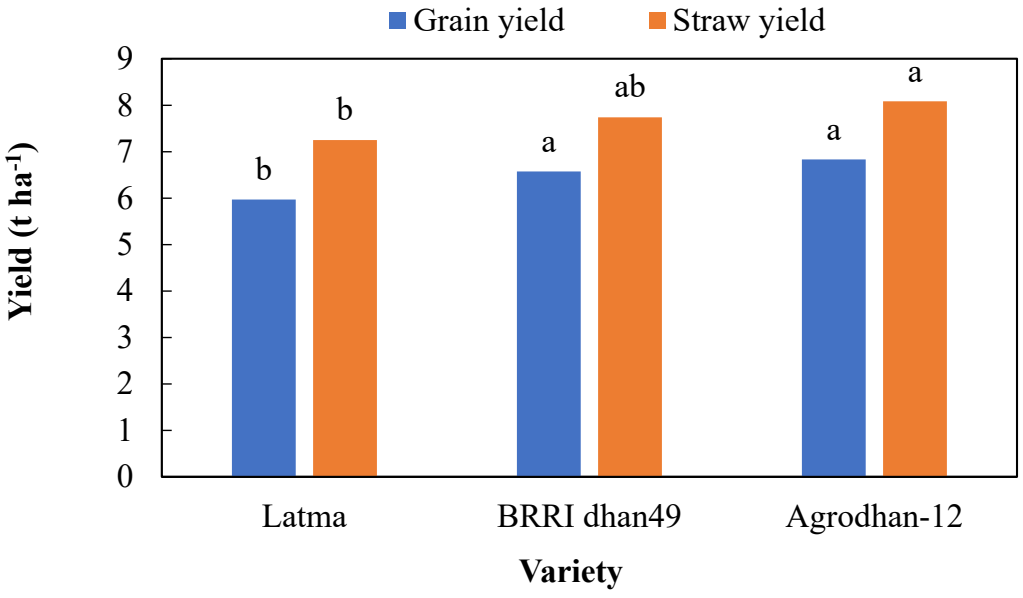

Fig 2. *Effect of variety on grain and straw yield of monsoon rice*

For interaction, the highest grain (8.70 t ha^{-1}) and straw (9.58 t ha^{-1}) yield were found in Agrodhan-12 applied with 120 kg N ha^{-1} which was statistically identical with BRRI dhan49 coupled with 80 kg N ha^{-1} (Fig. 3). The lowest grain (3.24 t ha^{-1}) and straw (4.12 t ha^{-1}) yield were found from Latma applied with no N. Similar results were also reported by Iqbal et al. [4], who reported that BRRI dhan49 and BRRI hybrid dhan4 produced highest grain yield of 5.4 and 4.9 t ha^{-1} at 80 kg N ha^{-1}, respectively. However, in the same study BRRI hybrid dhan2 gave the highest grain yield of 8.3 t ha^{-1} at 160 kg N ha^{-1}. Fertilizer rate more than 160 kg N ha^{-1} reduced the grain yield. Jisan et al. [20] estimated that the highest grain yield of some transplant monsoon rice varieties (BRRI dhan49, BRRI dhan56, BRRI dhan57 and BRRI dhan52) at 75 kg N ha^{-1} where the highest nitrogen rate used was 75 kg N ha^{-1}. In another study, Rahman et al. [12] obtained the highest grain yield of two transplant monsoon rice varieties (Binadhan-7 and BRRI dhan49) at 90-120 kg N ha^{-1} where the highest nitrogen rate used was 150 kg N ha^{-1}. Ferdous et al. [21] found highest grain yield of Binadhan-16 at 70 kg N ha^{-1} where the highest nitrogen rate used was 90 kg N ha^{-1}.

Harvest Index

Except of their interaction, nitrogen level and variety had no significant effect on harvest index (Table 1 and 2). Agrodhan-12 applied with 120 kg N ha^{-1} provided the highest harvest index (48.27%), and Latma without N application provided the lowest value (Table 2)

Nitrogen Use Efficiency

The results showed that the nitrogen use efficiency (NUE) was highest at 40 kg N ha^{-1}. Further increase in nitrogen levels decreased the NUE (Fig. 4). This is because at higher concentration of nitrogen, the absorption exceeds the utilization [22]. According to Yaduvanshi [23], an increase in doses of N fertilizer rates from 60 to 120 and 180 kg N ha^{-1} decreased NUE. It was also observed that the excessive use of nitrogen fertilizers resulted in decrease of physiological NUE and caused serious environmental pollution [22].

Grain Yield Merit and Monetary Advantage

An increasing trend of grain yield merit was found among the treatments up to 120 kg N ha^{-1} and thereafter decreased (Fig. 4). Apparently, 120 kg N ha^{-1} exhibited the maximum grain yield merit (93.62%) and which was very near (81.94%) to 80 kg N ha^{-1} over control treatment. Similar trend was also found in monetary advantage. Application of 120 kg N ha^{-1} gave the highest economic return (1, 65,356 Tk.) and which was very near (1, 55,378 Tk.) to 80 kg N ha^{-1} over control.

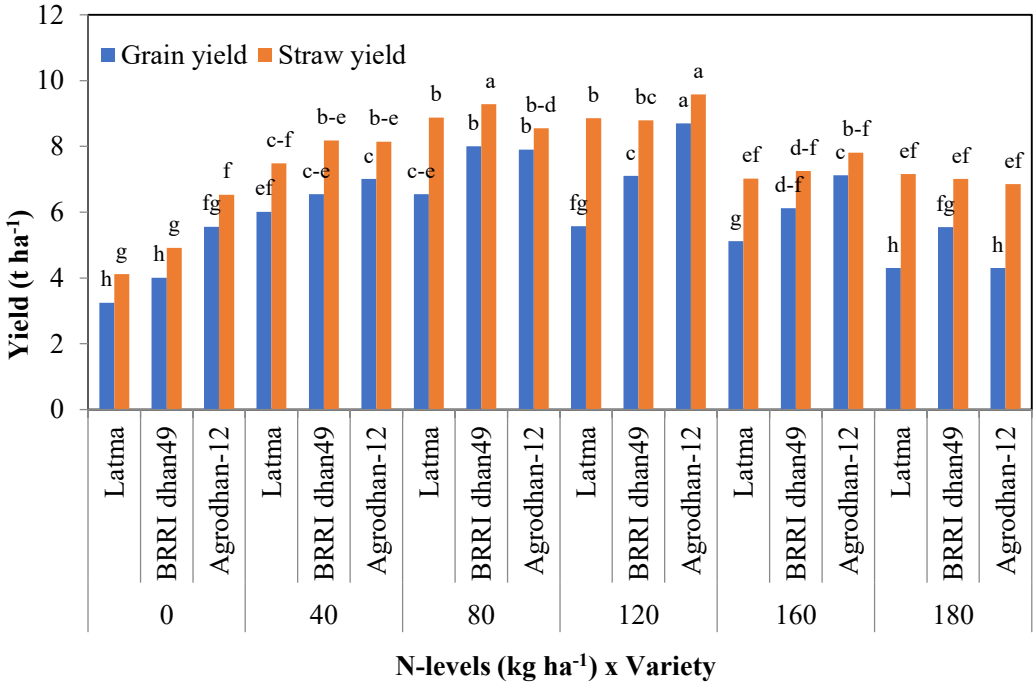

Fig 3. *Effect of variety on grain and straw yield of monsoon rice*

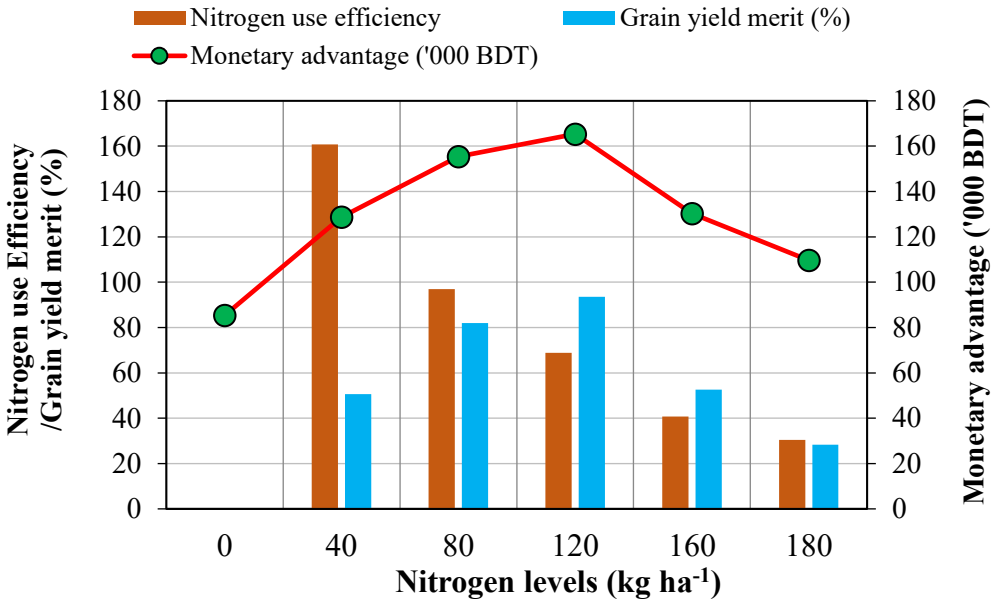

Fig 4. *Effect of N-levels on the nitrogen use efficiency, grain yield merit and monetary advantage of rice (The unit price of the grain was considered as 20 tk. kg^{-1})*

Optimum Nitrogen Dose

The yield response of three monsoon rice varieties in relation to nitrogen levels could be best explained by the quadratic equation (Fig. 5). The test analysis indicated that more than 88%, 95% and 93% of the variation in crop performance (grain yield) occurred due to nitrogen rates in local Latma, inbred BRRI dhan49 and hybrid Agrodhan-12, respectively. The estimated coefficients of the polynomial regression models showed significant variation. The estimated optimum dose of nitrogen for these three monsoon rice varieties lies in between 80 to 120 kg ha^{-1} because all these three varieties showed the highest yield when 80 to 120 kg ha^{-1} of nitrogen were applied (Fig. 5).

Conclusion

It is well known that hybrid variety needs more nutrient than inbred or local to exibit maximum yield potential. This statement also reflects in the current research where hybrid variety Agrodhan-12 produced highest grain yield when applied with 120 kg N ha^{-1}, and the local Latma and inbred BRRI

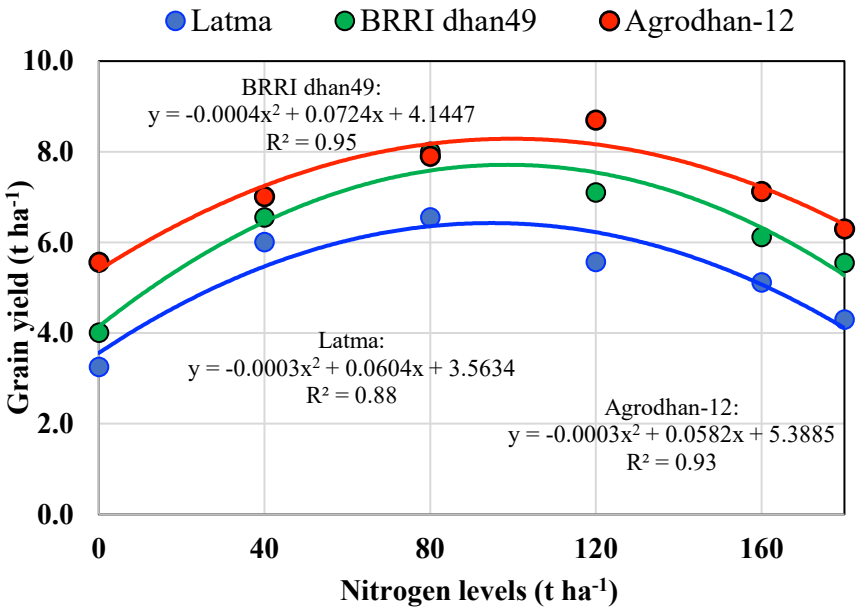

Fig 5. *Yield response of Latma (local), BRRI dhan49 (inbred) and Agrodhan-12 (Hybrid) to different nitrogen levels*

dhan49 produced highest grain yield at 80 kg N ha^{-1}. Based on the results it may concluded that Agrodhan-12 can be cultivated with the application of 120 kg N ha^{-1}. Whereas, local Latma and inbred BRRI dhan49 can be cultivated with the application of 80 kg N ha^{-1}. Their optimum dose of nitrogen lies in between 80 to 120 kg N ha^{-1}. However, further multi-location trials should be conducted with a wide range of varieties before drawing a concrete decision.

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The assessment and improvement of forest and agroecosystem services to promote ecotourism development (case study of Yenoqavan community, Republic of Armenia)

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The article is dedicated to the 90th anniversary of foundation of Armenian National Agrarian University

A B S T R A C T

The article, on the base of Yenoqavan community of Tavush region (Republic of Armenia) case study, analyzes and presents the importance of assessing the potential of certain forest and agroecosystem services in order to stimulate the development of ecotourism in the region. According to the results of the research, only the recreational and ecotourism services of community forest ecosystems accounts to 36 million AMD, but in 2019 only 55.6% or 20 million AMD were used from those services. Meanwhile, this value should be integrated in the general system of nature use and economy, aiming to re-direct the financial means for the forest and agro-landscapes improvement and protection. At the same time, the study revealed that unlike the ecotourism, agro-tourism is poorly developed, the main reasons for which are associated with degraded natural grasslands, low yields of arable lands, low productivity of livestock. The treatment means and measures are recommended in the study. The proposed improvement interventions can significantly increase the yield of fields and livestock productivity, also stimulate the development of ecotourism in the community.

Keywords: Forest ecosystem, agrocenos, production, recreational and ecotourism services, assessment, improvement.

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Background

Forest- and agroecosystem services provided direct and indirect contribution to human well-being based on the structure and functions of ecosystems.

Forest landscapes and agroecosystems provide a healthy environment for human living and economic activities, as well, as promote the development of human creative preferences [1, 2]. Forests have a positive impact on human health due to the release of volatile organic compounds by major forest tree species. They increase the amount of light oxygen ions in the atmosphere and weaken the intensity of solar radiation, reduce fluctuations in atmospheric pressure and temperature. The visual-auditory perception of forest and forest-agricultural landscapes has a beneficial effect on the human emotional and psycho-physiological condition [3]. The forest is a multi-functional ecosystem, a source of many services, each of which plays a special role in ensuring the stability of this ecological system and generally contributes to the organization of nature protection and improving the well-being of people [4, 5]: Studies conducted in the Hrazdan region [6] have shown that the amount of organic carbon in the forest, sub-forest and adjacent (neighboring) pasture soils are 8.21%, 6.33% and 5.88%, respectively. Pastures are most exposed to erosion, then sub-forest. Transformation of the forest land into pastures in Jordan have increased erosion-from 540 kg / ha to 1110 kg / ha / year [7].

The agroecosystem is a complex ecological unit, that includes both abiotic and biotic components, which are mutually related and determine the cy-

cle of nutrients and energy flow in the system: The function of agrocenosis depends on the flow of energy and the circulation of materials in the components of the ecosystem structure, depending on the level of investment, which seriously determine the productivity, aesthetic and cultural values.

Forest and agricultural systems, along with biodiversity, balancing of environmental processes, making availabile genetic resources, provision of species habitats and food and fodder security, also provide intangible, spiritual and physiological benefits that people receive from these systems or as a result of interacting with them [8, 9]:

It follows that the well-being of society is also determined by natural capital, in particular, through ensured continuous flow of ecosystem services from forest- and agroecosystems. Therefore, any research aimed to assess and valuate forest and agroecosystem services is extremely important, actual and conditioned the overall development strategy of the region.

Material and Methods

The methodological basis for evaluating ecosystem services is the "Economics of ecosystems and biodiversity" (TEEB) [10]. TEEB was approved in 2007 as part of a joint effort of Germany and the European Commission. Based on the TEEB methodology, this study attempts to evaluate some forest- and agroecosystem services of the Yenokavan community in Tavush region that can contribute to the development of ecotourism.

The studies were carried out on the basis of analysis of field, visual, cartographic materials, analyses of production indicators, available opportunities for recreational and ecotourism services in Yenoqavan community, as well as analysis of the results of soil laboratory and agrochemical analyzes and calculations.

The calculation of available recreational and ecotourism services in Yenoqavan forest ecosystems is performed according to A.A. Yermakov methodology [11], the level of fertility of arable lands and grasslands, as well as the degree of degradation is done on the base of soil samples taken both from degraded and non-degraded spots. The content of macronutrients (NPK) in soil and in aqueous extract, the reaction of the environment (pH) are investigated. Soil analyzes are performed using the generally accepted methods described in the Guidline of agrochemical methods edited by B.A. Yagodin [12].

The degree of vegetation cover in natural grasslands (pastures, hayfields) is determined by taking into account the qualitative and quantitative composition of plants on one square meter [13]. The preliminary results of treatments of degraded pastures of the Yenokavan and neighboring Lusadzor communities conducting by the United Nations development program (UNDP) in the framework of the program "Mainstreaming sustainable land and forest management in mountain landscapes of North-Eastern Armenia" [14] also are used.

The community's crop and livestock production data are taken from the community administration, and the qualitative and quantitative indicators of soils are taken from the Soils Atlas of RA [15,16]. The study used available scarce publications related to forest and agroecosystem services of the Tavush region [17-19].

Research results

Yenokavan community is located in the northeast of Armenia, in Ijevan region (Tavush marz). The total area of the community is 1564.2 hectares, the distance from Ijevan city is 10 km, from Yerevan - 150 km. The population of Yenoqavan community is 585 people, the number of households is 184 [20-24].

The terrain of the community is mountainous and is characterized by complex topographical conditions. The relief is characterized by vertical and horizontal dissection, which significantly affects the productivity of agricultural lands and the efficient management of agriculture. Despite this circumstance, erosion processes are not intensively developed, which mainly is due to the presence of forest cover. Some activity of erosion processes has been observed in the recent 15 years due to unregulated tree felling's carried out by the residents of the community.

The community is provided with electricity and drinking water. The community used to have a centralized gas supply 3 decades ago, but now it is not the case, due to which the residents use portable gasbags. In winter, the heating is carried out by wood-burning stoves. In the settlement, some houses (35.7%) have sewage disposal systems, which, without cleaning passes short distance and directly discharged into the river.

The community's economy is entirely based on agriculture, mainly is provided with a fodder base and pastures, but horticulture is very risky, as pe-

riodically is exposed to hail and frost. The major growing crops are wheat, barley, cabbage, etc.

The community residents have cattle, and some of them (54.0%) apiary. The community annually produces 300 tons of milk, 20 tons of meat, one ton of honey and 1.3 tons of wool.

Below is presented the land balance of Yenoqavan community (Table 1).

During the last 10-15 years, due to the intensive exploitation of the forests the ecological balance of forest ecosystems has been disturbed and one of its important feature- self regeneration ability- is lost. As a result only 12,2% or 17,8 ha of total forest area has reliable regeneration potential thanks to available natural seedlings (5-8 thousand per ha). But the regeneration of forests took place through non-value bale hornbeam and oriental hornbeam species. The 76% or 111,0 ha area out of total forest cover has 1000-2000 regeneration seedlings per ha, that has group allocation [5, 16].

According to sociological surveys (July-august, 2019), the main source of heating in the community is firewood. One household uses a minimum of 10 and a maximum of 15 m3 firewood per year. The demand for firewood in the community is annually 2300 m3 of storage mass (184 x 12.5 cubic meters or 1600 m3 of condensed mass). According to the Yenoqavan forest management plan draft from 2019, the annual demand for firewood in the community is estimated at 2,000 cubic meters.

We have calculated the cost of 2600 hectares of forest production, from which the villagers get firewood, ecosystem service- located both in the community and in the 10 km radius of Yenoqavan. The total annual net growth of the mentioned area is 3900 m^3 (1.55 m^3 per hectare) and the amount of annually available firewood will constitute 1360-1365 m^3 (35% of annual growth), out of which 1020 m^3 (75%) is available for use. The annual available for use amount of firewood from the 146 hectares of forest of Yenoqavan community is 60 m^3. As a result, the cost of both the community and 10 km radius forest production service will make 3 million 240 thousand. AMD (1020 m^3 + 60 m^3 x 3000 AMD), or the demand of Yenoqavan population for liquid fuel-wood will be satisfied only by 65%. Therefore, serious steps need to be taken to find alternative sources of fuel-wood to meet the population's demand.

The importance of Yenoqavan and neighboring forest ecosystems is crucial from the pperspective of estimating the spatial distribution and yield of forest fruits and berries. According to the results of a study conducted in 2017-2018 [18] only in the Ijevan region (the territory of the planned Ijevan state sanctuary), forest fruit and berry species occupied an area of 969.4 hectares, the total amount of the harvest was estimated as 96750 kg, of which 37.7%-cornelian cherry, 21.2%- blackberries and 20.4%-nuts.

One of the most important forest ecosystem service is carbon storage. According to studies, on average, 1 hectare of forest in RA provides 111-188 tons of carbon annual accumulation, which ensures the fertility of agricultural lands, contributes to food security [17]. The accumulated reserves of forest carbon for the 2600 hectare forest area located in the 10 km radius of Yenoqavan will make about 40,000 tons of carbon storage..

Together with forest production (timber, non-timber) services, it is extremely important to have an idea of the recreational and ecotourism opportunities of the community forest economy, to calculate the cost of those services. In general, historical-cultural and natural monuments, landscape diversity, favorable climate, springs, high biodiversity potential are important conditions for the development of the recreational sector, which can play an important role in the socio-economic development of the region and the country to improve the living standards of the population. From this point of view, the area of Yenoqavan is very remarkable, which is rather attractive after its famous rocky landscapes, table-like

Table 1. *Yenoqavan community land balance (01.01.2019), ha*

Community total area, ha	Including					
	Arable land	Pastures	Grass land	Non-used areas	Shrubs	Forest area
1564,2	229	484,4	391	234	80	146

peaks, mountain-forest and mountain-steppe natural and agricultural landscapes. For ecotourism, the areas of "Lastiver" waterfall, "Tandzut" caves, as well as the historical-cultural heritage of St. Gregory's Church (12th century) and "Cyclops" castles have been used for decades.

Yenoqavan recreation area was built in 2004-2005, at first it was a horse race, after that cottages were built thanks to the large flow of people. In 2008-2009, the construction of cottages began and became an active recreation area. In 2015 the "Yell Extreme" park was opened, which includes a zip line consisting of 5 lines with a total length of 135-750 m. There are climbing classes, rope park, off road tour, horse riding, and baseball areas.

The recreation area can currently accommodate 110 people a day. The cottage had 9,500 inhabitants in 2019, and the total number of visitors was 17,500. According to statistics, 49% of visitors were from Armenia, 51.0% from abroad - Russia, Spain and Germany. The recreation area is 25 hectares, where a restaurant complex has been built and operates. Based on the existing recreational and ecotourism opportunities in the Yenoqavan forest ecosystems and the number of annual visitors (2019), we have calculated these services according to the methodology proposed by A.A. Yermakov [11]. According to the availability of tourist resources, the coefficient of accommodation of tourists and the demographic capacity of the territory, as well as the values of the coefficient of recreation in green zones and the entry fee (500 AMD) are multiplied. Thus, if the number of visitors was 17,000, the coefficient of organizing recreation in green zones is 1.2, the coefficient of accommodation of vacationers is 1.12, and the entrance fee is 500 drams / person, then in 2019 recreational and ecotourism service cost:

17000 x 500 x (1,2+1,12) = 19 mln.720 thous. AMD

Meanwhile, the demographic capacity of the area is 31000 x 500 x (1.2 + 1.12) = 35 million 960 thousand. AMD: Thus, out of about 36 million AMD total recreational and ecotourism services of Yenoqavan forest ecosystem in 2019, about 20 million AMD services or 55.6% of the potential only we were used. In order to carry out the proper organization of ecotourism, it was carried studies to assess the state of agro-cenosis and their productivity of Yenokavan community: on agricultural lands- arable lands, pastures, to determine the level of fertility of grasslands, to reveal the need for crop yields to develop the agro-tourism potential.

As a result of complex studies, it was found out that in the administrative territory of Yenokavan community, mainly mountain forest, meadow-steppe and gray-meadow, in some parts brown soils are spread, which are mainly formed on basaltic rocks and andesitadacitic tuffs. According to R.A. Edilyan and others [22] studies in the mentioned soil types of that community, where the humidity is relatively high, accumulates 4.2-5.9% humus. According to the authors, the content of humus in arable lands, especially on slopes, is less than in virgin soils, depending on the location of the slope, the degree of erosion, the nature of their use. The content of humus diverse from 3,3-4,1 to 4,8% [6]. In the soil types of the administrative area of the community, the reaction of the soil solution is mainly in the areas close to neutral and the pH fluctuates in the range of 6.7-7.1. Due to irregular cultivation, the arable lands have lost their good structure and mainly are expressed with medium-grained, dust-grain structure. Until the last decade of the last century, these soils were rich in total nitrogen (0.16-0.26%), phosphorus (0.14-0.21%) and potassium (1.1 -1.9%), but they were weak and moderately supplied with available nitrogen, mediocre with phosphorus, and good with potassium exchange. In general, the studied lands, being in a moderate and mild natural-climatic zone, had sufficient natural fertility and before the privatization of lands (1991), were favorable for obtaining a higher crop yield [2].

Within the framework of the goal, the laboratory tests of soil samples taken from agricultural lands of Yenokavan administrative area revealed that the environmental reaction in the arable lands of the community is 7.5-7.7 (weak alkaline), the humus content fluctuates between 3.0- 3.6%. The content of easy hydrolyzable nitrogen and available phosphorus in 100 g of soil varies between 2.4-3.1 and 3.5-3.98 mg, respectively, and these elements are poorly provided, and the content of potassium in 100 g is 27.0-30.0 mg. Comparing the agrochemical indicators of the current state of the community arable lands with the similar indicators of the 90s of the 20th century, it is noted that the parts of the administrative territory that have been subjected to unsystem cultivation over the years, due to various negative natural and human-made factors, were allocated and marked on the cadastral map of the community and treatment measues for 60 ha were prescribed (Table 2). Similar studies conducted in pasture and haylands of the community found that the content of available nutrients and humus in

comparison with non-degraded areas significantly decreased (table 2): So, if the humus content in the soil was 4.4% in non-degraded pastures and 4.9% in haylands, then this indicators decreased in degraded pastures and haylands respectively by 3.8% and 4.1%. Degraded areas of hayfields and pastures of the community compared to non-degraded areas had decrease in the 100 g soil content of nitrogen, phosphorus and potassium: in hayfields- by 1.3; 2.2 and 3.0 mg and in pasture lands- 1.6; 2.7 and 2.3 mg respectively.

After studying the state of vegetation cover in community hay lands and pastures, it turned out that if there are 876 stems in non-degraded pastures and 826 stems in hay lands, then in the degraded hay lands of the community the number of plant stems is 407 pieces/m^2, and in degraded pastures this indicator is 469 pieces/ m^2 (Table 2).

Thus, as a result of research, it was revealed that 60 ha of arable land, 57 ha of hay lands and 92 ha of pasture territories are under the influence of various anthropogenic pressures and have undergone deep degradation. It is necessary, where it is possible, to organize superficial treatment activities:

a) to increase the fertility of degraded arable land, annually add to the soil 1.5-3.0 t/ha organ mix and 60 kg/ha of mineral fertilizers- nitrogen, phosphorus and potassium ($N_{60}P60K_{60}$),

b) application of the fertilizer system in degraded hay lands and pastures: organomix 1 t / ha + (N50P50K50).

c) Organize mixed herbs sowing of perennial grasses (clover, fescue, hedgehog, cockshead) at the dosage of 15-18 kg / ha in degraded and deforested grasslands and limit the grazing at least for one year. Within the UNDP program are performed surface improvement of 137ha of degraded pastures during 2019-2020 in Yenoqavan community [14]. Continued implementation of these activities in the community's degraded arable lands, pastures and hay lands will support to increase the community's agricultural culture, improve soil fertility, increase crop and livestock products, and contribute to the overall development of the region, particularly ecotourism development.

Conclusion and recommendations

Summarizing the results of the assessment of forest and agroecosystems production, recreational and eco-tourism services, we have reached the following conclusions:

1. Services for providing firewood of Yenoqavan and its surrounding 10 km forest area sum up at 3 million 240 thousand AMD, of which in Yenoqavan the cost of firewood is 180 thousand AMD, and in 10 km radius forest area - 3 million 60 thousand AMD.

2. The total capacity value of the recreational and ecotourism services of the community forest is 36 million AMD, of which, however, in 2019 only 55.6% or 20 million AMD were used.

Table 2. *Agrochemical indicators and the number of plant stems per m2 of arable lands, pastures, grasslands in the administrative territory of Yenokavan community*

Land cover condition and sampling depth, sm	Arable lands						Pastures							Hayfields						
	Humus, %	Related to CO_2, %	pH in water traction	Available nutrients, mg 100 g in soil			Humus, %	Related to CO_2, %	pH in water traction	Available nutrients, mg 100 g in soil			Number of stems per m2, pcs ,	Humus, %	Related to CO_2, %	pH in water traction	Available nutrients, mg 100 g in soil			Number of stems per m2, pcs ,
				N	P_2O_5	K_2O				N	P_2O_5	K_2O					N	P_2O_5	K_2O	
Degraded, 0-25	3,7	0,47	7,6	4,1	3,8	29,5	3,8	0,7	7,5	2,6	3,4	29,0	469	4,1	0,74	7,7	4,6	3,8	30,0	407
Non-degraded , 0-25	4,3	0,69	7,0	5,7	6,6	32,0	4,4	0,9	6,9	5,9	5,1	35,0	876	4,9	1,0	7,1	5,9	6,0	33,0	826

3. In order to increase the culture of agricultural activities carried out by the residents of the community, to improve the level of soil fertility, to create an abundance of crops and livestock products, in order to give a boost to agrotourism, it is necessary to carry out surface improvement works in degraded agricultural systems. In the arable lands every year should be applied 1.5-3.0 t / ha organomix and nitrogen, phosphorus and potassium 60 kg / ha dosage($N_{60}P_{60}K_{60}$) per of active substance. Organize the improvement of degraded pastures and grasslands through application of mineral and organic fertilizers: organomix with norm 1 t / ha + ($N_{50}P_{50}K_{50}$) and mixed sowing of perennial herbs (clover, fescue, hedgehog and cockshead with norm 15-18 kg/ha). Prohibit grazing in the improved natural grasslands for at least one year.

4. Yenoqavan forest and agroecosystems production, recreation and ecotourism services have serious value and they should be integrated in the general system of nature use. At least 25-30% of the received incomes should be directed to the improvement of forest and agro-landscapes conservation and improvement.

5. Taking in account the rather high value of forest and agroecosystem services, it is necessary to set up the regular accounting and evaluation scientific studies system and to establish a division with Ministry of Environment to coordinate studies and monitoring of ecosystem services.

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Procession of sulfide technogenic waste by means of biohydrometallurgy techniques

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ABSTRACT

In article the issues of harmful environmental impact of sulfide technogenic waste in mining industry are reviewed. Studies on reviewing the ecologically safe, inexpensive and simple method of biodestruction (biooxidation) for recovery of remaining useful components in the waste, are of significant importance. For the first time in Georgia, the studies are performed to consider a complex processing of stored tailings obtained from a flotation of chalcopyrite ores of the Madneuli mining complex, by means of biodestruction technique; for this purpose, Acidithiobacillus ferrooxidans and Acidithiobacillus thiooxidans are separated from the acidic quarry waters of Madneuli deposit and active cultures are obtained. It is determined from a chemical, mineral and granulometric analysis that by the copper and gold content, the tailings are very depleted, technologically stable raw material, in which gold in inserted in the finely divided form into pyrite, and copper is represented by primary, as well as secondary sulfides and in the oxidized form. Various techniques are reviewed in the studies for tailings processing. Direct cyanidation (cyanide leaching); bacterial oxidation before the cyanidation process. In parallel with a cyanidation, an ecologically safe solvent, thiourea is approved. The conducted studies proved inefficiency of the direct cyanidation, As a result of preliminary bacterial oxidation, 96,1% of copper is conveyed from the tailings to the solution, and by the further cyanidation of the biocake in the optimal conditions, determined in the studies, 94,1% of gold and 72,2% of silver is dissolved. A thiourea was tested in parallel with the cyanidation. The prospects of use of thiocarbamide as an ecologically safe solvent, is demonstrated. In the optimal conditions determined in the studies, 96,3% of gold and 84,1% of silver are conveyed from the biocake to the solution.

Keywords: Gold, Copper, Stored tailings, Bacterial oxidation-leaching, Thiourea (thiocarbamide), Hydrometallurgy.

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Introduction

Currently, it is not possible to fully extract all the useful components from a mineral raw material using the traditional methods, therefore, a waste obtained from the processing, contains parts of nonferrous, precious and rare metals.

The wastes generated as a result of functioning of mining enterprises, depending on their scale and content of useful components in them, are considered as technogenic mines [1].

In the environmental terms, wastes containing sulfides are especially hazardous group. During the process of extraction and processing of ores containing nonferrous metals, the sulfides remaining in waste, are oxidized because of drainage of atmospheric precipitation. Heavy metals are converted into water-soluble salts; “hypergenic” changes of the technogenic volume occur with significantly higher speed than in the natural geological processes; intensification of the process is caused by increase of activity level of sulfides surface.

In the foreign scientific literature, the term “Acid mine drainage” (AMD) is used for characterization of this process, which features the processes of water oxidation. It is known from the studies that the issue of acid streams in the volume of waste is mainly associated to the oxidatian of pyrite and marcasite [2].

Currently, the hazard, which is related to the atmosphere pollution by sulfur gases generated by pyrometallurgical processes is more apparent than the hazard arisen as a result of solid waste storage, but in the first case, introduction of new technologies significantly improves environmental conditions and already degraded ecosystem starts to recover, while in the second case, we have to deal with billions of tons of technogenic waste, which pollutes the environment with relatively slow speed but it is almost impossible to avoid this negative impact, because this process continues for a very long period and, what is more important, the process continues even after the cessation of manufacturing. According to the data of geochemical control of the Elliot Lake mine in Canada, leaching of toxic components from tailings and pollution of underground water is continued for around 100 years, so that the reduction of pollution process intensity is still not observed. Oxidation of pyrites in a sludge, after which a sulfur acid is created and which facilitates leaching of heavy metals, may continue for more than 200 years [3, 4].

Disposal of dump and waste requires large areas of land, which is the cause of shortage of agricultural land. Therefore, their procession has a double effect, because, on the one hand, the additional commercial output is obtained, and, on the other hand, non-renewable natural resources are saved, a life cycle of a mine is increased, an anthropogenic impact on the environment is reduced, which positively affects health of future generations.

The raw materials of such type are already disposed on the earth surface in the finely ground form and no significant expenses are needed to collect them and prepare for processing, considering that they are located close to the already developed infrastructure. Taking this into account, resolving the issue of their utilization is timely and relevant. In these conditions, the main factor for establishing an ecologically clean and economically efficient manufacturing process, is to use innovative technology, which allows increase of raw materials base by including such materials, processing of which in the past was unprofitable. In particular, the matter concerns depleted, stable sulfide ores of nonferrous metals containing gold and production waste [5].

When copper is represented in the ores in oxidized form, and gold in the form of free particles, then copper is dissolved by means of sulfur acid solution, and diluted cyanide solutions of alkaline metals are used for dissolution of gold. When gold is encapsulated in finely-divided form into sulfide minerals, it is necessary before the cyanidation process to arrange a destruction of sulfides, so that freed gold particles would be accessible for the solvent. In the practice, an ecologically unsafe oxidizing burning and autoclave leaching are mainly used for this purpose. Use of these methods is economically feasible for rich auriferous ores and concentrates.

As for depleted stable sulfide raw materials, containing nonferrous metals and gold, it is not economically feasible to use these techniques for them. The most promising method for processing of stable auriferous raw materials is a bacterial oxidation. Especially for technogenic raw materials, it is considered the very simple, ecologically safe and economically efficient method [6].

Since the second half of 20th century, an introduction of biotechnological methods in mining industry is a common practice, and the method of bacterial oxidation and leaching of metals has a special place among them.

Its main objectives are development of bacterial processes and drawing up such schedules of leaching, which would allow us to extract the target elements from depleted stable ores of complex composition, and from wastes and tailings of mining enterprises.

Under bacterial leaching it is meant the process of accelerated leaching of metals from sulfide ores, by means of activity of sulfur-oxidizing bacteria; this process is based on the interaction of trivalent iron sulfate, as a strong oxidant, created in the acid environment during the oxidation of pyrites and other iron-containing sulfides by means of bacteria, with sulfides of other metals. It is known that a trivalent iron sulfate obtained as a result of biooxidation, is a more strong oxidant than that obtained by means of chemical way [7]. During this process, an oxidation of sulfur occurs, existing in the sulfide minerals, and formation of sulfur acid as a result. Thus, the second active agent in the form of sulfur acid is formed in the area of reaction.

The process of biooxidation of sulfide ores by means of iron- and sulfur-oxidizing bacteria can be graphically presented in the following form:

$$2FeS_2+7{,}5O_2+H_2O=Fe_2(SO4)_3+H_2SO_4 \quad (1)\ \text{(chemical, bacterial)}$$

The reaction with the participation of bacteria happens intensely

$$FeS_2+7Fe_2(SO_4)_3+8H_2O=15FeSO_4+8H_2SO_4 \quad (2)\ \text{(chemically)}$$

$$2FeSO_4+0{,}5O_2+H_2SO_4=Fe_2(SO_4)_3+H_2O \quad (3)\ \text{(biologically)}$$

The third reaction goes on only by means of bacteria, because its occurrence in the acid environment is impossible. The process of chalcopyrite oxidation with the presence of microorganisms can be demonstrated in the following form:

$CuFeS_2+4O_2=CuSO_4+FeSO_4$ (4) (chemical, biological)
$FeSO_4+0,5O_2+H_2SO_4=Fe_2(SO_4)_3+H_2O$ (5) (biological)

The fourth reaction goes on very slowly without microorganisms, and the fifth happens only with the participation of microorganisms. Destruction of other copper sulfides occurs even more intensely:

$Cu_2S+2Fe_2(SO_4)_3=2CuSO_4+4FeSO_4+S^0$ (6) (chemically)
$CuS+Fe_2(SO_4)_3+CuSO_4+FeSO_4+S$ (7) (chemically)
$2S+2H_2O+3O_2=2H_2SO_4$ (8) (biologically)
pH=1,5-2,5

Thus, the process of combined bacterial and chemical leaching occurs.

The role of bacteria mainly is that they are catalysts of biooxidation processes, because they have a function of carriers of electrons from a donor (sulfide) to an acceptor (oxygen). As a result of the process, nonferrous metals are transferred to the solution in the form of ions, and gold freed during the destruction of sulfides becomes accessible for a further leaching.

The advantage of use of biotechnology for extraction of nonferrous and precious metals from the depleted, stable sulfide raw materials, compared to the alternative methods, is the following:

- It does not require high temperature and pressure, because of which this technology is more safe in terms of work-related safety;
- It is characterized by a high value of extraction of nonferrous and precious metals;
- It is ecologically safe - excludes the possibility of environmental pollution by means of toxic gases [8, 9].

The issue of utilization of technogenic waste is relevant for Georgia too.

The largest reserves of copper are in the sulfide deposit of Madneuli in Georgia.

In the Madneuli mining plant, a copper concentrate is obtained from auriferous copper ores by means of flotation method, in which the part of gold existing in the ore is extracted, and other part remains in the pyrite tailing, which is stored in the special storage for tailings, for the purpose of their further processing [10].

In the recent period, the copper content in the extracted ores is diminishing, which means that the mine gradually depletes; therefore, the prospects for nearest years are related to the complex development of mineral raw material, which means an introduction of substandard ores and stored tailings into operations.

Currently, the amount of waste stored in the storage for flotation tailings of pyrite ores exceeds 40 million tons. The average content of copper in the tailings is 0,22-0,24%, gold - 0,61-0,65 g/t, and the content of sulfides is 0,0-7,0%. In terms of amount of stored copper and gold, the tailing pond is a technogenic mine.

Waste rock and substandard ores generated during the mining works, are transported to the dump, where dumps are formed. Four dump sites are situated on the territory of mining enterprise [11].

Quarry waters of Madneuli have an acid reaction, they have a sulfate-sodium composition and are strongly enriched with heavy metals.

Among the anthropogenic chemical substances, the heavy metals are one of the most hazardous pollutants. They have high toxicity and ability to be accumulated in the living organisms, and can create organic compounds very soluble in water, which is the cause of their spillage to the natural water bodies.

Three rivers - Kazretula, Poladauri and Mashavera flow near the tailing pond and dump sites #1, #2, and #3. All of them are used for economic and household needs.

The Mashavera River is the main source of water for irrigation of agricultural lands in the region; despite the fact that the concentration of heavy metals in it, compared to the Kazretula River, is lower, their concentration in the irrigation channels still significantly exceeds the maximum permissible levels. As a result of it, in the valley of the Mashavera River, 12,4 kg of copper, 3,6 kg of zinc and 17 g of cadmium spill daily into the soil, during the irrigation of agricultural lands. According to the German standards for soil protection (Federal Soil Protection Act of Federative Republic of Germany, as of 17 March 1998), these values exceed the permissible levels by 36 times for copper, and 3 times for zinc and cadmium. Good absorbents and storages of heavy metals from a soil are carrot, spinach and potato.

By means of acidithiobacillus ferrooxidans and acidithiobacillus thiooxidans, it is possible to achieve a destruction of sulfides and exposure of surface of gold particles encapsulated in them in the finely-divided form, which would increase the efficiency of gold dissolution in solvents; at the same

time, transfer of copper to the biosolution occurs. Its recovery from the biosolutions is possible by means of known methods (cementation, extraction).

The base for creation of microorganism associations are strains, which correspond to their biocoenosis, and ecologically and genetically are adjusted to the climatic conditions and material composition of certain region [12-20].

The goal of the work is to determine the possibility of maximal recovery of copper, gold and silver from stored flotation tailings, by means of biohydrometallurgy methods, in particular, by means of bacterial leaching, in laboratory conditions.

Objects and methods

We conducted studies to analyze a microbiocoenisis and biogeochemical processes on the ore-containing deposit of Madneuli.

Samples were taken from the following objects: Dump sites of substandard sulfide and mixed ores, tailing storage facility, quarry acid waters, effluent waters from the tailing pond and dump sites.

The work was performed by means of the conventional methods, which are used in the field of soil and geological microbiology.

The spread of thiobacteria was studied by means of limit tenfold dilution on the liquid nutrient media. Counting of Acidithiobacillus ferrooxidans has been performed on Silverman and Lundgren medium (9K), and in case of Acidithiobacillus thiooxidans - on the Waksman medium with addition of sulfur; for th.thioparus - Beijerinck medium with addition of sodium thiosulfate; for th.novellis - Starkey medium, and for th.intermedius hov.sp - London medium.

For the preparation of nutrient media, we used the textbook of G. I. Karavaiko [9].

As the criterion of oxidizing activity of bacteria, we take the bivalent iron's oxidation level up to trivalent iron in the 9K nutrient medium. We performed cultivation of bacteria on the laboratory shaker (180 r/min) on the 9K nutrient medium with the temperature of 28-30^{0}C, solid-to-liquid=1:10.

pH and Eh was determined by means of electrometric method on the laboratory pH-meter (pH-340). We were determining bivalent and trivalent iron in the solutions by means of complexometric titration of copper with sodium thiosulfate solution, using Trilon B, and in the solid volume, we were determining copper by means of atomic absorption method.

Results and discussion

Counting of thiobacteria on various media showed that main microorganisms, which are spread to the entire mine, are A.th.ferrooxidans, and in the dominated form - A.th. thiooxidans (Table 1).

Table 1. *Distribucion of thiobacteria in the Madneuli Deposit*

№	Sampling place table	Bacterial celle count 1 gof 1 ml				
		Outotrophic bacteria			Mixotrophicbacteria	
		A.th. ferrooxidans	A. th. thiooxidans	th. thioparus	Th. novellis	Th. intermedius
1	Mine quarry waters (1)	10^7	10^4	0	10^3	0
2	Ore storage	10^5	10^3	10^3	10^2	10^2
3	Tailing pond	10^4	10^2	10^2	10^3	10^4
4	Effluent from the toiling (2)	10^5	10^3	10^2	10^2	0
5	Effluent from storage	10^6	10^4	10^2	0	0

Spread of thiobacteria on the Madneuli deposit

In the result of examination of technogenic objects of the Madneuli ore field, 7 cultures accumulating A.th.ferrooxidans and 1 culture, accumulating A.th. Thiooxidans were obtained. Among the obtained 7 cultures, in terms of oxidation of bivalent iron (100% in 4 days), the most active is A.th. ferrooxidans-5, which was used in the process of research in the association with A.th. Thiooxidans.

In the process of study, the stored flotation tailings of chalcopyrite ores of Madneuli deposit were used as a raw material. Chemical, mineral and granulometric composition of the stored tailings was studied.

The results of chemical and mineral analysis are presented in the Tables 2 and 3.

It was determined by the granulometric analysis that flotation tailings belong to the class of very fine-grained sands. The content of 0,1 mm class in the tailings is 58,3%, and the content of 0,074 mm class - 41,9%. The content of gold, copper and sulfur in the tailings is in correlation with the particle sizes. In the 0,074 mm class, their amount almost twice exceeds their average content in the tailings.

The phase analysis of gold in the stored tailings showed that ~72,0% of gold is encapsulated in pyrite in the finely-divided form, ~5,0% is in the rocks, ~4,5% in acid-soluble minerals, and 21,0-23,0% in the attachments and in the free form.

We detected the particle of free gold in the sample, with dimension of 30 μm (Fig. 1).

The phase analysis of copper showed that in the tailings, copper is present in the primary form

Table 2. *Mineral analysis of the stored tailings*

Stocked ponytails	Content of basic minerals, %								
	Pirit	Halcopirit	Halcosin	Kovelin	Bornit	Ferum oxid	Cvarc	Feldspat	Chlorite
	5-10	0,15	0,2	0,12	0,08	0,9	81,0	7-8	1,5-2,0

Table 3. *Chemical analysis of stored tailings*

Content %, გ/ტ															
Hymiditee	SiO_2	Al_2O_3	Fe_2O_3	FeO	P_2O_5	MnO	CaO	MgO	Na_2O	K_2O	So sulfide	S commen	Cu	Au	Ag
1,0	74,3	2,51	9,8	5,4	0,07	Tracc	0,85	0,97	1,0	1,4	6,0	6,1	0,22	0,6	3,2

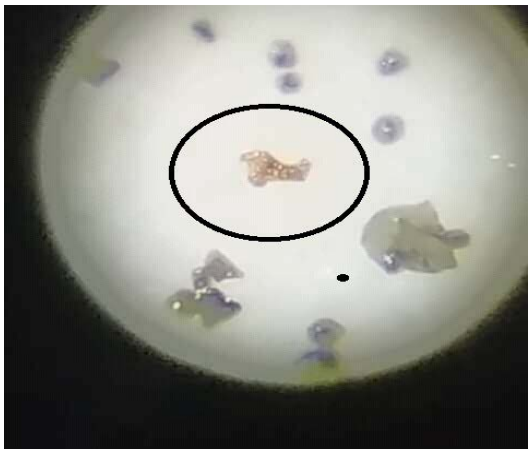

Fig 1. *Particle of free gold in the pyrite tailing (dimension - 30 μm.)*

- 15,3%, in the form of secondary sulfides - 69,7%, and in the oxidized form - 15,0%.

Based on the performed analyses, it was determined that stored tailings are very depleted, stable sulfide raw material containing gold, silver and copper.

The most common technology of processing nonferrous and precious metals is the preliminary concentration of all useful components with the purpose of their further pyro- pr hydrometallurgy procession.

As the granulometric analysis shows, the main amount of gold in the tailings is associated with pyrite, therefore, we chose flotation method of concentration, and we considered obtaining of collective sulfide floto-concentrate as an optimal variant. By means of optimal flotation mode, elaborated in the studies, the collective sulfide floto-concentrate was obtained with the following content: Au – 1,9 g/t; Ag – 5,0 g/t; Cu – 0,8%; S = 21,1%. The recovery in the collective concentrate is, respectively: 74,4%; 37,5%; 83,7% and 82,8%, and the output of the collective concentrate is 23,6%.

During the study process, various methods of processing of the stored tailings were tested. Direct cyanidation, biooxidation-leaching, cyanidation of biocake, processing of the biocake by means of thiourea.

Currently, in the international practice, 85% of gold extracted from ores comes from cyanidation process.

Dissolution of gold by means of cyanide compounds of alkaline metals goes on with the following reaction:

The phase analysis of copper showed that in the tailings, copper is present in the primary form - 15,3%, in the form of secondary sulfides - 69,7%, and in the oxidized form - 15,0%.

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$$4\,Au + 8\,NaCN + O_2 + 2H_2O \rightarrow 4\,NaAu(CN)_2 + 4\,NaOH$$

From the reaction equation it is seen that the existence of oxygen is necessary for the dissolution of gold. In the laboratory conditions, barium, sodium and hydrogen peroxides are used as a source of oxygen. For example, Barium peroxide interacts with water according to the following reaction:

$$BaO_2 + H_2O = Ba(OH)_2 + O_2$$

For avoiding decomposition of cyanide salts it the alkaline medium is necessary pH = 10,5 – 11,0, which is created by addition of lime. The perfect method of cyanidation process is an ore pulp agitation (stirring) method. The conditions of intense agitation ensure good contact between gold particles and cyanide compounds; cyanidation of silver is also carried out similarly.

Two samples of collective floto-concentrate were taken for the cyanidation process, with the different dimenstions: 1. 90,0% – 0,074 + 0 mm; 2. 90,0 % – 0,044 + 0 mm. The laboratory experiment was conducted in the agitator for closed tanks.

The following parameters were studied for determining the optimal mode of cyanidation of flotation concentrate:

A) The impact of cyanide concentration on the gold dissolution degree (C_{NACN} – 0,05%, 0,1%, 0,3%.)

B) Determination of optimal time of cyanidation process (t - 6, 12, 18, 24 hours).

The cyanidation was conducted in the following conditions: The weight of concentrate 100 g, solid-to-liquid ratio - 1:4, BaO_2 – 0,5 g., concentration of CaO - 0,2%, temperature - 22-23^{0}C .

The results of experimental study are presented in the Tables 4, 5 and Figures 2, 3.

Table 4. *Degree of extraction in gold solution based on concentration of sodium cyanide from pyroclastic concentrate*

Flotoconcen-trate thicknesse, mm 85% 0,074+0	Initial gold content, g/t	1,9			Cyan time, hr
	Sodium cyanide concentration, %	0,05	0,1	0,3	24
	Gold content concentrate, g/t	1,78	1,60	1,38	
	Gold solution extraction rate, %	6,3	15,8	27,3	

Table 5. *Degree of silver extraction by concentration of sodium cyanide*

Flotoconcent rate thickness, mm 85% 0,074+0	Initial silver content, g/t	5,0			Cyan time, hr.
	Initial concentration of sodium cyanide,%	0,05	0,1	0,3	24
	Residual content of silver in concentrate, g/t	4,23	3,44	3,0	
	Degree of extraction in silver solution, %	15,3	31,2	40, 1	

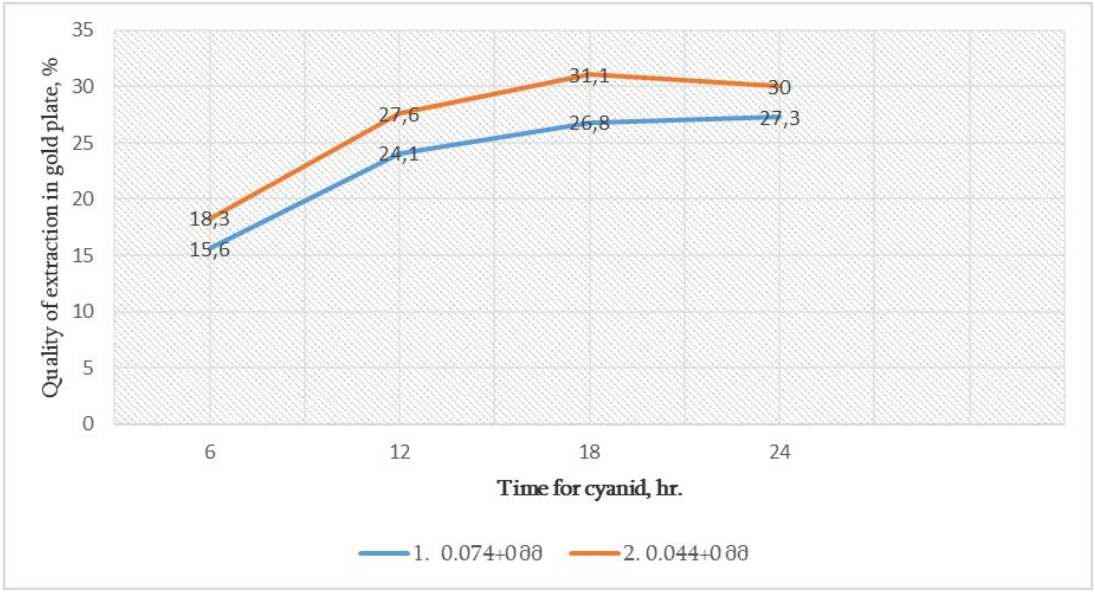

Fig 2. *Kinetics of the gold solution fluorescence from the floto-concentrate*

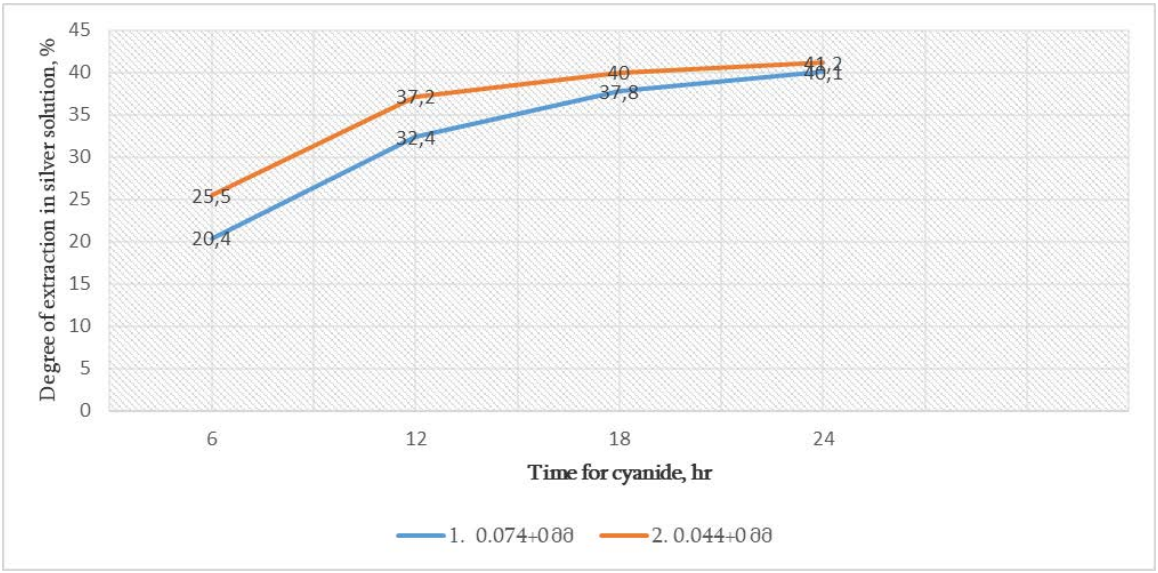

Fig 3. *Kinetics of dissociation from the floto-concentrate in silver cyanide*

As it is seen from the series of conducted experiments, the maximal amount of gold and silver, which transfers during the direct cyanidation, does not exceed 31,1%- and 41,2% in the solution, respectively, which corresponds to the data of phase analysis for gold. Proceeding from this, pyrite destruction is necessary for exposure of gold particles. Instead of oxidizing burning and autoclave leaching, we used the method of bacterial oxidation and leaching for oxidizing sulfides existing in the tailings (pyrite, chalcopyrite, chalcocite, covellite).

The bacterial leaching may be carried out in the three technological form: tank leaching, heap leaching and underground leaching. For our studies, we chose the tank leaching technique.

The efficiency of biooxidation-leaching process is mainly determined by three factors: Physical (acidity, oxidation and reduction potential, temperature, aeration degree), biological (bacterial titer, their activity, content of nutrient medium), technological (solid-to-liquid, size of particles, agitation speed).

For the purpose of conducting the bacterial oxidation-leaching process, the laboratory device was assembled, which consisted of glass cylinder with the volume of 2 l, micro compressor, electric agitator, and thermostat. The tests were conducted in the condition of permanent agitation, aeration and temperature; A.thiobacillus ferrooxidans and A.thiobacillus thiooxidans were used during the study process. The association ,which was in advance adjusted to the leached object by means of multiple inoculation with different values of solid-to-liquid ratio. During the cultivation, the nutrient medium 9K was used without iron. With the purpose of process control and regulation, pH and Eh of the solution, the concentrations bivalent and trivalent iron, and bacterial titer were determined. The optimal parameters of the process were determined by means of series of tests.

Table 6. *Results of bacterial oxidation-leaching process from pyrite concentrate to copper by Chinese method depending on material thickness*

N	Name of product	Concentrate particle swelling, mm	Solution %	Content, გ/ტ		Content,%	CuPicking up, %
				Au	Ag	Cu	
1	Bacterial residual	0,044	70,1	2,7	7,1	0,03	3,9
	Bacterial solution		-	-	-	0,77	96,1
	Flotoconcentrate		100,0	1,9	5,0	0,8	100,0
2	Bacterial residual	0,074	74,9	2,5	6,7	0,08	9,7
	Bacterial solution		-	-	-	0,72	90,3
	Flotoconcentrate		100,0	1,9	5,0	0,80	100,0

Table 7. *Results of the bacterial oxidation process of thefloto-concentrate by leaching time*

	Process options										
N	The number of concentrates	Pyrit content in concentrate %	Concentrate fat, mm	pH	Bacterial titer cell/ml	Acid/licuad	Taim of skip	Degree of pyrite oxidation, %	Oxidized piritte in g	Sulfur oxidation g	Degree of oxidation oxidized sulfur,%
1	100,0	68,6	0,044	2,5	10^4	1:5	0	0	0	0	0
2	100,0	68,6	0,044	2,3	10^4	1:5	48,0	12,3	8,4	4,48	7,0
3	100,0	68,6	0,044	2,0	10^7	1:5	96,0	30,0	20,6	11,0	17,2
4	100,0	68,6	0,044	1,9	10^7	1:5	144,0	43,9	30,1	16,1	25,2
5	100,0	68,6	0,044	2,0	10^6	1:5	240,0	44,0	30,2	16,1	25,2

Optimal parameters of the process are: Solid-to-liquid = 1:5; t^0C = 28-30; pH = 2.0-2.5, Eh = 620-700 m^3, leaching time 240 hr, fineness of particles - 85,0% 0,044 mm. Bacterial titer 10^7 cell/ml.

For determining the degree of gold release during the process of bacterial oxidation of the flotation concentrate, as a result of which the amount of oxidized pyrite reached 44,0%, the cyanidation of the obtained bacterial cake was carried out, as well as dissolution in the thiourea.

The process of cyanidation was carried out in the same condition, as for the non-oxidized collective sulfide floto-concentrate.

The alternative to the dissolution of gold and silver by the cyanide compounds is the use of thiourea; gold and silver, after interaction with thiourea, create complex compound that is very water-soluble.

The process of cyanidation requires alkaline medium (pH=10-11), and the necessary condition for dissolution of precious metals in thiourea is the existence of pH=2,5-3,0; strong oxidizer in the solution, which is able to convert gold and silver in the ionic state so that not to oxidize thiourea. Such is $Fe_2(SO_4)_3$. Exactly appropriate conditions are created during the oxidation of iron-containing sulfide minerals by thiobacteria. During the bacterial leaching process and pyrite destruction, the necessary amount of trivalent iron sulfate and sulfur acid are generated in the solution; the latter ensures the exact level of acidity in the solution, which is necessary for dissolution of precious metals in thiourea pH=2,5-3.

The test was conducted in conditions of thiourea concentration in the solution with the values of 0,5%, 1,0% and 2,0%. The fineness of particles 85,0% - 0,044 mm.

Table 8. *Impact of sodium cyanide concentration on the degree of gold dissolution by biocarriers*

Gold concentration, g/t	Flotoconcentrate swelling, mm	0,044			Time for cyanide, hr
2,7	Sodium cyanide concentration, %	0,05	0	0,3	24
	The residual gold content in the concentrate, g/t	0,40	0,20	0,16	
	Degree of extraction in gold solution, %	85,24	92,80	94,10	
Gold concentration, g/t	Flotoconcentrate swelling, mm	0,074			24
2,5	Sodium cyanide concentration, %	0,05	0,1	0,3	
	The residual gold content in the concentrate, g/t	0,5	0,22	0,19	
	Degree of extraction in gold solution, %	81,4	91,2	92,3	

Table 9. *Impact of sodium cyanide concentration on the degree of silver dissolution by biocarriers*

Silver concentration, g/t	Flotoconcentrate swelling, mm	0,044			Time for cyanide, hr
7,1	Sodium cyanide concentration, %	0,05	0,1	0,3	24
	The residual silver content in the concentrate, g/t	2,8	2,1	2,0	
	Degree of extraction in silver solution, %	60,2	70,2	72,2	
Silver concentration, g/t	Flotoconcentrate swelling, mm	0,074			24
6,7	Sodium cyanide concentration, %	0,05	0,1	0,3	
	The residual silver content in the concentrate, g/t	2,6	2,1	2,1	
	Degree of extraction in silver solution, %	60,6	68,8	69,1	

Table 10. *The effect of the concentration of thiocarbamide on the extraction of gold and silver from biocake in relation to time*

№	Tiocarbamidw concentration in solution, %	pH	$Fe_2(SO_4)$ concentration in solution, %	Extraction of gold and silver in solution, %							
				The duration of the dissolution process							
				6		12		18		24	
				Au	Ag	Au	Ag	Au	Ag	Au	Ag
1	0,5	2,8	3,4	65,0	60,5	70,3	68,0	79,4	77,8	81,9	80,0
2	1,0	2,8	3,4	71,1	66,2	88,6	76,3	95,1	81,2	95,4	83,3
3	2,0	2,8	3,4	73,2	69,0	90,0	75,1	95,4	84,0	96,3	84,1

Based on the studies conducted in laboratory conditions, the possibility of complex processing of stored flotation tailings of chalcopyrite ores of Madneuli was determined, for recovery of precious and nonferrous metals by means of ecologically safe processes: Bacterial oxidation-leaching by aborigene bacterial and dissolution of the obtained biocake in thiocarbamide instead of cyanidation process.

Conclusion

1. It was determined after examination of material composition of the stored flotation tailings of Madneuli chalcopyrite ores that they contain 0,6 g/t of gold, 3,2 g/t of silver and 0,22% of copper. Silver is presented as in the free form, as well as in the form of simple silver sulfide (acanthite), and copper is presented in the primary form (15%), as well as in the secondary (69,7%) sulfides, and in the oxidized form (15,0%). ~72,0% of gold is encapsulated in pyrite in the finely-divided form. Without the destruction of pyrite, gold recovery is difficult. The tailings are very depleted, technologically stable raw material. With the purpose of concentration of useful components, the collective sulfide floto-concentrate is obtained: Au – 1,9 g/t; Ag – 5,0 g/t; Cu -0,8% and S – 21,1%, recovery is, respectively, 74,4%; 37,5%; 83,7% and 82,8%, and the output is 23,6%.
2. From the quarry acid waters of Madneuli deposit, autotrophic acidophilic iron and sulfur-oxidizing thiobacteria (A. thiobacillus ferrooxidans and A. thiobacillus thiooxidans) are separated and their active cultures are obtained.
3. As a result of the conducted study, the inefficiency of direct cyanidation process for transfer of gold and silver into solution was determined. In the condition of material with 85,0% - 0,044 mm fineness, by 24 h agitation with 0,3% NaSN solution, only 30,0% of gold and 41,0% of silver are dissolved.
4. The process of bacterial oxidation-leaching in the conditions of tank was studied. The optimal parameters of the process are determined: Solid-to-liquid=1:5, pH=2,0-2,5; t^0C=28-30, permanent aeration of bacteria (A.thiobacillus ferrooxidans and A. thiobacillus thiooxidans) titer 10^5-10^8 cell/ml, material fineness 85,0% - 0,044 □□, leaching time 24 h. The amount of copper dissolved into the solution is 96,1% (1,5 g/l).
5. The processing of obtained biocake was carried out for dissolution of gold and silver into solution, as by means of sodium cyanide, as well as by means of thiocarbamide. In the first case, the maximal amount of gold and silver (94,1% and 72,2%) is dissolved after 24 h of cyanidation into the solution, and in the second case, during the same time, 96,3% of gold and 84,1% of silver is dissolved into the solution.

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Antibiotics and heavy metals in Georgian honey

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A B S T R A C T

Georgia is considered the oldest producer of honey. Honey is a therapeutic and preventive product, so it is important to study the content of antibiotics and heavy metals, since their presence adversely affects human health. Using HPLC-UV and Vis UPLC-MS methods, we have studied 12 antibiotics in the samples of chestnut, acacia, lime, field and polypropylene (canned) honey produced in Western Georgia. The research has shown that the use of antibiotics is impractical. In the analyzed 50 samples of honey the content of heavy metals - Cd, As, Cr, Hg, Zn, Pb is below the allowable rate.

Keywords: Honey, Antibiotics, Heavy metals, Therapeutic, Mineral content, Pesticides.

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Background

Georgia is one of the historical places of beekeeping and honey production. Honey is produced according to different vegetation (monofloric, polypropylene, lime, acacia, chestnut) and location (meadow, alpine, etc.) origin. For Georgia honey is one of the products that can be exported to the EU market. International honey standards are specified in a European Honey Directive and in the Codex Alimentarius Standard for Honey. The article deals with the present knowledge based on the different quality criteria. The standard drafts include standards and methods for the determination of the following quality factors: moisture, ash, acidity, HMF, apparent reducing sugars, apparent sucrose, diastase activity and water-insoluble matter. International honey standards for fructose/glucose content, the sucrose content and electrical conductivity are proposed. There has also been discussed the use of other quality factors, such as invertase activity, proline and specific rotation, used in many countries [1]

Honey is used in medicine as a therapeutic and prophylactic agent for coughing, stenocardia, skin ulcers, stomach ulcers and in other cases [2-4], but there may be an excess of antibiotics and heavy metals in honey, due to which this important product may become quite dangerous.

Antibiotic waste is perceived as a serious problem, because the waste products themselves can cause a toxic, allergic and other hypersensitive reaction to the consumer [5], as well as skin irritation, dermatitis, gastrointestinal irritation, very low dosage of anaphylaxis [6].

Waste adversely affects the so-called positive microorganisms, and some (nitrofuran, nitromimazole) of them can be carcinogenic and cause cancer. Even a small amount of them in honey can cause microbial resistance [7].

The main causes of contamination of honey with antibiotics are the beekeepers, who improperly use antibiotics against bacterial diseases, and the bees themselves. Many international scientific works deal with the above issues. Honey contains an excess of the norm [8.9] of Oxytetracycline and Chloramphenicol, but because of its resistance to these antibiotics, there are often used such antibiotics as Erythromycin, Lincomycinin and Streptomycin. Various antibiotics were found in honey gathered in different countries. Thus, honey collected on the coast of the Marmara Sea (Turkey) often contained from 50 to 1700 ng / kg of antibiotics. At the same time, their content was maintained after 3 months as well [9]. As it was proved in Belgium, the greater the amount of Sulfonamide was in combs, the greater its content was in honey [10]. In the case

of Lincomycin, its concentration was 24 mg after 3 days after the start of treatment, 3.3 mg after 4 months and 1 mg after 1 year [11].

The content of 5 antibiotics - Tetracycline, Oxytetracycline, Doxycycline, Chlorotetracycline and Chloramphenicol, has been studied in China; the minimum amount was 10 mg / km [12]. The high content of antibiotics has also been noted in honey brought from India to the EU and the USA. Streptomycin, Tetracycline, Sulfonamide [13,14] were found in 20% of the tested samples: in Greece and France, Tetracycline metabolism wastes [15], in the UK - Oxytetracycline [16], in Switzerland - antibiotics as a degradation product when using herbicides [17], in Spain - Tylosin, Sulfamidine and Sulfachloropyridazine [18]; more than 20% of honey samples in Germany contained Streptomycin [19], in Asia - Chloramphenicol [20,21], and in Turkey - Sulfonamide and Tetracycline [22].

Many EU countries, such as Switzerland, Great Britain, Belgium, etc., prohibit the use of antibiotics in beekeeping. The minimum limit values for antibiotics are set to be from 0.01 to 0.05 mg / kg [23]. The negative effects of antibiotics, pesticides and their metabolites on human health were studied [24, 25] as well.

The mineral content of honey depends on many factors - environmental conditions, botanical and geographical origin, and others [26]. A part of heavy metals gets into honey from the environment, and a small part comes from machine installations used during technological processes. The content of heavy metals in honey is much less in a clean environment, since the way they get into honey is not only the environment, but also nectar obtained from the plant grown in it [27, 28].

Many countries study honey samples in heavy metals [29-31]. According to FAO / WHO reports, there are cases when the amount of heavy metals in honey is at the tolerable limit [32.33].

The amount of Zn is undesirable, although a small amount is a necessary component for many drugs used against human diseases. Its especially large amount is contained in Malaysian honey (4.70 and 173.77 mg / kg), much less than it is in the honey collected in Italy (3.1 mg / kg), Spain (3.9 mg / kg), Turkey (2.7 mg / kg), Ireland (5 mg / kg) and India (12.69 mg / kg) [34-38].

The Cd content in Malaysian honey is maximum 1.03 mg / kg, and in the famous Manuka honey its content is slightly lower (1.01 mg / kg), Greek and Indian honey [39] is also characterized by low Cd content; it is slightly more in Turkish honey. The honey, collected in honeycombs in the vicinity of where the railway passes, contains a large amount of Pb, which is characterized by high toxicity [40.41]. Co concentration is rather low in Malaysian and Indian honey and relatively high in Turkish one [42].

European regulations rightly prohibit the ingestion of antibiotics into honey and limit the presence of heavy metals in it. The intensification and diversification of agriculture have radically changed the problems of beekeeping.

Improper use of drugs in agriculture causes bee disease. Antibiotics are often used in an unbiased way for medical treatment. The problem is also complicated by the fact that most of these drugs are not registered in Georgia. After the association of Georgia in the EU, the requirements of the Euro regulation were recognized, and as a result of the ingestion of antibiotics and heavy metals in honey, this useful product remains unrealized on the market, while honey, produced in Georgia, is distinguished by a large number of antioxidants [43].

The objectives and goals of the work is to study the quantitative content of west Georgian Honey Antibiotics and Heavy metals.

Objectives and Methods

Research material

There have been studied the 50 samples of various botanical origin honey gathered in Western Georgia (Adjara, Guria, Samegrelo and Imereti), among which there are 10 samples of chestnut, 10 - lime, 10 - acacia, 10 - polyflora (meadow) and also 10 samples of polyphora, collected in semi-wild conditions [44].

Sample preparation

Samples for concentrating antibiotics were processed in the following way: 3-5 ml of honey were released into the clipboard, then samples were placed in Waters Sep-Pak C18 (500 mg); All samples were filtered before analysis; the Filter Waters Acrodisc LC PVDF Filter 13 mm 0,45 μm was used for samples filtering.

Used techniques and chemical compounds

The experiment has been conducted in the Chemical Analysis and Food Security Department of Agricultural and Membrane Technologies Institute of Batumi Shota Rustaveli State University and the Chromatographic Center of Western Georgia.

The research of biochemical indicators was carried out by physico-chemical and instrumental methods. The division-identification analysis of the compounds required: UPLC-MS-PDA (Waters Acquity QDadetector), HPLC (Waters Brceze 1525, UV–Vis 2489 detectors), HPLC (Waters Brceze 1515, Conductivity detectors), PH- Meter (Mettler Toledo); Conductometer (Mettler Toledo); C18 Cartridge Solid Phase Extraction (SPE) Waters Sep-Pak C18 (500 mg), Chemicals –Metals cations (Merck-Germany). Metals cations analysis was conducted by ICP-MS.

HPLC-UV, Vis UPLC-MS

Antibiotics research is based on chromatographic methods, using ultra violet and mass-detectors, which allow to reveal even the smallest amount of them (0.1 ppb).

The analysis of antibiotics was conducted by HPLC, in the C18 analytical and preparatory column C18. The solution A: Acetonitrile,Thesolution B: Water–pH (8.5) (B) adjusted with 0.01% ammonia, the gradient (0-7 min- 20%-from 0%B, 8 min 0% B, 10-12 min 20% B, 14–20% B). UPLC-MS the analysis BEN C18, 1.7 µm, BEN Amide1.7 µm, column. Flow 0,4 ml/min, columntemp 50 °C,MS- scan 200–1200 da, Probe 600 °C, Positive (Negative) 0,8 kV, Capilari 1,5 kV, CV -15. The DAD detector monitoring (220-400 nm), the sample injection volume was 10 µl.

The sample was analysed by HPLC equipped with UV detector using a Bridje C_{18} 5µm (150 x 4.6 mm I.D.) column in gradient conditions in gradient conditions given below,with mobile phase - Acetonitrile (A) andWater–pH (8.5) (B) adjusted with 0.01% ammonia. The gradient (0-14 min- 20%-from 0%B, 16 min 0% B, 20-24 min 20% B, 25–80% B). Flow (1 ml/min).

Results and discussion

The following 12 antibiotics are mainly used in beekeeping in Georgia: Metronidazole (Retention Time-6,759), Ronidazole (RT-8,228), Erytromycin (RT-8.868), Nitrofuran RT-11,712), Lincomycinum (RT-12.185). By UPLC-MS method there have been identified: Oxytetracycline (m/z-459.14, m/z+461,14), Tetracycline (m/z-443.15, m/z+445.16), Streptomycin (m/z-580.25, m/z+582.27), Sulfadimethoxine (m/z- 309.06, m/z+311.08), Chloramphenicol (m/z- 321.00, m/z+323.01), Metronidazole (m/z-170.05, m/z+ 172.07), Ronidazole (m/z- 199.04, m/z+201.06), Erythromycin (m/z-732.45, m/z+ 734.47), Nitrofuran (m/z-112.00, m/z+114.01), Lincomycinum (m/z- 405.21, m/z+407.22), Tylosin (m/z-914.51, m/z+916.52), Rifampicinum (m/z- 821.39, m/z+823.41) (Fig).

The conducted analysis has shown that antibiotic-Oxytetracycline is observed in 20% of the chestnut honey samples, in 30% of lime ones, in 30% of acacia ones and in 20% of meadow honey its quantity is more than the allowable rate; Tetracycline is in 30 % of chestnut honey samples, in 20% of lime ones, in 40 % of acacia ones and in 20% of meadow ones it is more than the allowable rate; Streptomycin is in 30 % of chestnut honey samples, in 30% of lime ones, in 50 % of acacia ones and in 20% of meadow ones it is more than the allowable rate; Sulfadimethoxine is in 20 % of chestnut honey samples, in 20% of lime ones, in 30 % of acacia ones and in 10% of meadow ones it is more than the allowable rate; Chloramphenicol is in 10% of chestnut honey samples, in 10% of lime ones, in 30% of acacia ones and in 10% of meadow ones it is more than the allowable rate; Metronidazole in in 30 % of chestnut honey samples, in 30% of lime ones, in 40 % of acacia ones and in 20% of meadow ones it is more than the allowable rate; the percentage of Ronidazole is distributed in the same way as in Metronidazole; Erythromycin is in 20 % of chestnut honey samples, in 20% of lime ones, in 30 % of acacia ones and in 10% of meadow ones it is more than the allowable rate; Nitrofuran is in 20 % of chestnut honey samples, in 20% of lime ones, in 20 % of acacia ones and in 10% of meadow ones it is more than the allowable rate; Lincomycinum is in 30 % of chestnut honey samples, in 30% of lime ones, in 50 % of acacia ones and in 20% of meadow ones it is more than the allowable rate; Tylosin is in 20 % of chestnut honey samples, in 20% of lime ones, in 30 % of acacia ones and in 10% of meadow ones it is more than the allowable rate; Rifampicinum is in 20 % of chestnut honey samples, in 40% of lime ones, in 50 % of acacia ones and in 10% of meadow ones it is more than the allowable rate (Table 1).

In the honey production process, human intervention is virtually eliminated (only a hive – Jara is made by a man).

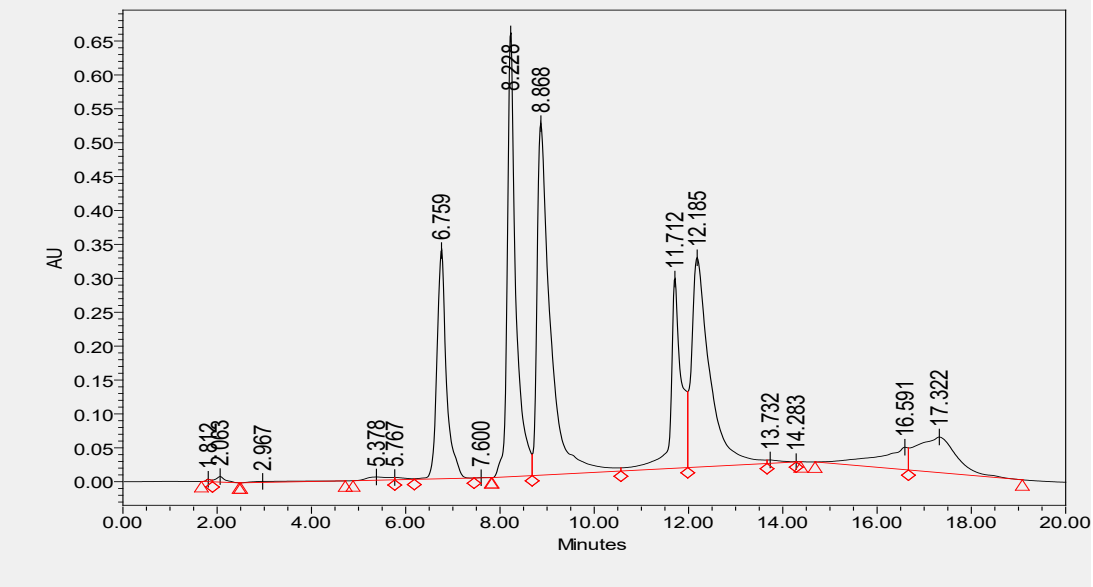

Fig. *HPLC-UV detector-320 nm, Chromatograme of standart antibiotics (Metronidazole, Ronidazole, Erytromycin, Nitrofuran, Lincomycinum)*

Table 1. *Honey antibiotics M / Z specifications and the number of honey samples (%), in which the quantity of antibiotics is more than 1.5 mg / kg*

Parameter	µg/kg	HoneyJara	Chestnut Honey	Lime Honey	Acacia Honey	Midow Honey	MS-	MS+
Oxytetracycline	5.0	n.n.*	20	30	30	20	459.14	461,14
Tetracycline	5.0	n.n.	30	20	40	20	443.15	445.16
Streptomycin	5.0	n.n.	30	30	50	20	580.25	582.27
Sulfadimethoxine	5.0	n.n.	20	20	30	10	309.06	311.08
Chloramphenicol	5.0	n.n.	10	10	30	10	321.00	323.01
Metronidazole	5.0	n.n.	30	30	40	20	170.05	172.07
Ronidazole	5.0	n.n.	30	30	40	20	199.04	201.06
Erythromycin	5.0	n.n.	20	20	30	10		734.47
Nitrofuran	5.0	n.n.	20	20	20	10	112.00	114.01
Lincomycinum	5.0	n.n.	30	30	50	20	405.21	407.22
Tylosin	5.0	n.n.	20	20	30	10	914.51	916.52
Rifampicinum	5.0	n.n.	10	40	50	10	821.39	823.41

n.n. = below loq = limit of quantitation 2 ppb*

The accumulation of antibiotics in honey samples is naturally caused by their use in inadequate and high doses. The studies have shown that a high percentage in spring honey (acacia and lime) is associated with the frequency of antibiotics use, since an excess amount of antibiotics and other drugs is used in spring to care for the health of bees. The honeycombs, previously used in the hive and not tested for the content of antibiotics, are also used in spring.

We have studied heavy metals in all honey samples, regardless of its origin. No arsenic content was found in any of the samples. The Cd content in all samples ranges from 0.26 to 0.29 mg / kg, only in Jara honey it is in the range of 0.15 mg / kg. The content of Co is from 0.28 to 0.31, and in Jira honey it is much less (0.17 mg / kg).

Table 2. *The content of heavy metals in honey samples is mg / kg.*

Sample Name	Cd mg/kg	Co mg/kg	Cr mg/kg	Hg mg/kg	As mg/kg	Pb mg/kg	Zn mg/kg
Max. limit	2.0	1.0	1.0	0.01	0.2	1.0	20,0
Honey Jara	0.03±0.01	0.17±0.01	0.24±0.05	n.n.*	n.n.	n.n.	0.7±0.01
Honey Castanea	0.28±0.02	0.31±0.02	0.53±0.05	n.n.	n.n.	0.14±0.001	4.57±0.1
Honey Tilia	0.26±0.01	0.32±0.02	0.535±0.05	n.n.	n.n.	0.16±0.002	10.3±0.2
Honey Acacia	0.295±0.03	0.27±0.01	0.54±0.05	n.n.	n.n.	0.07±0.001	6.40±0.1
Honey Field	0.27±0.01	0.30±0.02	0.875±0.07	n.n.	n.n.	0.16±0.002	4.23±0.1

n.n. = below loq = limit of quantitation 1 ppb*

The content of Cr and Zn in honey is often associated with the utensils used in the production of honey, although their content in our samples is not close to the critical threshold (0.53–0.87 m / kg and 4.23–10.3 mg / kg respectively). The copper content is quite low - from 0.3 to 1.06 mg / kg. The iron content in honey is comparatively higher, from 9.65 mg / kg to 12.7 mg / kg. It is important that the lead content is low - from 0.07 to 0.16 mg / kg. In all the analyzed samples, the content of Hg and As is less than LOQ. Particularly, it is noteworthy that the lead content in Jara honey is lower than that of LOQ determiner and the content of other heavy metals is much less than in samples of honey of other breeds. As a rule, Jara honey is collected in a relatively ecologically clean mountain region, which minimizes contamination of the plants and, consequently, the nectar and honey, obtained from them (Table 2).

The content of heavy metals in honey mainly depends on environmental factors and is not related to botanical origin.

Conclusion

The following 12 antibiotics have been detected by 50 HPLC and UPLC-MS methods in 50 local and vegetable honey samples produced in Western Georgia: Oxytetracycline, Tetracycline, Streptomycin, Sulfadimethoxine, Chloramphenicol, Metronidazole, Ronidazole, Erythromycin, Nitrofuran, Lincomycinum, Tylosin, Rifampicinum.

The quality characteristics of antibiotics were established. The samples of acacia and lime honey are characterized by an average level of pollution; this indicator is relatively small in samples of meadow and chestnut honey. The wild Jara Honey also does not contain antibiotics.

The samples of acacia and lime honey contain the greatest amount of iron, and are relatively less, and also within the normal range of Cd, Co, Cr, Hg, As, Zn, Pb. Jara honey is characterized by a minimum content of heavy metals, due to the peculiarity of its origin.

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Typical departure-arrival cycle emissions in international airports of Georgia

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A B S T R A C T

The role of air traffic, the number and geography of flight worldwide is rapidly growing. Situation in Georgia is not exception of this pattern. Along with positive effect of air traffic such as development of global business, tourism, etc, the negative impacts are worth to mention. Increase of the number and frequency of flights leads to increase of the load on environment both at the local and the global level. Of the local impacts noise and emissions are noteworthy. The objective of this study was to assess emissions of landing – take off (LTO) cycle for international airports of Georgia and suggest mitigation measures for emission reduction. Daily distribution of flights in Tbilisi and Kutaisi international airports has been analysed. Emissions at various stages of the mentioned cycle have been calculated using the International Civil Aviation Organization (ICAO) database and airport specific information. Effect of continuous arrival-departure on reduction of fuel consumption and related emission of main pollutants have been looked into. Additional impact reduction achieved in case of e-taxiing have been considered.

Keywords: LTO cycle, E taxiing, Air emissions, Airport, Continuous descent, Continuous departure

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Introduction

In conditions of global economy the role of air transport – the fastest way of cargo and passengers transportation is growing. Number of flights, frequency and geography of the travel gradually increases. Aviation contributes the global market by increasing access to international markets, is essential for global business and tourism as well as ensures rapid delivery of humanitarian and first aid to any location in the world.

In 2018, on daily basis, aviation served 12 million passengers, 120,000 flights and transported 18.8 billion USD worth cargo. Direct jobs in the industry accounted for 10.2 millions. The share of aviation in global GDP reached 794.4 billion USD [1].

According to the International Air Transport Association (IATA) this trend will persist. 1.9 time increase in passenger number worldwide in 2015-2035 is forecasted [2]. Situation in Georgia does not differ from the mentioned pattern. According to the Georgian Civil Aviation Agency, number of flights via airports of Georgia, including cargo increases. In 2018, compared to the previous year, almost 17% increase in the number of flights was registered [3]. The number of passengers travelling to/via Georgia reached 5,024,883 – showing around 23.5% growth against the previous year.

Results and Analysis

There are three international, two local (Mestia and Ambrolauri) and two private (Natakhtari and Telavi) airports in Georgia. General information on international airports is given in Table 1.

Table 1. *International airport in Georgia – general information*

Tbilisi Shota Rustaveli International Airport	Coordinates: N41°40.15' / E44°57.29' Runway - 3000mX45m Pavement – asphalt-concrete Distance from runway to nearest residential area - 860m
Kutaisi David Aghmashenebeli International Airport	Coordinates: N42°10.61' / E42°28.96' Runway - 2,500x45m; Pavement – asphalt-concrete Number of terminals – 4, number of gates - 3 Distance from runway to nearest residential area - 2.3-2.4 km.
Batumi Alexande Kartveli International Airport	Coordinates: N41°36.61' / E41°35.97' Runway - 2500∂X45∂ Pavement – asphalt-concrete Distance from runway to nearest residential area - 240-260m

The main passenger flow is via Tbilisi, however, the role of the Kutaisi airport is also growing. These airports serve in average 50-55 (Tbilisi) and 5-10 (Kutaisi) flights daily. Compared to 2017, the number of passengers travelling though Kutaisi in 2018 increased by 52.5%.

However, along with benefits of air traffic such as simplicity, speed and positive impact on economy, air traffic, airports and related infrastructure have certain negative impact on environment on local and global scale. The main impact factors being noise and emissions.

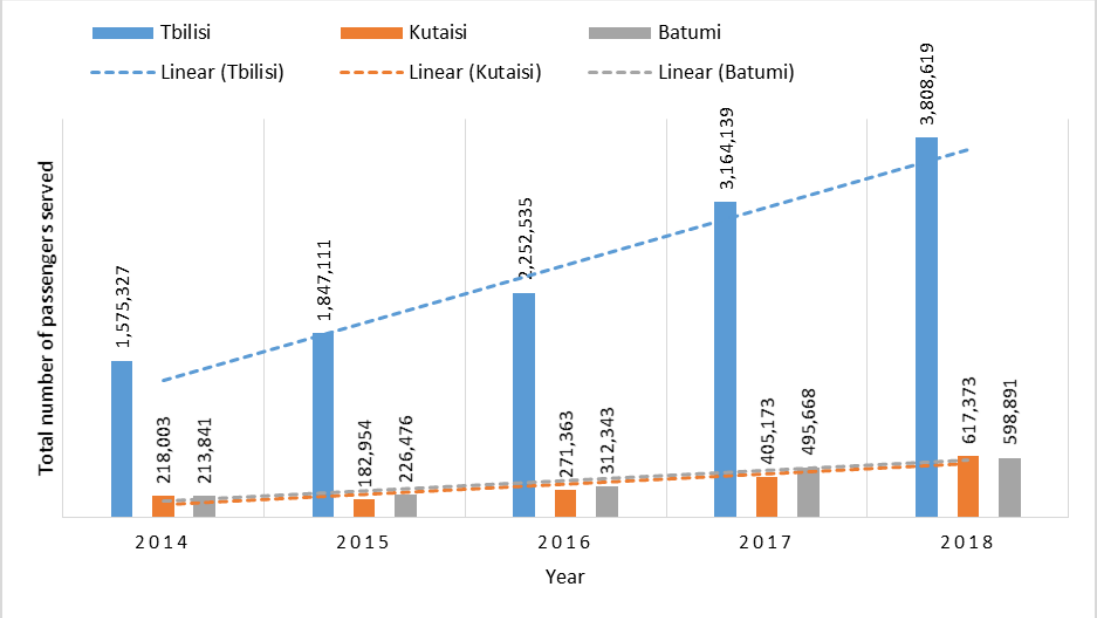

Fig. 1. *Dynamics of passengers served*

The purpose of the study was calculation of departure-arrival cycle emissions for international airports of Georgia. This article provides information on air emissions with consideration of maximum number of flights per time interval followed by recommendations for impact reduction and effect of suggested mitigation measures on total emission values.

Assessment is based on of the flight statistics via international airports of Georgia. In the course of assessment data on distribution of flights within 24 hours timeframe through the busiest hubs - Tbilisi and Kutaisi airports were collected and analysed. The results show that the main load is registered in day (08:00-19:00) and night (23:00-08:00) time interval, whereas the evening flights account for 10-12% of total daily flights only (Fig.2).

Impact of landing – take off (LTO) cycle emissions on local air quality has been assessed based on information on the main type of aircrafts [4], engine type and characteristics and duration of LTO stages for selected airports. Using ICAO data bases [5] mass of the fuel burnt per stage of the cycle and related emissions have been estimated. Considered LTO stages are shown in Fig.3.

It should be mentioned that at each stage of the cycle the engines of the aircraft are operating in different regime (power settings), respectively the fuel usage differs. Amount of the burnt fuel also depends on 'duration' of the stage.

Description of the main characteristics of the LTO stages considered in assessment is described below:

Departure

- A. *Engine start* - the main engines start immediately prior to taxi.
- B. *Taxi to runway* - all or fewer engines are on. Taxi-out is normally carried out at the idle/taxi

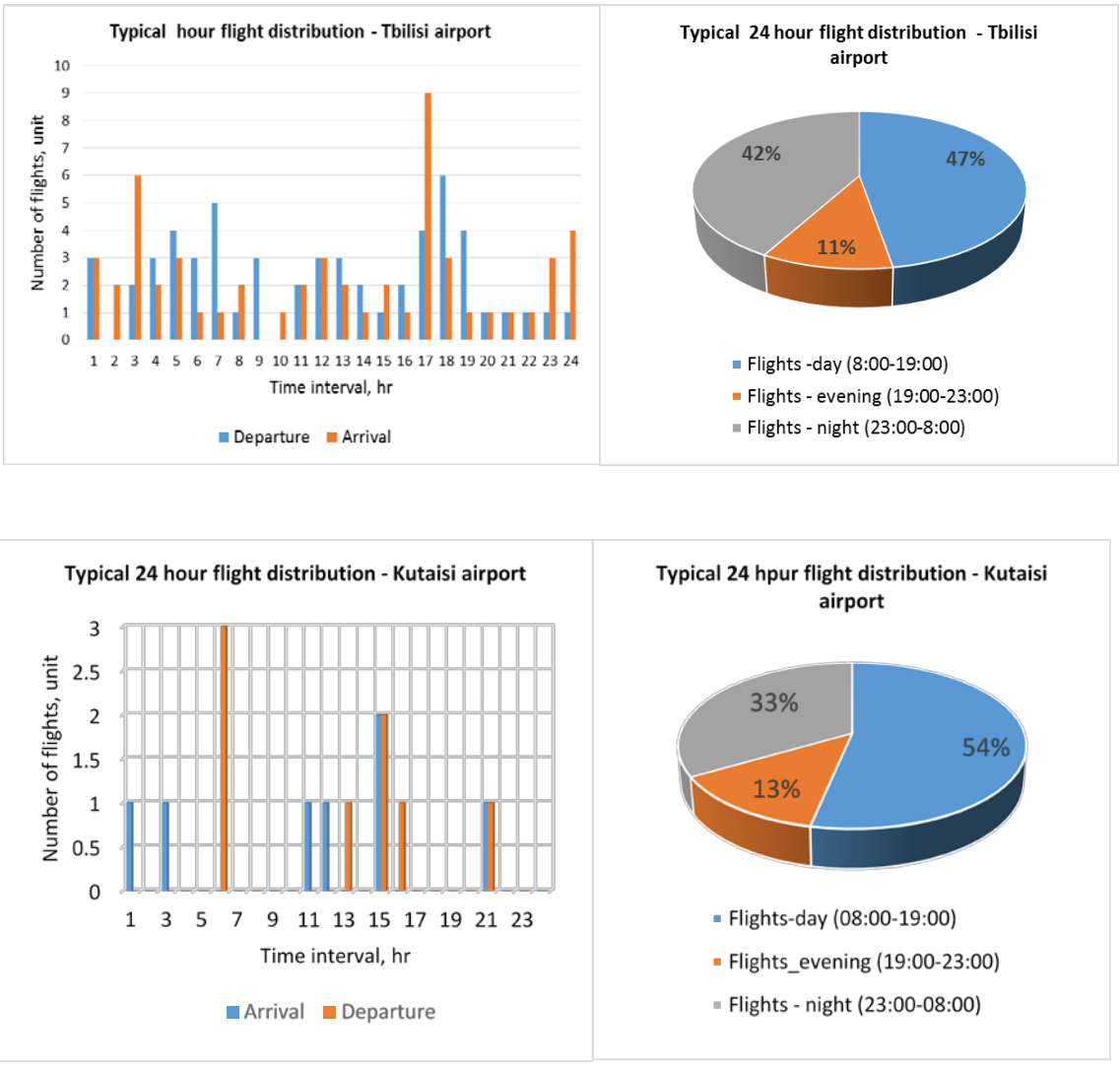

Fig. 2. *Typical distribution of flights (Tbilisi and Kutaisi airports)*

power setting, apart from brief bursts of power to overcome the initial inertia at the start of taxiing or, if necessary, to negotiate sharp turns.

- C. *Holding on ground* - main engines are set to idle thrust with brief bursts of power to move into position.
- D. *Take-off roll to lift-off* - the aircraft is accelerated along the runway to the predetermined rotation speed at the end of the take-off run with the main engines set to take-off power. Full power for take off is rarely used; a predetermined thrust setting is set at the beginning of the take-off roll. Either derated take-off thrusts or, reduced thrust settings, which are determined by the aircraft's actual take-off weight, runway length and prevailing meteorological factors are used.
- E. *Initial climb to power cutback* – the wheels of the aircraft are raised, the aircraft climbs at constant speed with the initial take-off power setting until the aircraft reaches the power cutback height (i.e. between 244-457m above ground level) where the throttles are retarded.
- F. *Acceleration, clean-up and en-route climb* - the aircraft climbs at a thrust setting less than that used for take-off with flap/slat retraction following as the aircraft accelerates and reaches cruising altitude.

Arrival

- G. *Final approach and flap extension* - thrust settings are increased to counteract the additional drag as flaps and the undercarriage are lowered, while speed decreases towards the flare.
- H. *Flare, touchdown and landing roll* - throttles are normally retarded to idle during the flare and landing roll. This is followed by application of wheel brakes and, where appropriate, reverse thrust to slow down the aircraft on the runway.
- Taxi from runway to parking stand/gate – similar to taxi-out described above; however, one or more engines can be shut down, as appropriate, during the taxi-in if the opportunity arises.
- J. Engine shutdown - remaining engines are shut down after the aircraft has stopped taxiing and power is available for onboard aircraft services.

While moving from terminal to runway the airplane uses 7% of engine capacity, from entering the runway until departure 100% capacity is used, while the climb required 85% of the capacity. On the descent stage 30% capacity is used, after landing and taxiing to the terminal 7% of capacity is required.

At local level assessment of impact on air quality of one LTO cycle during the standard stepwise departure-arrival with consideration of the time per each stage of the cycle and engine load, fuel consumption data and ICAO data bases was done. Fuel consumption and emissions for three international airports for typical aircrafts Airbus A320 (type and number of engine: Turbofan/turbojet, 2; engine code and model: 1CM008 (CFM56-5-A1)) and Boeing 737 (type and number of engine: Turbofan/turbojet, 2; engine code and model: 3CM030 (CFM56-7B20)) has been evaluated. Results of calculation for Airbus A320 are given below.

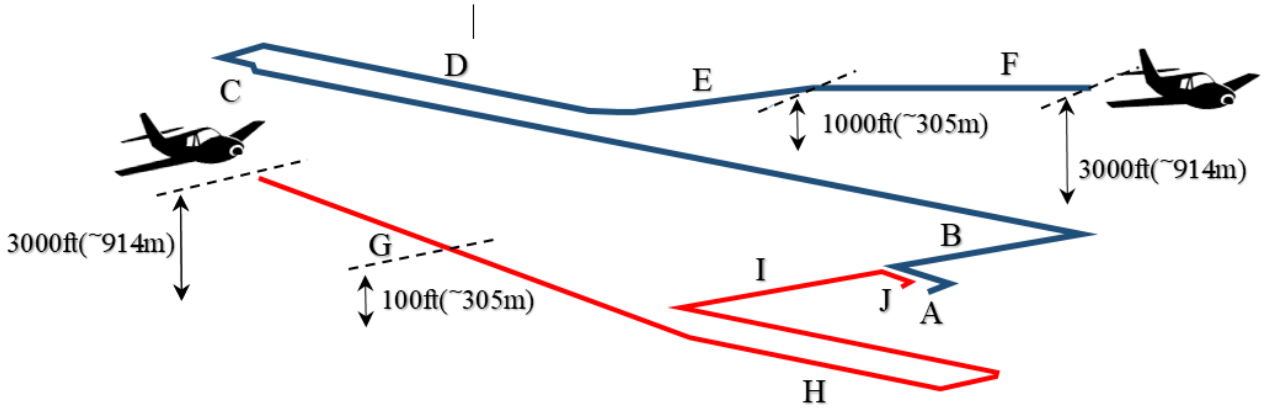

Fig. 3. *LTO flight cycle [3]*

Table 2. *LTO cycle emissions calculated for International airports (Airbus A320)*

	Departure phase	Arrival phase	Total departure+ arrival
Tbilisi airport			
Taxi out time (sec):			706
Taxi in time (sec):			453
Fuel burnt (kg)	458.792	231.296	690.089
CO emitted (kg)	2.8	1.961	4.761
HC emitted (kg)	0.273	0.184	0.457
NOX emitted (kg)	7.205	1.484	8.689
CO2 emitted (kg)	1445.196	728.583	2173.779
Kutaisi airport			
Taxi out time (sec):			640
Taxi in time (sec):			459
Fuel burnt (kg)	445.17	231.296	676.466
CO emitted (kg)	2.56	1.9613	4.521
HC emitted (kg)	0.254	0.1841	0.438
NOX emitted (kg)	7.15	1.4839	8.634
CO2 emitted (kg)	1402.287	728.583	2130.869
Batumi airport			
Taxi out time (sec):			310
Taxi in time (sec):			284
Fuel burnt (kg)	378.588	231.296	609.884
CO emitted (kg)	1.387	1.9613	3.349
HC emitted (kg)	0.16	0.1841	0.344
NOX emitted (kg)	6.883	1.4839	8.367
CO2 emitted (kg)	1192.555	728.583	1921.138

At the local level impact on air quality depends on the number of flights per time unit (1 hour). With consideration of the airport load, this number is maximum in Tbilisi. According to the typical flight schedule, the maximum number of flights served per hour totals 9-10 flights (Fig.1). Respectively, total emission within this time frame is 10 times higher.

Taxiing time in Georgian airports is less than ICAO default taxi-out time (=1140 sec) and average taxi-out time for the busiest airports (=816 sec). Thus, fuel consumption and LTO cycle emissions are lower [6]

Emission can be reduced by substitution of standard stepwise departure-arrival procedure with continuous departure-arrival method. Calculation revealed significant reduction of emissions through this change [7.8]

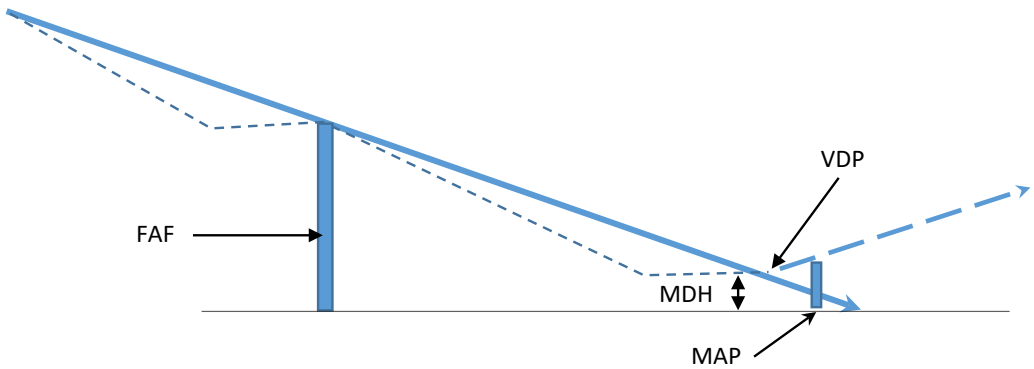

Fig. 4. *Stepwise and continuous arrival scheme*

VDP – Visual Descend Point; MDH – Minimum Descend Height; FAF – Final Approach Fix;
MAP – Missed Approach Point

The method enables reduction of emissions through decrease of 'amount' of the fuel consumed. Calculation showed that substitution of stepwise with continuous departure and arrival scheme reduces fuel consumption by 48% and 40-45% respectively. The change based on example of the Tbilisi airport is given in Table 3.

Addition reduction of emission can be achieved by using e taxiing instead of conventional method. The e taxiing system allows fully autonomous aircraft movement on ground, almost fully avoiding main engine emissions during taxing in and out [9-16]

Continuous departure-arrival and e taxiing allows to reduce emissions sharply. Mass of the fuel burnt and emission reduction while using both mitigation measures – by the example of Tbilisi airport is shown in Table 4.

Conclusion

Results of calculation show that compared to the standard (stepwise) departure-arrival scheme, continuous departure-arrival coupled with the e taxiing enables to reduce the mass of the burnt fuel by 63%. Emission reduction achieved as a result of this change is: CO emissions – by 92%; HC – by 84%, NOX – by 52% and CO2 – by 63%.

It is worth to mention that, along with reduction of emissions, continuous departure-arrival and e taxiing reduces noise related local impact that can

Table 3. *Comparison of stepwise and continuous departure-arrival (Tbilisi airport, Airbus A-320)*

Description	Departure (total)		Arrival (total)		Total departure + arrival	
	Stepwise	Continuous	Stepwise	Continuous	Stepwise	Continuous
Fuel burnt (kg)	458.792	238.572	231.296	138.778	690.089	377.350
CO emitted (kg)	2.800	1.456	1.961	1.177	4.760	2.632
HC emitted (kg)	0.273	0.142	0.184	0.110	0.457	0.252
NOX emitted (kg)	7.205	3.746	1.484	0.890	8.689	4.637
CO2 emitted (kg)	1445.196	751.502	728.583	437.150	2173.779	1188.652

Table 4. *Fuel burnt and emissions - continuous arrival-departure and e taxing – example of Tbilisi airport*

Description	Departure phase		Arrival phase		Arrival-departure	
	Departure (total)	Total – continuous departure with e taxiing	Arrival (total)	Total – continuous arrival with e taxiing	Total departur e-arrival	Total – continuous departure – arrival with e taxiing
Fuel burnt (kg)	458.792	164.243	231.296	83.808	690.089	248.051
CO emitted (kg)	2.800	0.148	1.961	0.210	4.760	0.357
HC emitted (kg)	0.273	0.038	0.184	0.034	0.457	0.071
NOX emitted (kg)	7.205	3.449	1.484	0.670	8.689	4.119
CO2 emitted (kg)	1445.196	517.366	728.583	263.995	2173.77 9	781.361

be also considered as significant positive effect and additional evidence of efficiency of the proposed mitigation approach [17].

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Scientific experimental research on plants stem vibro-cutting in dense environment

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A B S T R A C T

The article discusses the objective of testing the results of theoretical researches on cutting the water plants stem (cane) in the dense medium and in water medium in particular by means of empiric methods. A plant for cane vibro-cutting in the water environment has been developed, which enables to determine the cutting resistance force factors by means of resistance strain gage both in case of vibration and vibrationless cutting. Data obtained upon the results of the experiments from the theoretical research have been factually proved.

Keywords: Water plants, Vibro-cutting, Resistance forces, Energy consumption, Experimental results, Theoretical research.

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Introduction

The exploitation practice of different mowers/harvesters and the results of numerous research works [1-4] indicate that the segmental and rotary apparatus available for the plants stem cutting in the dense medium (water, soil) are not applicable. The segmental cutting apparatus aren't relevant for cleaning the reservoirs and channels from the water plants due to transmitters with complex structure and insufficient relief copy. They aren't applicable in the soil medium at all since the contacting surfaces get covered with soil, which inevitably leads to the breakdown and destruction of the machine parts.

The mentioned shortcomings are lacking in the rotary apparatus. Anyhow, their application in the dense environment is still related to other types of difficulties, which are caused due to the resistance forces of that very dense environment. The available cutting apparatus implement cutting of the plants stems without any support in usual conditions in case of 30÷50m/s circumferential velocity of the blade tip [2, 5].

Such a speed rate in the blades of the rotary apparatus generates forces in the dense environment, which exceed the stem cutting forces in several times. Due to those forces the rotation numbers of the rotor sharply fall down, as a result of which the overwhelming part of the stems is left uncut, the technological processes of harvesting is disrupted and the exploitative indices of the cutting apparatus deteriorate. In order to realize flawless cutting in the dense medium it is necessary to increase the rotation numbers in the rotor and therefore the consumed power.

The exploitation practice of the cutting apparatus and numerous research experiments testify that in order to implement proper cutting with the rotary cutting apparatus in the dense medium it is necessary to increase their power in 5÷6 times [1, 2, 4].

It is obvious that the wide-scale application of such cutting apparatus isn't economically viable; so upgrading of rotary cutting apparatus or the design of the new ones is an urgent issue.

The practice has shown that the first method is not prospective, since the attempts aimed at the improvement of the working process of the existing apparatus in the dense environment have doomed to failure [1, 5].

Thus, it is necessary to follow the second method, i.e. to develop a fundamentally new cutting machine.

The long-year experience gained from the activities implemented in the mentioned direction indicates, that the most efficient way of stem cutting in the dense medium is vibrational cutting in case when the blade performs vibrational movement with low amplitude (2÷8mm) and high frequency (50÷100 s^{-1}), while the rotor is provided with relatively small rotation numbers 0.1÷0.25s^{-1} [2, 3, 6].

The small rotation numbers and consequently the small circumferential (moving) speeds hardly cause any resistance forces in the dense environment, while the vibration movement of the blades rapidly reduces the cutting resistance forces in the stems [1, 2, 4].

As a result of investigations of the research works and analyses related to the mentioned issues we haven't managed to find one where the significance of the vibration cutting effect could be theoretically interpreted. That is why we have conducted some theoretical investigations with the aim of disclosing the main point of the mentioned phenomenon [6, 7].

During the theoretical research a calculation pattern has been selected, which enables to determine the resistance forces of the blade movement in the rotary cutting apparatus in water medium with great precision in case of blade vibration and without it. In the result of the theoretical investigations it has been proved that in case of vibration of the blade in the cutting apparatus, the resistance forces of the water medium decrease from 10 to 35 times [1, 7] depending on the rate of critical speed in the cutting process.

It is worth mentioning that due to the application of the selected original calculation scheme and the patterns of hydrodynamics it becomes possible to evaluate the phenomenon of resistance force reduction caused by the blade vibration in the water environment.

Materials and methods

It is obvious that the results of theoretical investigation can be accepted as a base only if they have been proved through the experiments. To this end we have developed and designed a laboratory plant, which enables to determine the dynamic parameters of the cane stem vibro-cutting in water medium.

The general layout and view of the mentioned laboratory plant are introduced in figures 1,2 respectively, while the working principle is as follows: the container filled with water, where the stems of the experimented plant, particularly those of canes are attached, rotates with the help of transmission shaft connected to the engine, while the rotary equipment consisting of the electromagnetic vibrator stays fixed/immobile. So, through rotation of the container the cane stems in the water medium is transferred to the vibration blade edge and their cutting is implemented.

The scientific experiments were conducted with two types of blades with toothed and flat edges. Besides, it has been proved through both theoretical [2, 4] and experimental methods, that the critical cutting force in case of the blade with toothed edge is much lower, than that of in case of the flat-edge blade.

Determination of some parameters in the process of vibration cutting will enable to conduct accurate analyses and to find optimal cutting regime for the stems. During vibro-cutting the oscillation amplitude (1÷5mm) and frequency (50÷100s^{-1}) of the vibro-blade, as well as the blade supplying speed (0.1÷0.5m/s) or the rotation number (0.1÷0.25s^{-1}) of the rotor are the most significant factors.

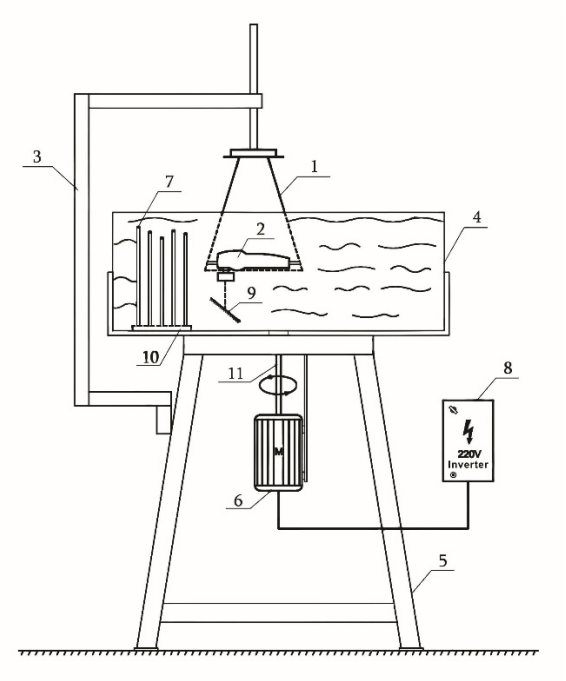

Fig. 1. *The general layout of the experimental plant for the stems vibration cutting in the water medium: 1 - framework, 2 - electromagnetic vibrator, 3 – metal bar, 4 – container filled with water, 5 -trapezium, 6 - engine, 7 – cane stem, 8 - converter, 9 – vibration blade edge, 10 – metal disk, 11 – transmission shaft.*

To determine the cutting force of the plants stem and to register the resulted data, resistance force gages were attached to the vertical bar of the blade and then dehydrated, moreover one of the resistance strain gages is installed at 45˚ angle towards the longitudinal axis of the vertical cylindrical sector, which enables to gain reliable data on the torque moment. Hinging schemes consisting of the strain gages (resistance elements) were connected with the ends of the resistance strain gages, which exclude any deformations and thermal effects. The obtained data were recorded and processed through the measuring and recording computer software ZetLab.

Fig. 2. *The general view of the experimental plant for the plants vibration cutting in the water medium.*

Results and discussions

Upon the conducted theoretical investigations [6, 7] some expressions have been derived, which enable to identify the blade of the apparatus cutting the resistance forces in the dense environment:

- vibrationless

tangent force: $\boldsymbol{T_x = \frac{8}{15}\rho\omega^3 \cdot \sqrt{\frac{\upsilon b}{\omega}} \cdot \ell^2 \cdot \sqrt{\ell}}$,

resistance moments: $\boldsymbol{M_1 = \frac{c\lambda\omega^2\rho\ell^4}{8} + 4b\sqrt{\mu\rho\omega^3} \cdot \ell^3}$, $\boldsymbol{M_2 = \frac{4}{9}\omega^3\rho\sqrt{\frac{\upsilon b}{\omega}} \cdot \ell^4 \cdot \sqrt{\ell}}$.

- in case of vibration

$\boldsymbol{T_x = 0}$, $\boldsymbol{M_2 = 0}$, and $\boldsymbol{M_1}$ is determined by the same formula,

where $\boldsymbol{\rho = 1000 kg/m^3}$ is the concentration of water medium, $\boldsymbol{\omega}$ is the rotation frequency of the rotor shaft ($\boldsymbol{0 \div 100 s^{-1}}$), $\boldsymbol{\upsilon = 0.01 cm^2/s}$ is the water kinematic viscosity, $\boldsymbol{b = 0.03 m}$ is the width of the blade sheet, $\boldsymbol{l = 0.3 m}$ is the length of the blade cutting edge, $\boldsymbol{\mu = 0.1 kg/m \cdot s}$ is the coefficient of water viscosity, $\boldsymbol{\lambda = 0.001 m}$ is the thickness of the blade sheet, $\boldsymbol{c = 1.45}$ is a coefficient, the value of which depends on the ratio of $\boldsymbol{b/\ell}$.

Placing the numerical values we'll have the following:

– Without vibration of the blade - $\boldsymbol{M_1 = 47.1 N \cdot m}$

– In case of vibration $\boldsymbol{M_1 = 1.3 N \cdot m}$.

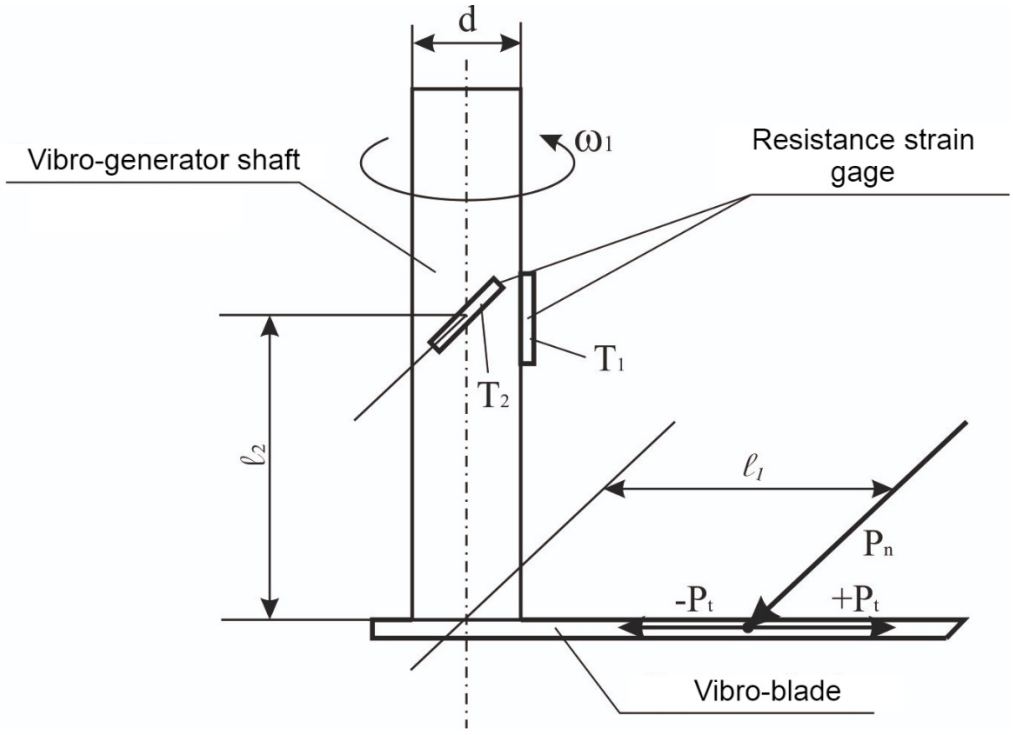

Fig. 3. *The scheme of experimentally identified force factors of vibro-cutting and system calibration.*

The calibration of the force factors in the experimental plant has been conducted in line with the methodology [8] developed by our research group according to the scheme depicted in figure 3. The relation of the measured force factors between the recorded deformations (strains) of the resistance strain gages is

apparent. $\boldsymbol{T_1}$ strain gage records the tangent force factors at the blade cutting edge, the maximum regular strain in the sticking sector of transmitter:

$$\boldsymbol{\sigma_{max} = \frac{M_z}{W_z}},$$

where $\boldsymbol{M_z = (T_x \pm P_t) \cdot l_2}$, is the bending moment in the mentioned sector, while $\boldsymbol{W_z = \frac{\pi d^3}{32}}$, is the resistance moment of the vibro-generator shaft.

$\boldsymbol{T_2}$ resistance strain gage records the deformation of the regular component of the cutting power ($\boldsymbol{P_n}$) and the twisting of the shaft in the vibro-generator affected by the resistance forces of the environment. The resistance strain gage is stuck at the angle of 45˚, hence $\boldsymbol{\sigma_{max} = \tau_{max}}$, besides:

$\boldsymbol{\tau_{max} = \frac{M_t}{W_\rho}}$, where $\boldsymbol{M_t = \left(P_{n(c)} + P_r\right) \cdot l_1}$, $\boldsymbol{W_\rho = \frac{\pi d^3}{16}}$ is the polar resistance moment of the shaft sector.

In the result of conducted scientific investigations the most significant force factors have been determined: $\boldsymbol{M_1}$ **and** $\boldsymbol{P_t}$.

Figure 4 depicts the cutting oscillograms (for $\boldsymbol{M_1}$ moment) received from the $\boldsymbol{T_2}$ resistance strain gage in the air medium for two individual cane stems in case of vibro-blades with toothed cutting edge and flat edge and in case of oscillating amplitude along the cutting edge with the value of $\boldsymbol{a_x = 2.0mm}$ and with the frequency equal to $\boldsymbol{\omega = 60s^{-1}}$.

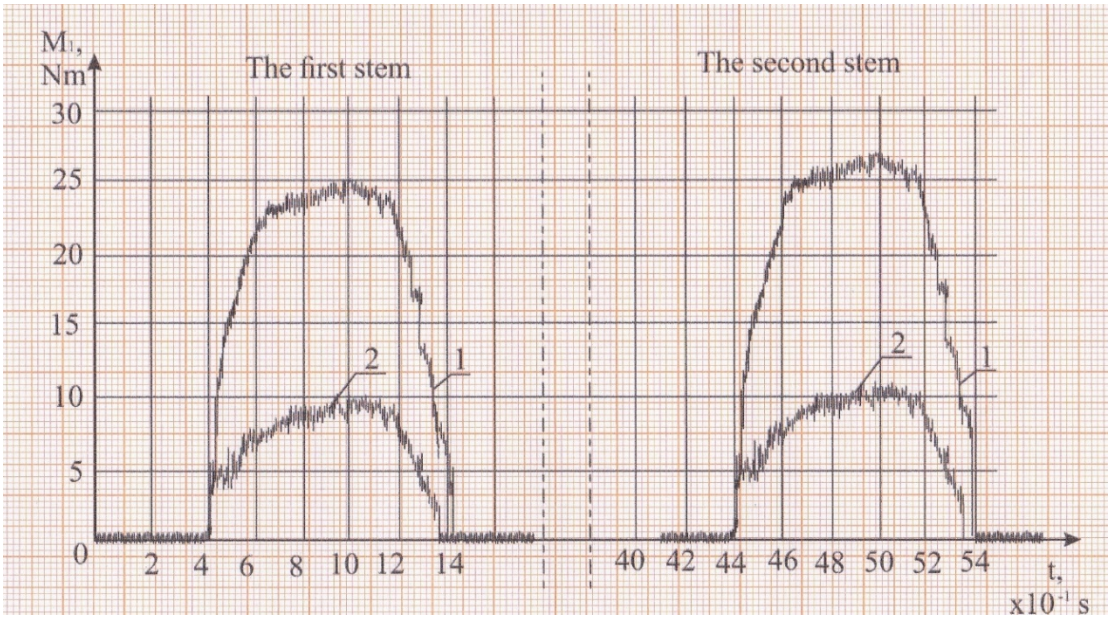

Fig.4. *The osscilloram sample of the resistance* $\boldsymbol{M_1}$ *moment caused by the regular component (*P_n*) of vibro-cutting (* $\boldsymbol{a_x = 2.0mm}$ *and* $\boldsymbol{\omega = 60s^{-1}}$ *) power in the air medium for one cane stem. 1- Blade with flat cutting edge, 2- Blade with toothed cutting edge.*

Figure 5 depicts the changing oscillogram of the tangent component in the cutting force of one cane stem (apart from each other, also the second stem) in air medium in case of parameters of $\boldsymbol{a_x = 2.0mm}$ and $\boldsymbol{\omega = 60s^{-1}}$.

It is noteworthy that the tangent component of the cutting force in case of flat cutting edge is smaller than that of recorded in case of toothed cutting edge.

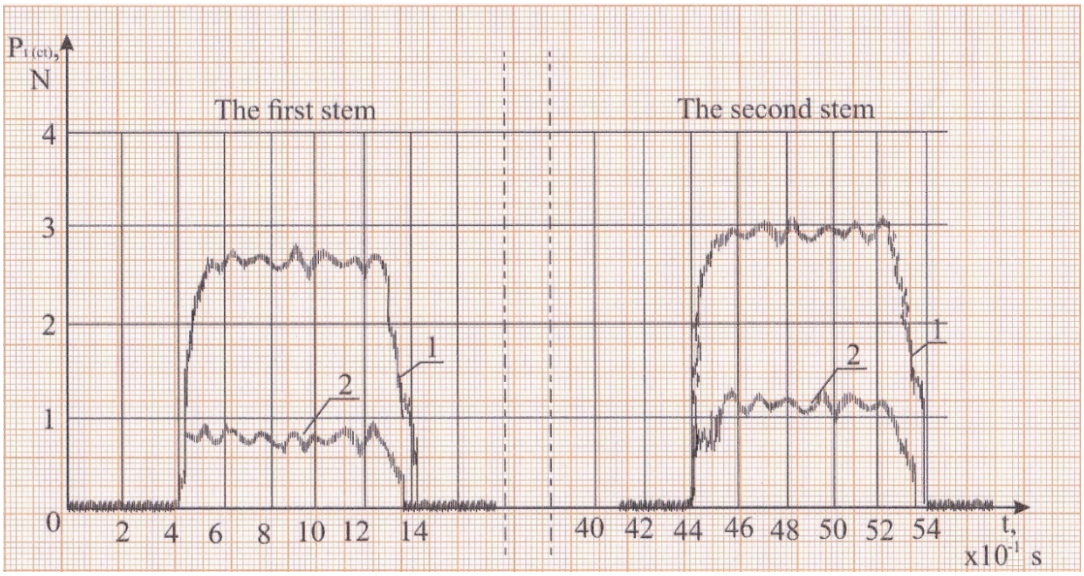

Fig.5. *The sample of changing oscillogram in the tangent component (P_t) of the vibro-cutting ($\boldsymbol{a_x = 2.0mm}$ and $\boldsymbol{\omega = 60s^{-1}}$)force for one cane stem in air medium.*
1- Blade with toothed edge, 2- blade with flat cutting edge.

Figure 6 illustrates the most important oscillogram in view of the discussed issue, that is the change of resistance $\boldsymbol{M_1}$ moment in the water medium without blade vibration (curve 1) and with its administration (curve 2).

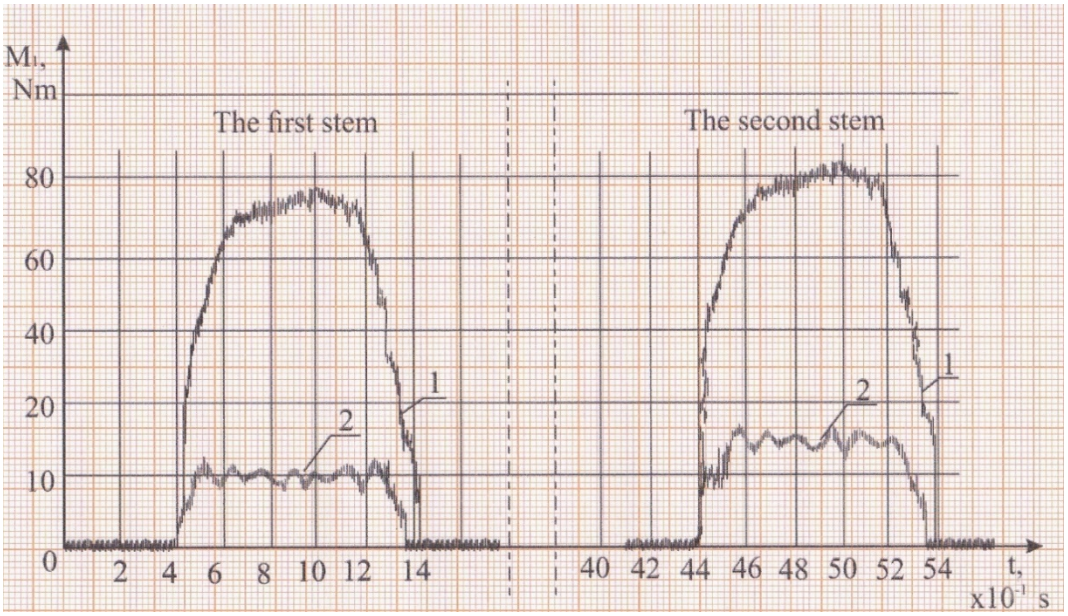

Fig.6. *The sample of the changing oscillogram of the resistance moment $\boldsymbol{M_1}$ affected by the environmental resistance forces and the regular component of the cutting resistance force for one cane stem in water medium.*

1-Without blade vibration (vibrationless) in the water medium, 2- with blade vibration in the water medium ($\boldsymbol{a_x = 2.0mm}$ and $\boldsymbol{\omega = 60s^{-1}}$).

As we can see from the last oscillogram, the resistance moment in water medium is about 10 times less in case of blade vibration as compared to that of observed in case of vibrationless cutting, besides, in case of oscillation frequency increase this difference becomes even larger. Thus, by increasing the oscillation frequency from $60s^{-1}$ to $90s^{-1}$, the mentioned difference amounts from 10 to 23 times.

As to the tangent component of the resistance forces in case of vibro-cutting, they hardly undergo any significant changes in water medium as compared to that of observed in air medium. The main point in the tangent component of the cutting forces is that it is about three times higher in case of the toothed blade in comparison with the index recorded in case of flat blade (Fig. 5), this being quite expected.

It is also quite clear that irrespective of the above mentioned, the cutting efficiency in case of the toothed blade grows up, as a result of which the regular cutting component, which determines the general resistance $\boldsymbol{M_1}$ moment, falls down in 2.5÷3.0 times.

Conclusion

Thus, in the result of the laboratory research experiments the most significant outcomes received through the theoretical researches have been mostly verified. Particularly, this is related to the fact that the cutting resistance forces in case of vibro-cutting in water medium, and hence the energy costs fall down in about 20 times. In case of vibro-cutting the toothed blades are effective, the application of which reduces the cutting resistance force factors in about 3 times, as compared to those observed in case of applying flat cutting edge blades.

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Laboratory studies of the physicomechanical properties in the cane stem

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A B S T R A C T

The article considers the research results of the physicomechanical properties in the wild plants, particularly in cane. The experiments have been conducted through special testing devices, as a result of which it has been disclosed that per the height of the stem the proportional and strength (fatigue) limits, as well as the modulus of elasticity fall down, while the relative deformations rise up. The experimental results have been introduced through a table and diagrams.

Keywords: Wild plants, Physicomechanical properties, Stem pull-out, Elasticity, Deformation, Special testing.

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Introduction

There are multiple factors affecting the cutting process of the plants stems and they are mainly related to the physicomechanical properties of the stem in the cutting plant, which are factually taken into account when designing the cutting apparatus. The values of the stem height, its thickness, resistance during the cutting process, the threshold pressure and strain in the cutting plant, as well as the knowledge and analyses of other properties are necessary to estimate the strength of individual units in the cutting apparatus and the main geometric parameters in the blade. As a result of the force exerted by the blade, considerable pressure appears between the blade and the cutting material, which results in the destruction of the connections between individual parts of the material.

The phenomenon related to the changes of physicomechanical properties in the stem is based on the restrictions of the strains and the size of deformation variation depending on the effect of the blade speed, humidity of the environment, on the thickness of the stem in the cutting plant, etc. [1, 2].

In the accomplished works [3, 4], the investigations of the physicomechanical properties of the plants have shown that throughout the process of stems' pull-out only elastic deformation (there is no plastic deformation) takes place before their cutting; the directly proportional relationship between the drag force and deformations holds up, while the limits of strength and proportion overlap. Nevertheless, the diagrams designed as a result of the investigations conducted by the academician A.P. Tarverdyan [5, 6] have enabled to clearly enhance the differences between the limits of strength and proportion. As a result of pulling out the samples, plastic deformation together with the elastic one is generated and the directly proportional relationship between the cutting force and deformation fails to keep up until the cutting moment. Also it has been shown [5, 6] that from the lower stem part of the cutting plant upwards the proportional and strength (fatigue)limits, as well as the elasticity modulus are reduced, while the deformation increases.

Materials and Methods

In order to describe the mechanical properties four parameters have beed identified: proportional limit (σ_r), elastic deformation (ε_r), endurance (fatigue) limit (σ_e), plastic deformation (ε_e) and modulus of elasticity (E).

Fig. 1. *The general view of the device for testing the samples made from the cane stem*

The stem properties of the thick-stemmed crops and wild plants are subjected to huge changes parallel to the plants height, which apparently causes some problems during the cutting process.

The experiments on pulling out the stems of the plants, particularly those of the canes have been conducted on the machine of PTM-3 series (Fig. 1). It should be mentioned that the mentioned machine has been subjected to some structural changes by the academician A.P. Tarverdyan in order to eliminate the existing shortcomings (damage of the stem samples in the handles and slipping out of the stems through them), which enable to gain verified measurement data [5, 6]. Taking into account that our observations concern the cane stem cutting process in the water medium with vibro-cutting principle, it is relevant to implement the experiments in the 3rd inter-node from the lower part of the cane stem. Strata/samples with 150 mm length and 2-3 mm width have been prepared which have been experimented through the methodology and machine developed and recommended by A.P. Tarverdyan. Metallic rings have been adhered to both ends of the stem with special glue (würth), which are intended for fastening the samples in the handles (Fg.2). The choice of the width in the samples (2-3 mm) depends on the need to reduce the cutting force down to the value in case of which the sticking connection by glue and the obtainment of verified measurement data are simultaneously ensured for the determination of the mechanical properties of the sample and for the design of the deformation diagrams.

Fig. 2. *Experimented samples of the cane*

Results and Analysis

The average values for the changes of physicomechanical properties of the stem material in the plant studied by our research group are introduced in the table below, while the diagrams of the stem pullout are introduced in Figures 3,4.

Table. *Indicators describing the physicomechanical properties of the cane stem*

Indicators describing the mechanical properties / The height of the sample location from the root node (cm)	Proportional limit, σ_r [MPa]	Elastic deformation, ε_r	Modulus of elasticity, E [MPa]	Strength (Fatigue) limit, σ_e [MPa]	Plastic deformation, ε_e
10	21.6	0.083	260	25.9	0.0061
40	20.4	0.09	226	24.5	0.0068
70	19.6	0.095	206	23.5	0.0074
100	18.8	0.1	188	22.6	0.0078
130	18.2	0.104	175	21.8	0.0083

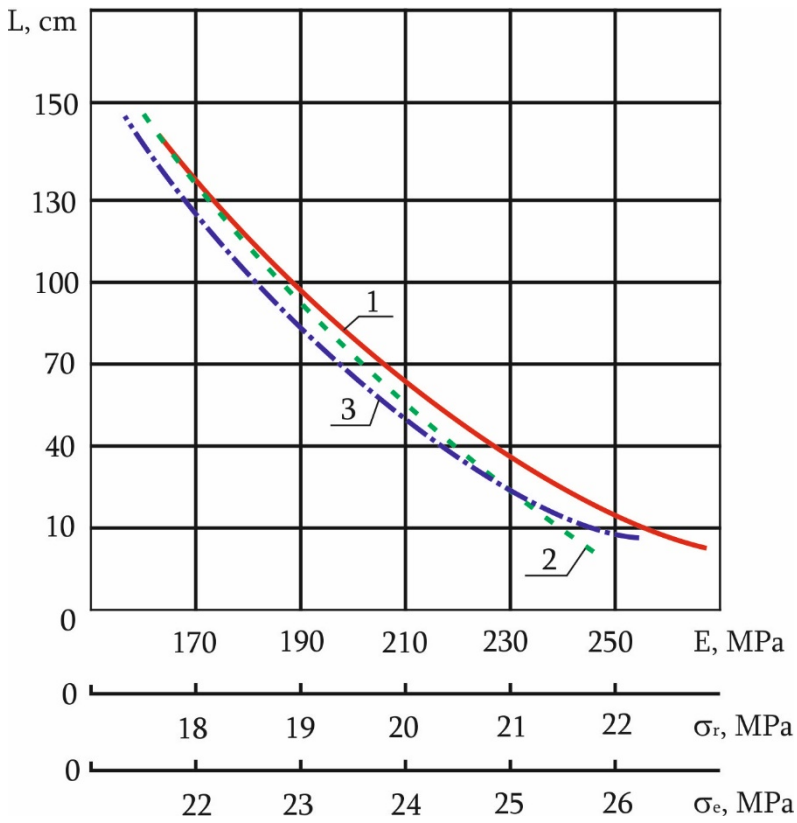

Fig. 3. *Diagrams of the changes of mechanical properties in the cane stem per its height.*

1- Modulus of elsaticity (E), 2- Proportional limit (σ_r), 3- Strength/Fatigue limit (σ_e)

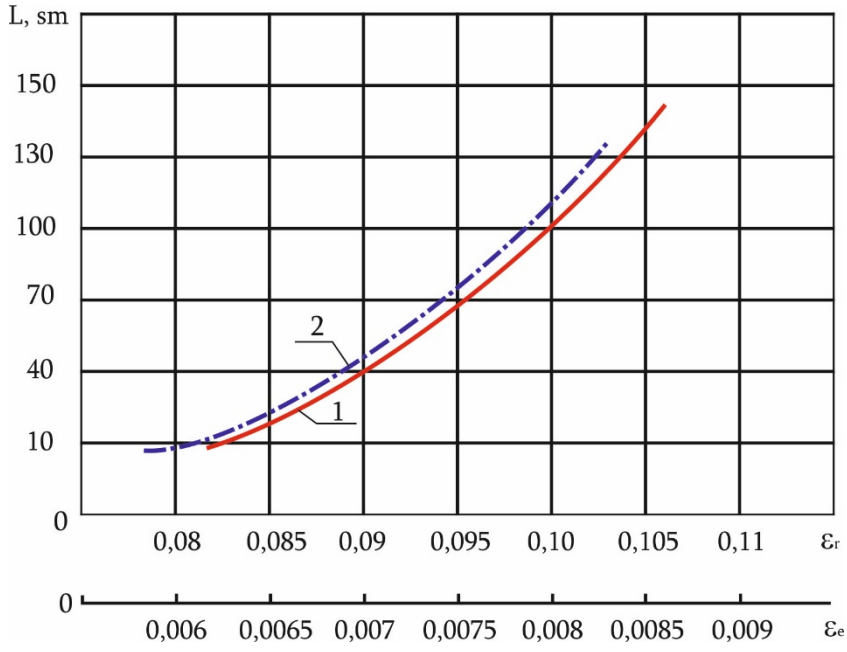

Fig. 4. *Diagrams of the deformation changes in the cane stem per its height.*

1- Elastic deformation (ε_r), 2- Plastic deformation (ε_e).

The laboratory experiments of the studies on physicomechanical properties of the cane have testified that the updated device and developed methodology enabled to adjust the indices of the physicomechanical properties in the cane substance. The data received by our research group differ from those commonly found in literature [7] in 1.5-2 times, which surely will give an opportunity to adjust the geometric and kinematic parameters in the blades of cutting apparatus.

Conclusion

1.The methodology and updated devices applied during the laboratory studies of physicomechanical properties in the cane stem have enabled to significantly adjust (in 1.5-2 times) the indicators of the physicomechanical properties.
2.As a result of investigations it has been found out that the indices of the strength in the stem material fall down per the plant height, while the deformation indices grow up.
3.Based on the concise analyses of the laboratory trials on the cane stem it can be inferred that the acquired results enable to adjust the kinematic and geometric parameters of the operating parts in the cutting apparatus.

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